



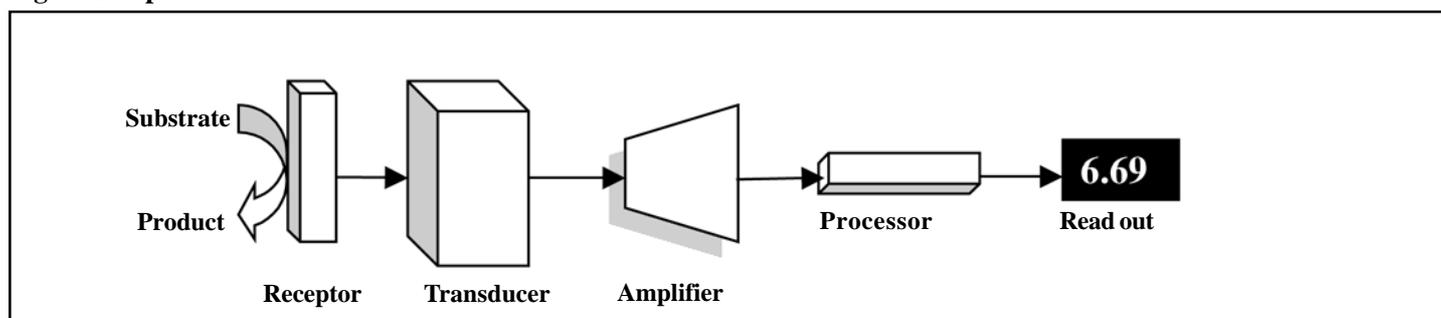
## Biosensors

A biosensor is an analytical instrument which converts a biological response into an electrical signal. They are to detect specific substances or conditions. For example, a **glucose biosensor** can detect the presence of glucose in a solution and also measure the concentration of the glucose. Sugar diabetics use them to monitor the concentration of glucose in their blood.

Biosensors are used extensively in forensic science, industry, agriculture, environmental science and medicine, to measure specific chemicals or conditions quickly and accurately.

Biosensors have been developed to detect and/or measure, for example, body temperature, blood pressure, pulse rate, oxygen tension, pH, glucose, enzymes, antibodies, the presence of illegal drugs, the presence of specific bacteria, cancers and specific DNA sequences.

Fig 1. Components of a biosensor

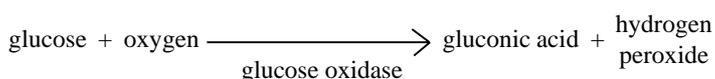


- The **receptor** could consist of, for example, living cells or tissues or immobilized enzymes or antibodies. These would be attached to some sort of membrane, such as a plastic strip, or embedded in a gel into which the substance being measured can diffuse. The sample applied could be, for example, blood, urine, bacteriological medium, or pond water.
- The **transducer** converts a chemical or biochemical signal into an electrical signal.
- The **amplifier** boosts the electrical signal so that it enables the **processor** to convert the electrical signal into a reading or measurement.

### The blood glucose biosensor

The sensitive end of the plastic strip, which is where a drop of blood will be placed, contains two immobilized enzymes, **glucose oxidase** and a **peroxidase**. It also contains a colourless **hydrogen donor**.

- glucose oxidase catalyses the oxidation of glucose in the blood forming gluconic acid and hydrogen peroxide.



- the peroxidase then catalyses a reaction between the hydrogen peroxide generated and hydrogen from the colourless hydrogen donor.



The removal of hydrogen from the hydrogen donor causes the hydrogen donor to develop double bonds which makes it become coloured. The intensity of the colour indicates the concentration of glucose in the blood sample.

### Question

An immobilised enzyme called glucose oxidase is used in a biosensor for detecting glucose. Explain why glucose oxidase acts on glucose and not on any other substance.

Active site has specific shape;  
Enzyme has complementary shape to glucose / only glucose fits/ binds to/joins to enzyme/forms enzyme-substrate complex; 2  
(Only glucose fits active site = 2 marks)

In most modern biosensors the minute electric current generated by the chemical reactions is amplified and processed to give a numerical readout as shown in Fig 1 above.

Fig. 2. A glucose biosensor (battery-powered)

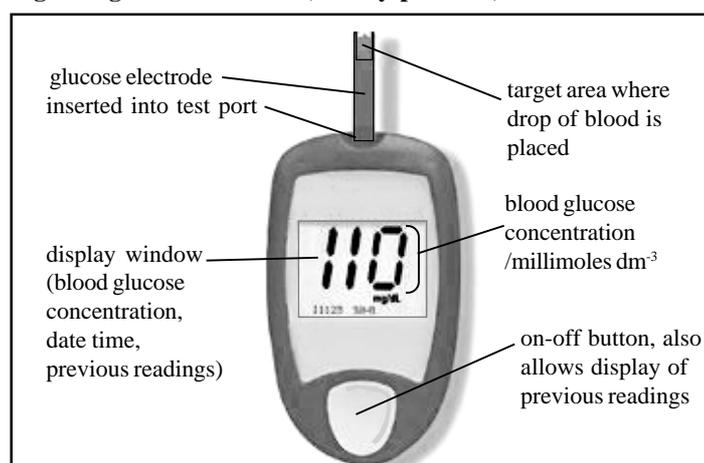
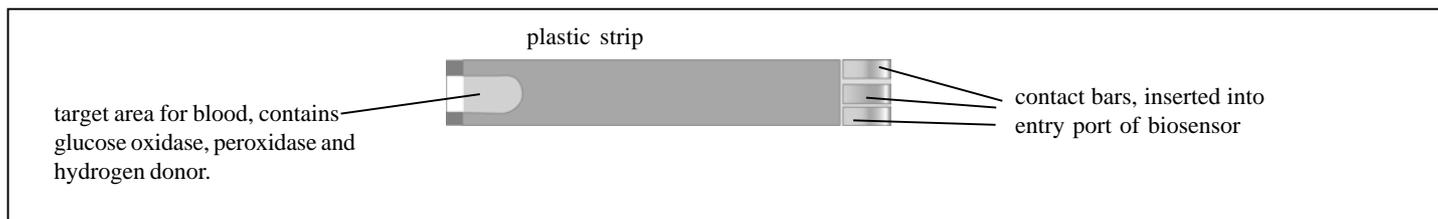


Fig 3 Glucose electrode

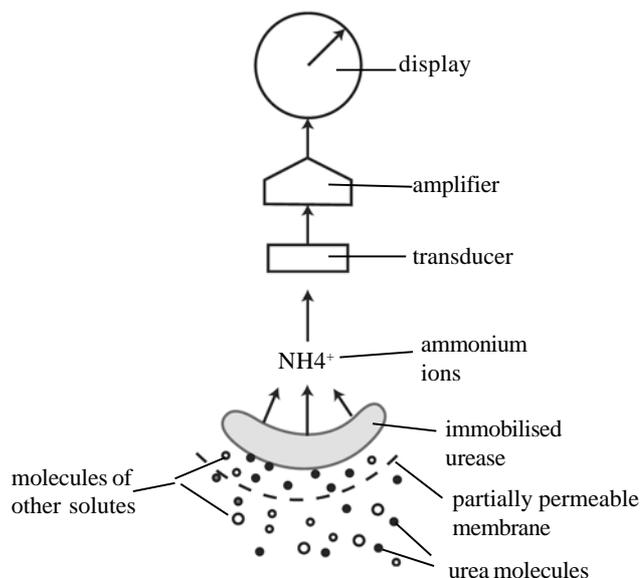


Once blood is placed on the target area the reaction occurs within seconds and the blood glucose concentration appears in the display window.

The biosensor must be calibrated before use. This is done by inserting a special calibration electrode into the test port which automatically calibrates the instrument. To check that the biosensor is measuring accurately it should be periodically used to measure the concentrations of a number of standard glucose solutions.

### Typical Exam Question

1. The diagram shows a biosensor that makes use of the enzyme urease to measure urea in either blood or urine. Urease catalyses only the following reaction:



- Explain the function of the partially permeable membrane
- Describe the function of the transducer.
- State **two** advantages of using a biosensor, rather than a chemical method, to measure the concentration of urea.
- The biosensor was to be used on two blood samples. Explain why the temperature of the two samples should be the same at the time of testing.

### Answers

- only allows urea to pass to the recognition layer/ other solutes/blood cells cannot pass through it;
- absorbs ammonium ions; converts the concentration of ammonium ions into electrical signal;
- specificity/ biosensor only measures urea; quantitative result obtained; only a small sample required; rapid;
- rate of enzyme reaction increases with temperature; so more ions formed; will give bigger electrical signal;

### Typical Exam Question

2. One possible indication that a person has diabetes is the presence of glucose in the urine. Glucose can be detected in urine by using plastic strips containing two immobilised enzymes which form a coloured compound if glucose is present. Describe the function of each of the following enzymes on the strips:
- Glucose oxidase.
  - Peroxidase.

### Answer

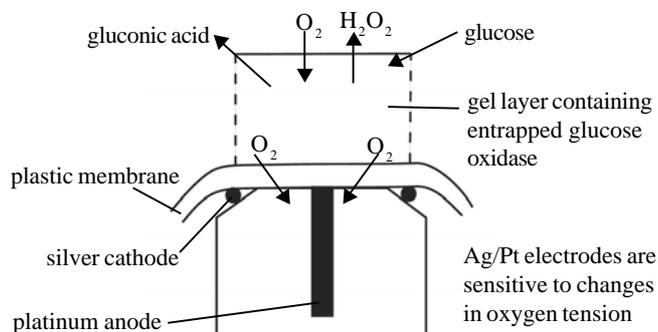
- (glucose oxidase) catalyses the oxidation of glucose to gluconic acid and hydrogen peroxide;
  - Hydrogen peroxide ( $\text{H}_2\text{O}_2$ ) reduced to water and oxygen (by peroxidase enzyme);

### Extract from Chief Examiner's report

The functions of the enzymes in a biosensor were familiar to many candidates but, again, vague answers failed to gain credit. Glucose oxidase was often thought to detect glycogen or amylase, and peroxidase was sometimes thought to react with either glucose or glucose oxidase.

### Practice Questions

1. The diagram shows an enzyme electrode from a glucose biosensor.



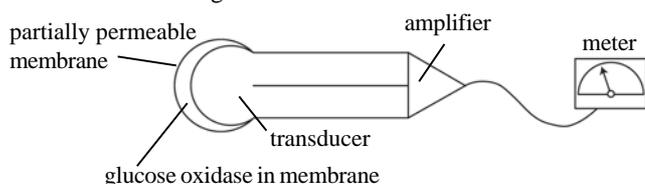
- Explain what is meant by the term 'biosensor'. **2**
- This type of biosensor uses the immobilized enzyme 'glucose oxidase'. Describe the action of this enzyme and say why it is immobilised. **3**
- Describe how the biosensor works to measure blood glucose concentration. **5**
- How has the development of the glucose biosensor made life easier for sufferers from sugar diabetes? **2**

**Total 12**

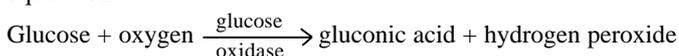
2. (a) To be used in a biosensor an enzyme must have certain properties. Suggest two of these. **2**
- (b) An enzyme from the bacterium *Rhodococcus* will breakdown heroin to morphine. Another enzyme, from the bacterium *Pseudomonas* will breakdown morphine. In doing this it will cause a colourless hydrogen donor to become red.
- (i) How could these reactions be used to make a biosensor to detect heroin in blood? **5**
- (ii) Why would a heroin biosensor be a valuable tool in policing drug use? **3**

**Total 10**

3. The diagram below shows a biosensor used to measure the concentration of glucose in a solution.



The reaction taking place inside the biosensor is shown by the equation:



Gluconic acid is a source of hydrogen ions which in turn attract electrons in the sensor. This is monitored as a source of electric current.

- (a) Explain what is meant by the term biosensor
- (b) (i) State the function of the partially permeable membrane in the biosensor
- (ii) Explain how loss of the enzyme is prevented from a biosensor
- (iii) Explain the relationship that exists between the production of gluconic acid and the size of the electric current produced in the biosensor
- (c) Explain how this biosensor could be used with an insulin injection pump by diabetic patients

**Answers**

1. (a) an instrument used to measure a biological value/substance; uses a transducer to convert a biological signal/value into an electrical signal; **2**
- (b) glucose is oxidized by oxygen; yielding gluconic acid and hydrogen peroxide; it is immobilized to prevent it diffusing away so that it can be used hundreds of times; **3**
- (c) glucose diffuses from blood into the gel/absorbed into gel; acted on by glucose oxidase which means oxygen is absorbed into the gel; amount of oxygen absorbed is equivalent to the amount of glucose in the gel; electrodes respond to oxygen uptake by generating an electrical potential; size of electrical potential is proportional to oxygen uptake and thus to glucose concentration; **5**
- (d) diabetics can easily measure their blood glucose levels themselves (using capillary blood from a finger); so can monitor the efficiency of their insulin treatment so cutting out regular visits to be measured in hospital; **max 2**
2. (a) should be specific to the substance under test; must be capable of immobilisation; must have good stability; **max 2**
- (b) (i) immobilize the two enzymes and hydrogen donor into a gel; attach gel to suitable electrodes; when blood containing heroin is placed on the gel, heroin diffuses into the gel; breakdown by enzymes generates an electrical potential/change in hydrogen ion concentration; electrical potential amplified and processed to give a readout value; **5**
- (ii) heroin use/sale/drug 'pushing' is illegal; biosensor could be used to test blood of suspects to check use of heroin; could be used to check clothing/fingers/eq of suspected 'pushers' to find if they had been in contact with the drug (heroin can be washed off items with small volumes of water); **3**
3. (a) a device that uses (micro) electronics/transducer/detects physical or chemical reactions/ electrical signals; sensitive/to measure low levels; of (biological) materials/enzymes/antibodies/ reference to biological recognition layer; **3 max**
- (b) (i) allows passage of small molecules/prevents the passage of larger molecules; ref. to glucose/glucose oxidase; **2**
- (ii) immobilised/fixes in membrane; gel/fibrous matrix/ cellulose; **2**
- (iii) the greater the concentration of acid produced/ the greater the H<sup>+</sup> concentration; the greater the flow of electrons the greater the current recorded; **2**
- (c) biosensor monitors blood glucose; high blood glucose produces more acid; if high H<sup>+</sup> sends current to pump; releases insulin; level of blood glucose drops; less H<sup>+</sup> less current; no insulin released; negative feedback; **4 max**

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