BIO & PHARMA ANALYTICAL TECHNIQUES

Chapter 8 Sensor

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Chapter Description

- Aims
  - Discuss theory, principles and application of analytical techniques used in material characterization, pre-formulation development, manufacturing process and storage stability.

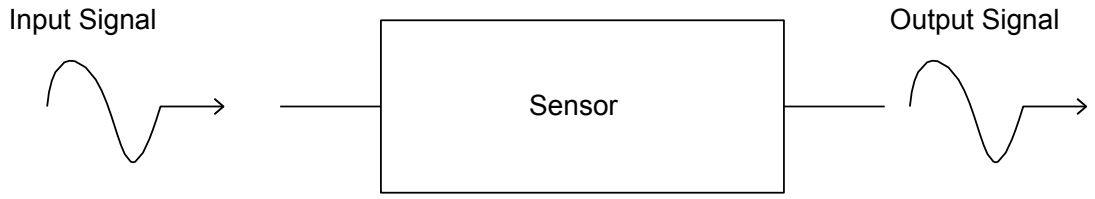
- Expected Outcomes
  - Explain general facts of sensors including application in other field.
  - Illustrate theory and principle of both instruments: biosensors and acoustic sensors.
  - Discuss on the application of both instruments in pharmaceutical.

- References

  - Gunzler H. & Williams A. (2002). Handbook of Analytical Techniques. Wiley-VCH, Weinheim, Germany.
  - Mullertz, A., Perrie, Y. and Rades, T. (2016) Analytical Techniques in the Pharmaceutical Sciences (Advances in Delivery Science and Technology). Springer, United States.

What are sensors?

- It **receives a signal (**energy) and **converts it** to a signal in another form (measureable)



- Acquires a physical parameter → converts it into a signal suitable for processing (e.g. optical, electrical, mechanical)
- For example, a thermocouple converts temperature to an output voltage which can be read by a voltmeter.

Detectable Phenomenon

Stimulus	Quantity
Acoustic	Wave (high-frequency signals)
Biological & Chemical	Fluid Concentrations (G or L, substrates)
Electric	Charge, Conductivity, Voltage, Current, Electric Field (amplitude, phase, Polarization)
Magnetic	Magnetic Field (amplitude, phase, polarization), Flux, Permeability
Optical	Refractive Index, Reflectivity, Absorption
Thermal	T, Flux, Specific Heat, Thermal Conductivity
Mechanical	Position, Velocity, Acceleration, Force, Strain, Stress, Pressure

TYPES OF SENSORS

Thermal Energy/Temperature Sensors

Electromagnetic Sensors

Mechanical Sensors

Chemical Sensors

Acoustic Sensors

Biological Sensors

THERMAL SENSOR

- **Devices that are used to monitor temperature changes.**
- Application: - safety, alarm when a certain temperature has been exceeded
  - measurement (coolant)
- Temperature sensor : thermometers, thermostats, pyrometer
- Heat sensor : bolometer, calorimeter

ELECTROMAGNETIC SENSOR

= **detect or measure electrical and magnetic forces or effects produced by them**

Parameters involved:

i.	Electrical resistance	: ohmmeter
ii.	Electrical voltage	: voltmeter
iii.	Electrical power	: watt-hr meter
iv.	Magnetic field	: magnetic compass
v.	Metal detectors	

MECHANICAL SENSOR

- = **Measure mechanical quantities.**

Parameters involved:

i. Pressure : barometer
ii. Vibration/shock : vibration meter
iii. Speed : speedometer
iv. Acceleration : accelerometer

CHEMICAL SENSOR

- **Device or instruments that transforms chemical information (presence, concentration or composition of analyte) into an analytical signal.**

- Analyte can be present in a gas, liquid or solid phase

Example : Gas sensors (toxic gas)
: Smoke detectors
: Electrochemical sensor (moisture, humidity)
: pH meter

ACOUSTIC SENSOR

- **Device or instruments that 'listen' to high frequency signals (waveform).**

- As the acoustic wave propagates through or on the surface of the material, any changes → affect the amplitude of the wave

Application :related to structural issues (storage tanks, piping, reactors, petro-chemical plants)
: sound wave (microphone, hydrophone, amplifier)

Principles:

1. Acoustic wave propagates through or on the surface of the material, any changes → **affect the velocity** and/or amplitude of the wave.
2. Changes in velocity can be monitored by **measuring the frequency** the sensor and can then be correlated to the corresponding physical quantity being measured.

BIOLOGICAL SENSOR/BIOSENSOR

What are biosensors?

- **A sensor that integrates a biological element with a physicochemical transducer → produce an electronic signal proportional to an analyte → conveyed to a detector.**

- Enzymes as the biologically responsive material,cell metabolytes, ligand binding and ab-ag reaction

- Biosensors can be used directly to monitor the bioprocess

WORKING PRINCIPLE

1. Analyte diffuses from the solution to the surface of the Biosensor.
2. Analyte reacts specifically & efficiently with the Biological Component of the Biosensor.
3. This reaction changes the physicochemical properties of the Transducer surface.
4. This leads to a change in the optical/electronic properties of the Transducer Surface.
5. The change in the optical/electronic properties is measured/converted into electrical signal, which is detected.

TYPES OF BIOSENSORS

1. **Thermal Detection Biosensors.**
2. **Resonant Biosensors.**
3. **Optical Biosensors.**
4. **Piezoelectric Biosensors.**
5. **Ion Sensitive Biosensors.**
6. **Electrochemical Biosensors.**

Thermal Detection Biosensors.

- Uses **Absorption / Production of Heat.**
- Temp. measured by Enzyme Thermistors.

Advantages:

- No need of frequent recalibration.
- Not sensitive to the optical properties & electrochemical properties of the sample.

Uses:

Detection of (1) Pesticides and (2) Pathogenic Bacteria.

❑ Optical Biosensors.

- Colorimetric for ***colour*** - Measures change in Light Adsorption.
- Photometric for ***Light Intensity*** - Detects the Photon output.

❑ Resonant Biosensors.

- An acoustic wave transducer is coupled with bioelement.
- Measures the change in Resonant Frequency.

❑ Piezoelectric Biosensors.

- Uses **Gold** - To detect specific angle at which electron waves are emitted when the substance is exposed to laser light/crystals which vibrates under the influence of an electric field.
- Change in Frequency is proportional to the Mass of Absorbed material.

❑ Ion Sensitive Biosensors.

- Are semiconductor Field Effect Transistors (FETs) with ion-sensitive surface.
- Surface Electrical Potential changes when the ions & semiconductors interact.
- Measures the Change in Potential.

Uses:

- pH Detection.

❑ Electrochemical Biosensors.

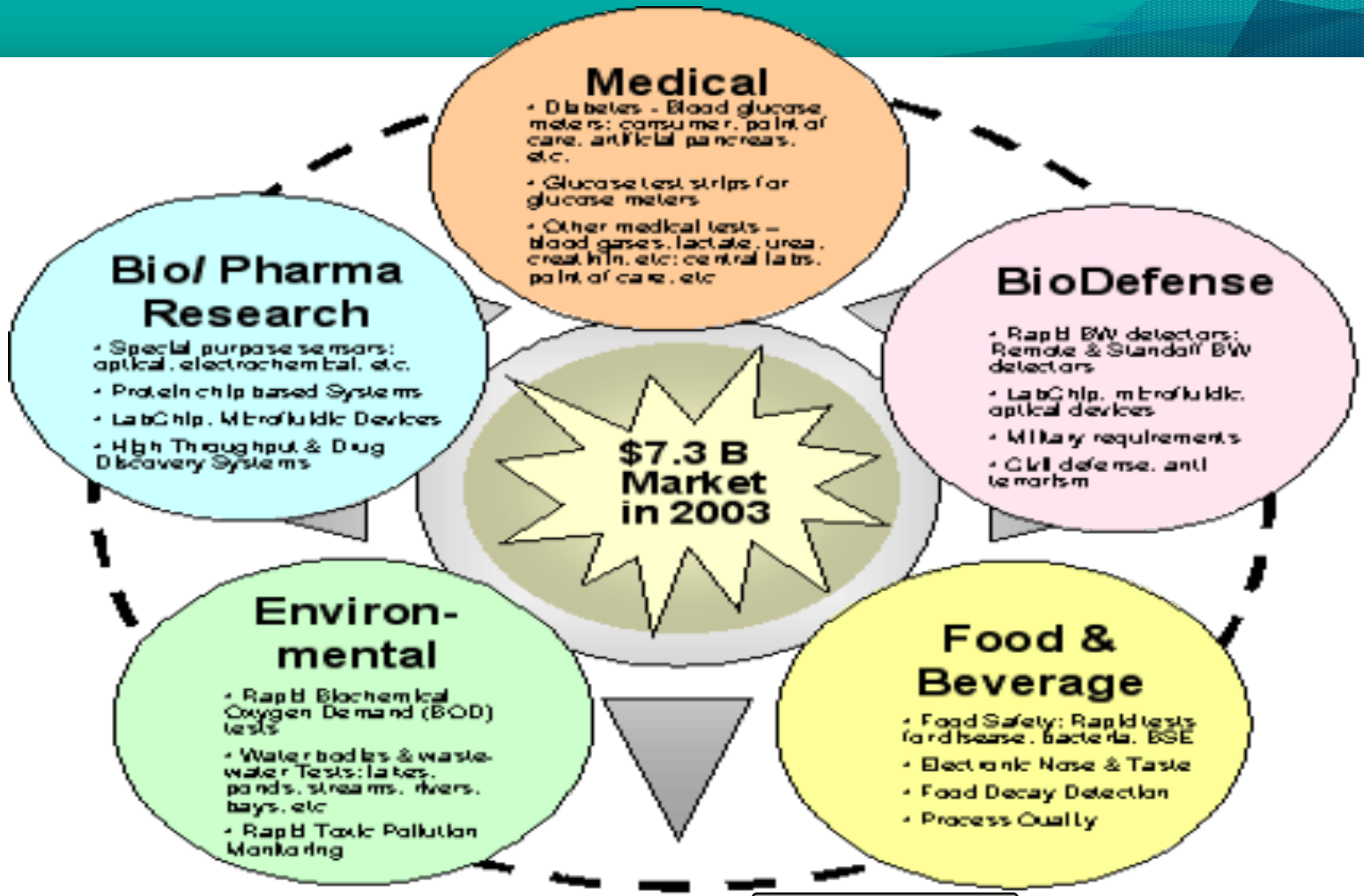
Underlying Principle – Many chem. reactions produce or consume ions or electrons causing some change in the electrical properties of the solution that can be sensed out & used as a measuring parameter.

Uses:

Detection of :

- Hybridized DNA
- DNA- binding Drugs &
- Glucose Concentration.

Application



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Application of Biosensor

- Food Analysis
- Study of biomolecules and their interaction
- Drug Development
- Crime detection
- Medical diagnosis (both clinical and laboratory use)
- Environmental field monitoring
- Quality control
- Industrial Process Control
- Detection systems for biological warfare agents
- Manufacturing of pharmaceuticals and replacement organs

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Application: fermentation

Biosensors are excellent analytical tools for various measurement needs, e.g. enzymatic measurement of glucose, sucrose, and lactate or various immunoassays.

Current bioreactors are equipped with a number of:

i. physical parameters (temperature, weight, pressure, liquid flow, foam level, stirrer speed and power)
ii. chemical sensors (pH, pO2, outgas O2 and CO2) and
iii. biological sensors (substrates)

Fill & Finish (Packaging)

Pharmaceutical manufacturers – and companies producing packaging for them – rely on automated equipment for efficient, cost-effective operations.

Frequently, this automation requires sensing systems to screen products for acceptable quality – and to help control equipment.

Opacity & Color

Opacity sensors typically work with an infrared special light source, and can be used for applications such as verifying the opacity of containers and packaging films, checking the turbidity or clarity of solutions

Adequate opacity ensures, for example, that a container will block enough light to protect the contents from deterioration due to light absorption.

Color sensors are used in similar pass/fail applications where the product characteristic being measured is its color.

For this purpose a white light source is used, which allows the red, green, and blue components of a product's color to be measured.

The relative magnitudes of these three color values determine how the product's color appears to the human eye.

Other Examples of Factory Automation

1. BLISTER PACKAGING MACHINE
2. TUBE FILLING MACHINE
3. BOTTLE FILLING MACHINE
4. LABELING MACHINE
5. CARTONING MACHINE
6. SHRINK WRAP MACHINE

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Any Question?

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