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BIOSENSING FOR HEALTH APPLICATIONS

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OUTLINE

- Introduction
- Biosensors and Biosensing Process
- Bioreceptors
- Biotransducers
- Case Study: Continuous Glucose Monitoring (CGM) Sensor
- Discussion
- Conclusion and Future Work

INTRODUCTION

- Biosensor in nature - human sensory system
- Bioanalysis - sensory organs
- Biotransducer - central nervous system

- Human sensory system has limitation
- Gets help from biological organisms

- Biosensor = reaction of organisms + transduction system
- Biosensor: (i) bioreceptor, (ii) biotransducer [1]

BIOSENSORS AND BIOSENSING PROCESS

- Biosensing process:
  (i) Analyte
  (ii) Bioreceptor
  (iii) Molecular recognition
  (iv) Transducer
  (v) Measurement
  (vi) Data recording and display [1]

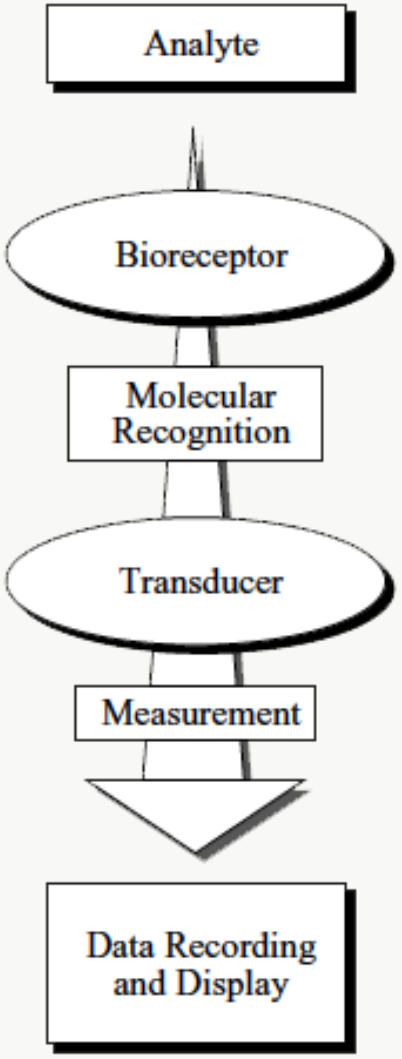

Figure 1: The Biosensing Process [1]

BIOSENSORS AND BIOSENSING PROCESS

- Types of bioreceptors:
  - Antigen/Antibody (Ag-Ab)
  - Enzymatic
  - DNA/Nucleic acid
  - Cellular
  - Biomimetic materials [1]

- Types of biotransducers:
  - Optical
  - Electrochemical
  - Mass-sensitive [1]

BIORECEPTORS: ANTIGEN/ANTIBODY (AG-AB)

- Antigen (Ag)
- Antibody (Ab)
- Binding (Ag-Ab)

- Process:
  (i) Ab binds Analyte
  (ii) Physicochemical change
  (iii) Indicate presence of substance [2]

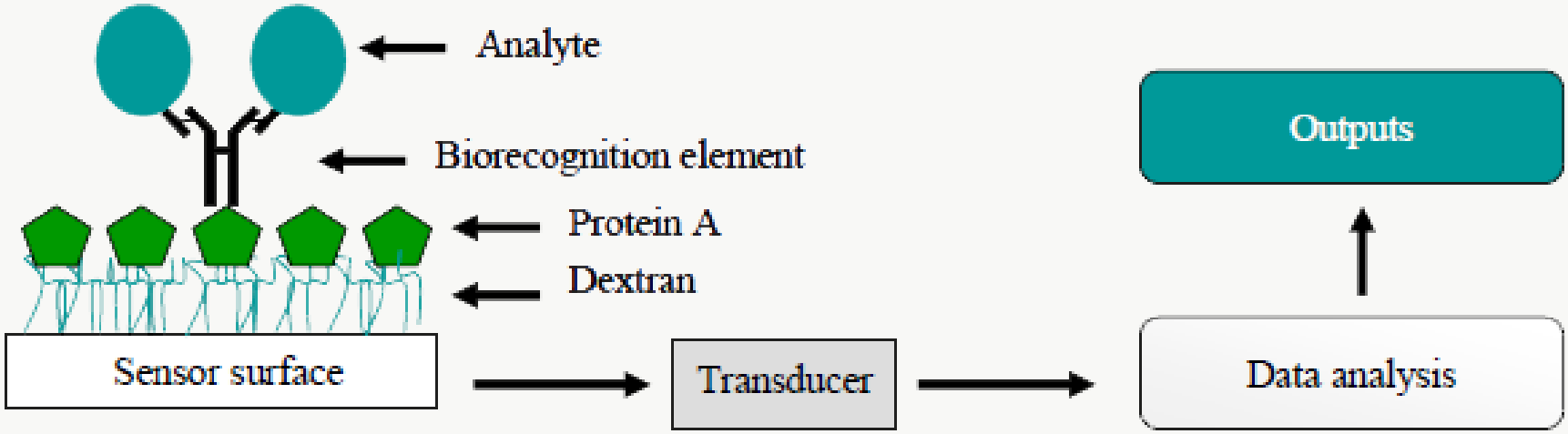

Figure 2: Ag-Ab Interaction [2]

BIORECEPTORS: ANTIGEN/ANTIBODY (AG-AB)

- Example: Detection of foodborne bacterial pathogens
  - Antibody: anti-*Campylobacter*
  - Antigen: *Campylobacter*
  - Reaction: transport of ions
  - Measurement: amperometric [2]

- Advantages:
  - Robust
  - Sensitive
  - Rapid [2]

- Disadvantage:
  - Reaction reduced by stress conditions [2]

BIORECEPTORS: ENZYMATIC

- Enzymes
  - catalytic reaction
- Process:
  (i) Compose/decompose analyte
  (ii) Physicochemical change
  (iii) Indicate presence of substance [1]

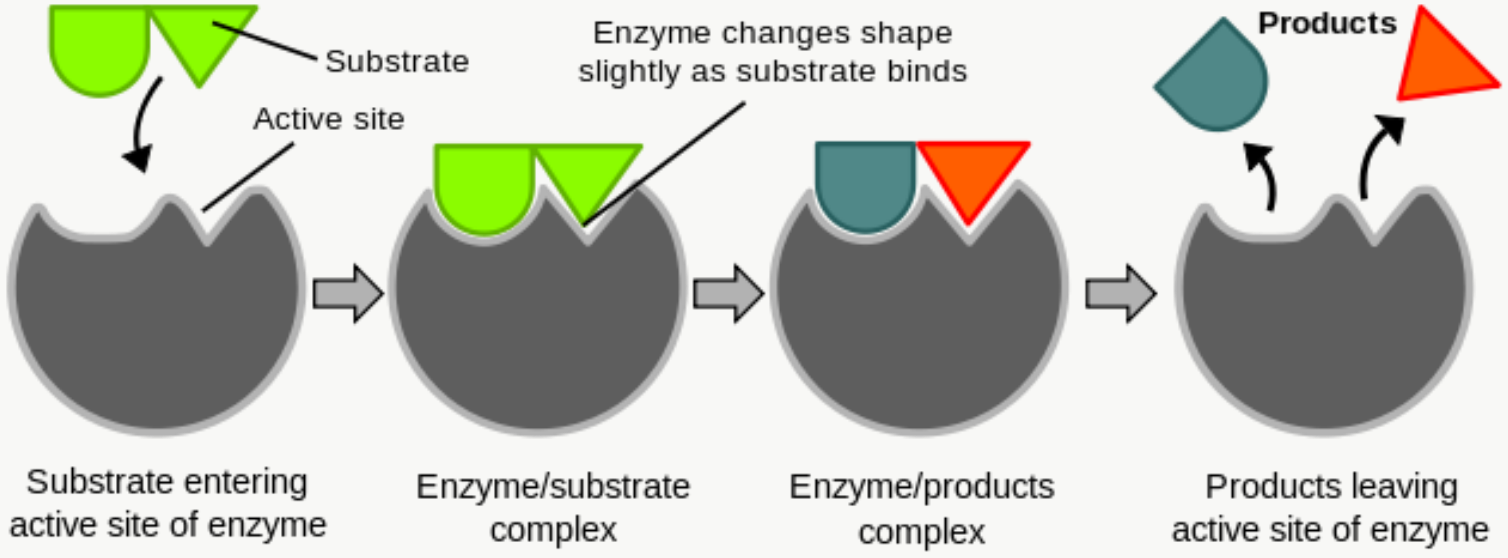

Figure 3: Enzymatic Interaction [1]

BIORECEPTORS: ENZYMATIC

- Example: Determination of uric acid
  - Enzyme: Uricase, Uox
  - Analyte: Urine
  - Reaction: *allantoin* + CO_2 + H_2O_2 , H_2O_2 --> O_2 + $2H_+$ + $2e_-$
  - Measurement: amperometric [3]

- Advantages:
  - Usable in large concentration range
  - Very low detection limit
  - Acceptable response time [3]

- Disadvantage:
  - Reaction affected by pH and temperature [3]

BIOTRANSDUCERS: OPTICAL

- Measure radiation intensity
  - **Surface Plasmon Resonance (SPR)**
  - Fluorescence
  - Raman, etc. [1]

- Process:
  (i) Change in radiation intensity
  (ii) Increment/decrement of electricity
  (iii) Convert to measurable information [1]

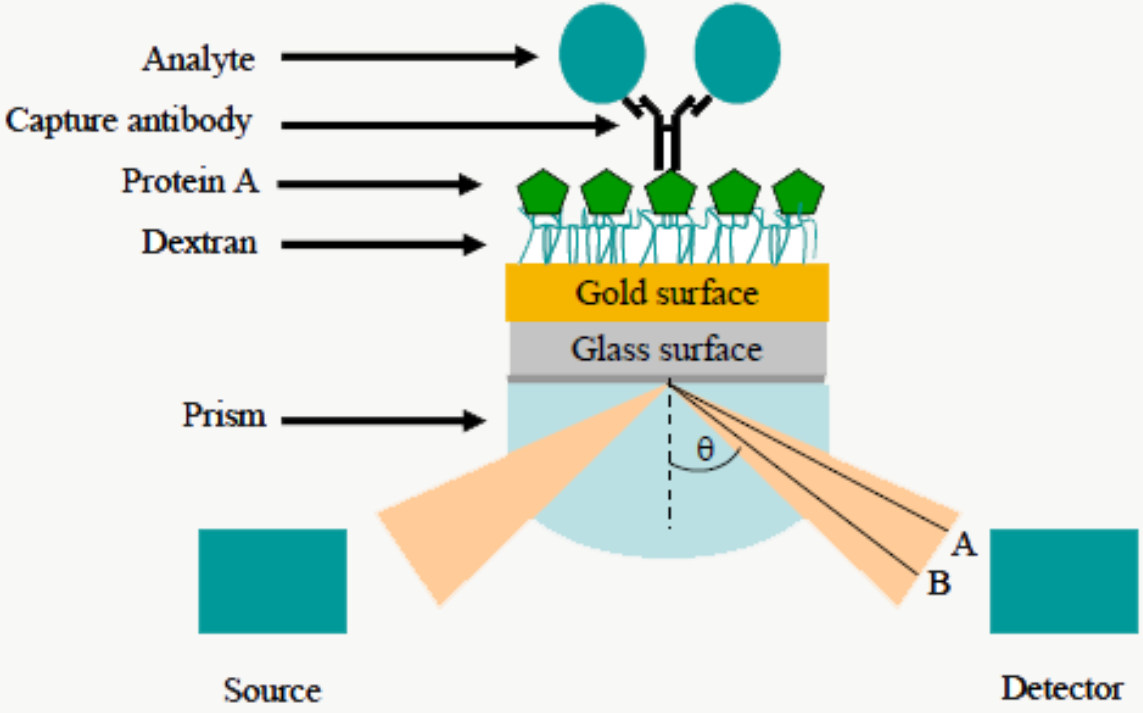

Figure 4: Optical Detection - SPR [2]

BIOTRANSDUCERS: OPTICAL

- Example: Detection of foodborne bacterial pathogens
  - Reaction: pathogen binding, change in mass
  - Measurement: changes in refractive index [2]

- Advantages:
  - Real-time monitoring
  - Good precision in small changes [1]

- Disadvantage:
  - Extra effort on data interpretation [1]

BIOTRANSDUCERS: ELECTROCHEMICAL

- Measure electrochemical changes
  - **Amperometric**
  - Potentiometric
  - Conductometry
  - Impedance [4]

- Process:
  (i) Change in current
  (ii) Convert to measurable information [1]

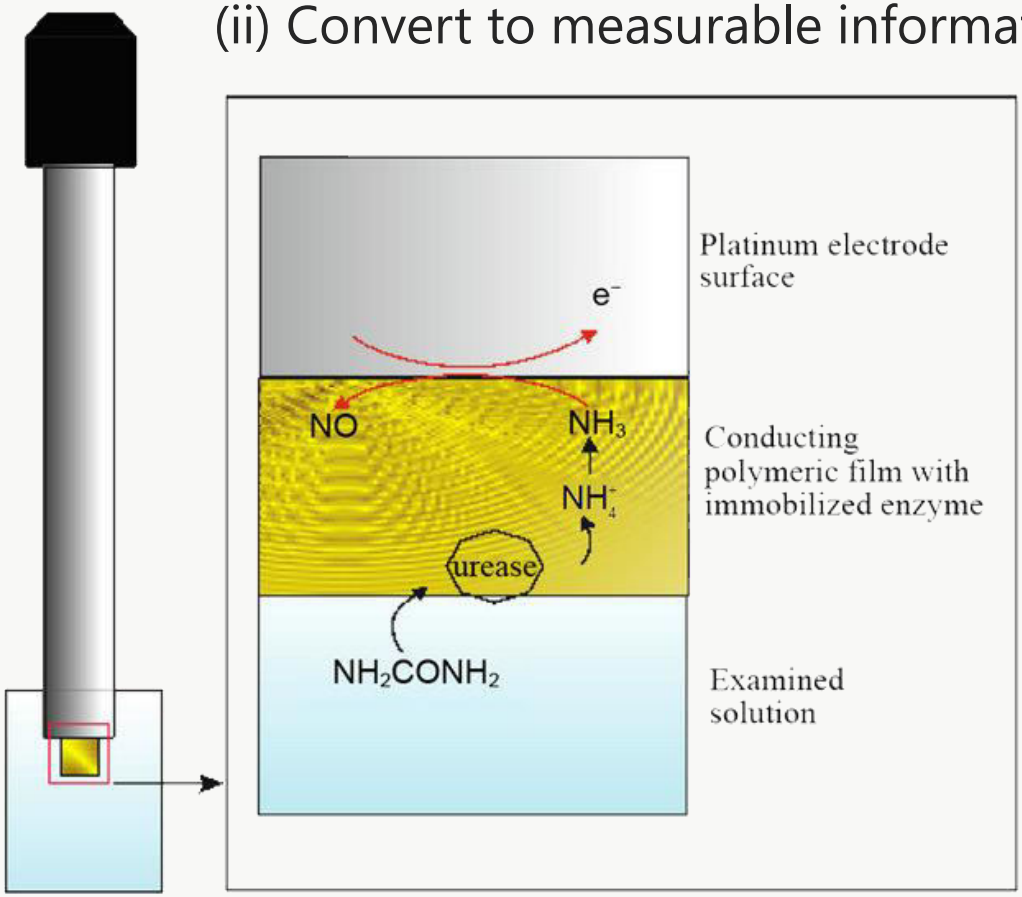

Figure 5: Electrochemical Detection - Amperometric [5]

BIOTRANSDUCERS: ELECTROCHEMICAL

- Example: Determination of uric acid
  - Reaction: $H_2O_2 \rightarrow O_2 + 2H^+ + 2e^-$
  - Measurement: changes in current [3]

- Advantages:
  - Results are highly reproducible
  - Satisfactory storage stabilization [3]

- Disadvantage:
  - Limited shelf life [6]

CASE STUDY: CONTINUOUS GLUCOSE MONITORING (CGM) SENSOR

- Product: Enlite Glucose Sensor
- Manufacturer: Medtronic MiniMed Inc.
- Contact point: Interstitial fluid
- Components: sensor, transmitter, receiver [7]

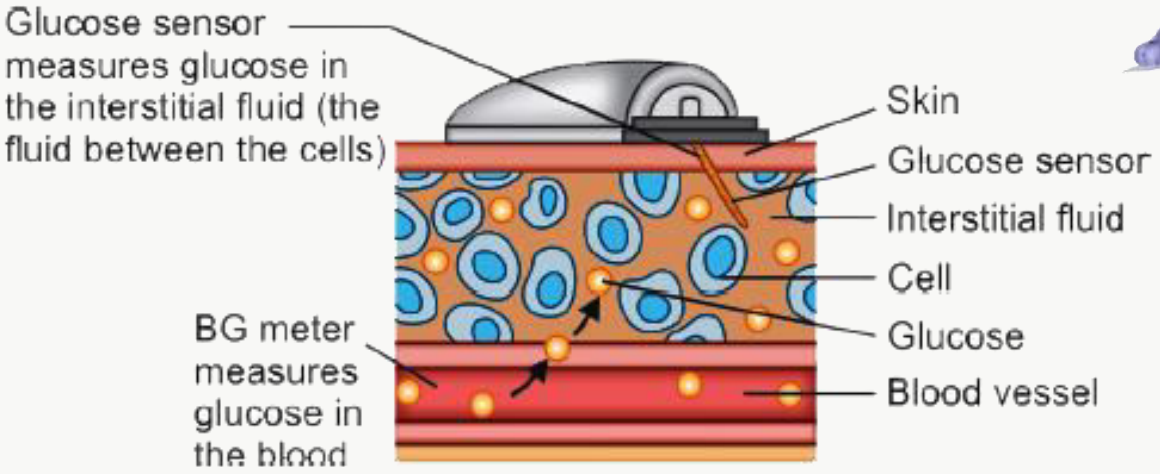

Figure 6: BG Meter vs CGM Sensor [9]

Figure 7: Medtronic Enlite CGM Sensor [7]

CASE STUDY: CONTINUOUS GLUCOSE MONITORING (CGM) SENSOR

- Bioreceptor: enzymatic
- Biotransducer: electrochemical

- Sensing process:
  - Glucose
  - Semi-permeable membrane
  - Enzyme
  - Peroxide
  - Electrode
  - Transmitter
  - Receiver [7]

- Reaction:
  Glucose + GOx -->
  H_2O_2 -->
  $O_2 + 2H^+ + 2e^-$ [8]

Figure 8: CGM Sensor Components [7]

CASE STUDY: CONTINUOUS GLUCOSE MONITORING (CGM) SENSOR

- Advantages:
  - Provides large number of glucose measurements
  - Alert for lows or highs [10]

- Disadvantages:
  - Discomfort to patients
  - Frequent replacement of sensor
  - High cost [10]

Figure 9: Enlite Serter and Receiver [11]

DISCUSSION

- Ethical challenges of ubiquitous healthcare:
  - Privacy
  - Agency
  - Equity
  - Responsible for errors [12]

- Application domains of biosensors:
  - Home and community
  - Hospitals and primary healthcare facilities
  - Over-the-counter diagnostic sensors [13]

CONCLUSION AND FUTURE WORK

- Biosensors in reality - not a silver bullet

- Reactive healthcare model --> proactive wellness-preservation
- Pervasiveness
- Technology
- Personal health
- Crowdsourcing [13]

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