SCIENCE
OF
MEASUREMENT
What are biosensors?

- A device that uses specific biochemical reactions mediated by isolated enzymes, immuno systems, tissues, organelles or whole cells to detect chemical compounds usually by electrical, thermal or optical signals.
Principle of Biosensors

Fig. 2. Principles of biosensors.
Required Characteristics

- Sensitivity
- Low detection limits
- Cost
- Simplicity
- Reliability
- Speed
- Accuracy
- Precision

- Utility
- Field portability
- Ruggedness
- Reproducibility
- Ease of calibration
- Stability
- Room for improvement
Types of biosensors

- Based on use of different biological material and sensor devices following are the main types:
  - Electro-chemical Biosensor
  - Amperometric Biosensor
  - Thermistor containing Biosensor
  - Bioaffinity sensor
  - Whole cell Biosensors
  - Opto-electronic Biosensor
Define Measurement

- **Measurement** is the assignment of a number to a characteristic of an object or event, which can be compared with other objects or events.

In the metric and SI systems, one unit is used for each type of measurement:

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Metric</th>
<th>SI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length</td>
<td>meter (m)</td>
<td>meter (m)</td>
</tr>
<tr>
<td>Volume</td>
<td>liter (L)</td>
<td>cubic meter</td>
</tr>
<tr>
<td>Mass (m³)</td>
<td>gram (g)</td>
<td>kilogram (kg)</td>
</tr>
<tr>
<td>Time</td>
<td>second (s)</td>
<td>second (s)</td>
</tr>
<tr>
<td>Temperature</td>
<td>Celsius (°C)</td>
<td>Kelvin (K)</td>
</tr>
</tbody>
</table>
Define Calibration

- The set of operations which establish, under specified conditions, the relationship between values indicated by a measuring instrument or measuring system, and the corresponding standard or known values derived from the standard.
Types of calibration methods

**External Calibration:**
- Signal is proportional to concentration - established using externally prepared standards
- Assumes that the sensitivity (signal/ conc) is the same for samples and standards
- Assumes that the signal arises only from the analyte in most cases
- Does not account for sample matrix or instrumental drift

**Standard Addition:**
- Known amounts of analyte are added to aliquots of sample
- Signals are measured as a function of concentration added
- Accounts for sample matrix, but not for instrumental drift
Error

- Error is the difference between the true value of the variable and the measured value.
- Errors are classified as

1. Gross error / Human error (human mistakes and instrument malfunctions)

2. Random errors (Noise/Interference)

3. Systematic errors (which may be either constant or variable) - Due to shortcoming of the instruments
Random Errors

Associated to any measurement or electronic signal we find random, non-deterministic variations as the result of different sources:
- Electronic noise (Johnson, shot, ..)
- Interference
- Even though interference is systematic, for the easiness of modeling, it can be rendered as random.

All the random sources are independent.
Gross error

- Instrumentation misuse, calculation errors and other human mistakes (mistakes in reading, recording) are the main source of Gross errors.
- Gross error mainly occur due to carelessness or lack of experience of a human being or incorrect adjustments of instruments.

- These errors can be minimized by
  - 1. Taking great care while taking reading, recordings and calculating results.
  - 2. Taking multiple readings preferably by different persons.
Systematic errors

A constant uniform deviation in the operation of an instrument is known as systematic error.

- There are three types of systematic errors as:
  - Instrumental errors
  - Environmental errors
  - Observational errors
Systematic Errors

Observational Errors
Error introduced by the observer

- **Few sources are:**
  - Parallax error while reading the meter,
  - Wrong scale selection,
  - Habits of individual observer

- **Elimination**
Use the
  - instrument with mirrors,
  - instrument with knife edge pointers,
  - Instrument having digital display
Systematic errors

INSTRUMENTAL ERRORS

- Misuse of instrument
  A good instrument if used in an abnormal way gives misleading results.
  - Poor initial adjustments,
  - Improper zero setting,
  - Using leads of high resistance.

Elimination: Use the instrument intelligently & correctly

- Loading effects
  Loading effects due to
    - Improper way of using the instrument

Elimination: Use the instrument intelligently & correctly

Correctly
Systematic Errors

Environmental Errors (due to the External Conditions)

- The various factors: Temperature changes, Pressure, vibrations, Thermal emf., stray capacitance, cross capacitance, effect of External fields, Aging of and Frequency sensitivity.
Error due to Other Factors

- **Effect of the Time on Instruments**
  - There is a possibility of change in calibration error in the instrument with time. This may be called ageing of the instrument.

- **Mechanical Error**
  - Friction between stationary and rotating parts and residual torsion in suspension wire cause errors in instruments. So, checking should be applied. Generally, these errors may be checked from time to time.
Error Analysis

- Repeating Measurements
- Calculation of Mean and Standard Deviation
- The Gaussian distribution
- Propagation of Errors
- Significant Figures
It is important to distinguish between error and uncertainty.

Error is defined as the difference between an individual result and the true value of the measurand.

Error is a single value.

In principle, the value of a known error can be applied as a correction to the result.

Error is an idealized concept and a single number, which cannot be known exactly.

Uncertainty takes the form of a range, and, if estimated from an analytical procedure and a defined sample type, may apply to all determinations so described.

In general, the value of the uncertainty cannot be used to correct a measurement result.

The difference between error and uncertainty should always be borne in mind.

The result of a measurement after correction can unknowably be very close to the unknown value of the measurand, and thus have negligible error.

Even though it may have a large uncertainty
Uncertainty Analysis

- The **estimate of the error** is called the **uncertainty**.

- It includes both bias and precision errors.
- Identify all the potential significant errors for the instrument(s).
- All measurements should be given in three parts:
  - Mean value
  - Uncertainty
  - Confidence interval on which that uncertainty is based (typically 95% C.I.)

- Uncertainty can be expressed in either absolute terms (i.e., 5 Volts ± 0.5 Volts) or in % terms (i.e., 5 Volts ± 10%)

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\text{relative uncertainty} = \frac{\Delta V}{V} \times 100
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