Biomedical Instrumentation

Michael R. Neuman, PhD, MD

Memphis Joint Program in Biomedical Engineering

E-mail: mneuman@memphis.edu

Orhan Soykan, PhD

Medtronic, Inc. and Michigan Tech

E-mail: osoykan@mtu.edu

Heidi Niska, BSEE

Graduate student, Michigan Tech

E-mail: hmniska@mtu.edu

General Information on the Course

- Instructors
- Textbook: J. Webster, Medical Instrumentation: Application and Design
- Lab: No lab this and next week! (Withhold Cheers!)
- Recitation sessions
- Office hours

Instrumentation

Devices that can be used to make a measurement and give quantititave (or sometimes qualititative) results

Biomedical Instrumentation

Devices that can be used to make measurements of **biologic** or **medical** quantities and give quantititave (or sometimes qualititative) results

Examples of Familiar Biomedical Instrumentation

Clinical Thermometer

Stethoscope

Neonatal Intensive Care Unit

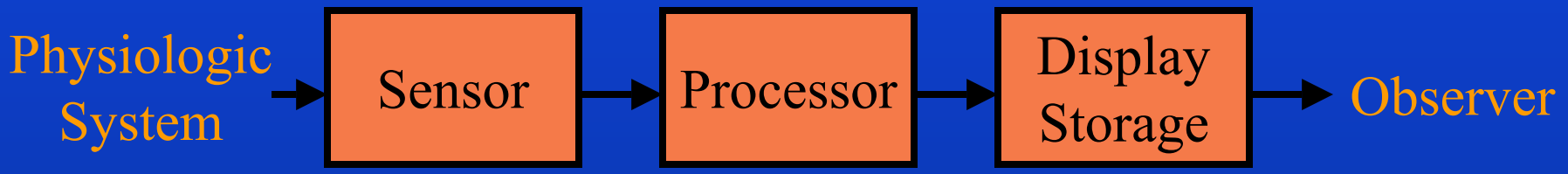
Future Biomedical Instrument

- Tricorder (Star Trek)
- Completely non-invasive
- Internal and external measurements
- Imaging
- Internal intelligence to make diagnosis and suggest therapy

Home Glucose Monitoring

- Requires blood sample (<10μL)
- Must use microlancet
- Colorimetric or electrochemical determination
- Newer units have software instructions and memory

Basic Biomedical Instrument



Fundamental Rules of Biomedical Instrumentation

- Minimum disturbance to physiologic system
- Sensor must be at physiologic variable value
- Maintain simplicity

Important Instrumentation Terms

Sensitivity - Change in output as a function of a change in input

Stability - Consistency in output for a constant input

Specificity - Ability to distinguish desired variable from other competing variables

Accuracy - Difference between true value and measured value divided by the true value

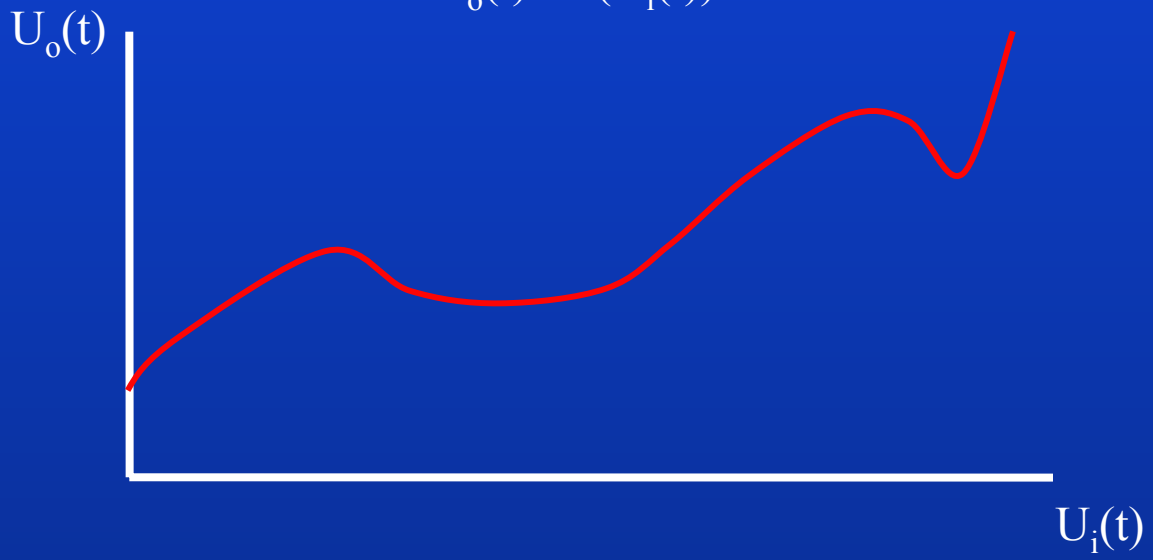
Precision - Number of distinguishable alternatives from which a given result is selected

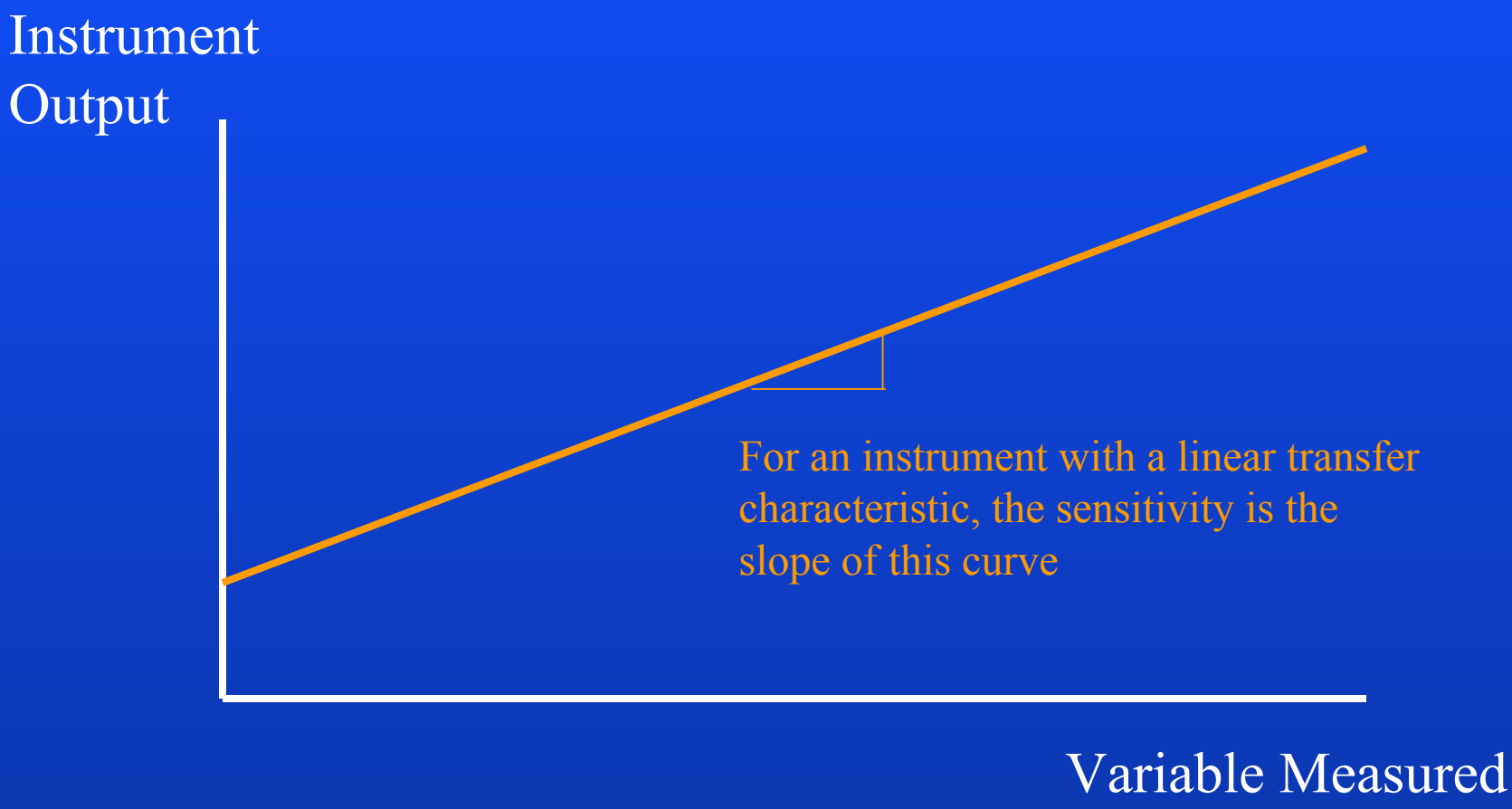
Resolution - Smallest increment that can be measured with certainty

Reproducibility - Same output for the same input

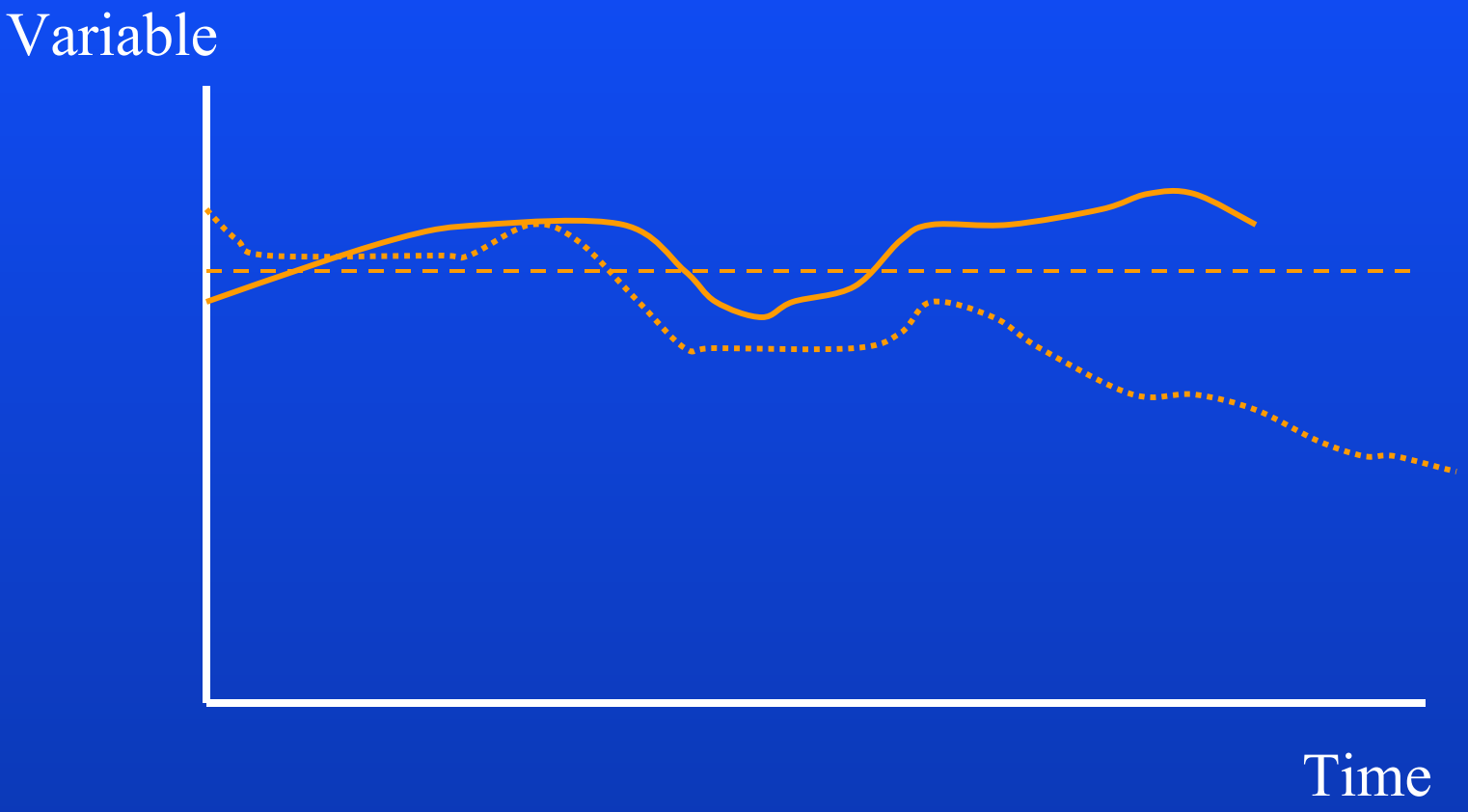
Transfer Characteristic

$$U_o(t) = f(U_i(t))$$

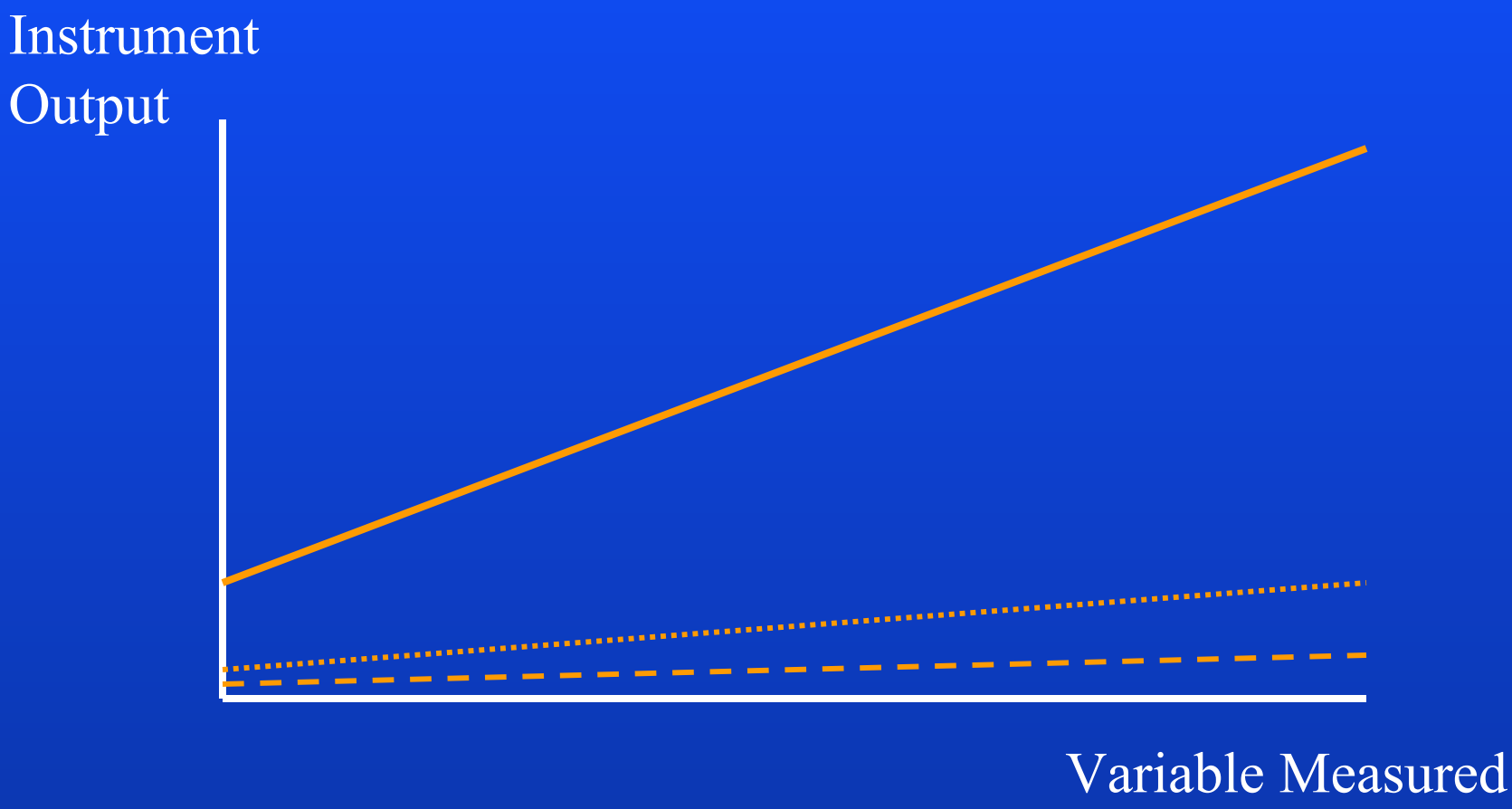




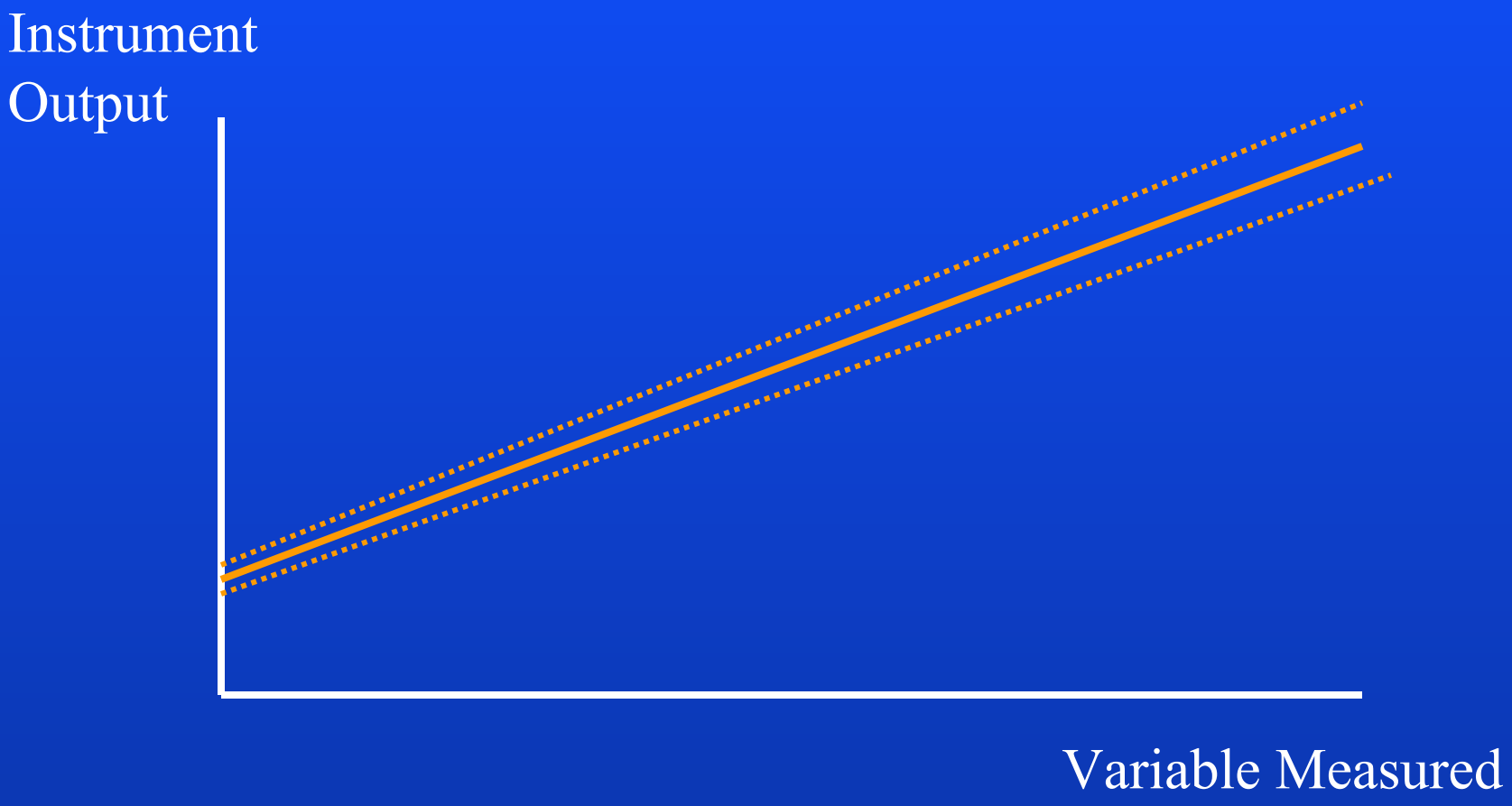
Sensitivity - Change in output as a function of a change in input



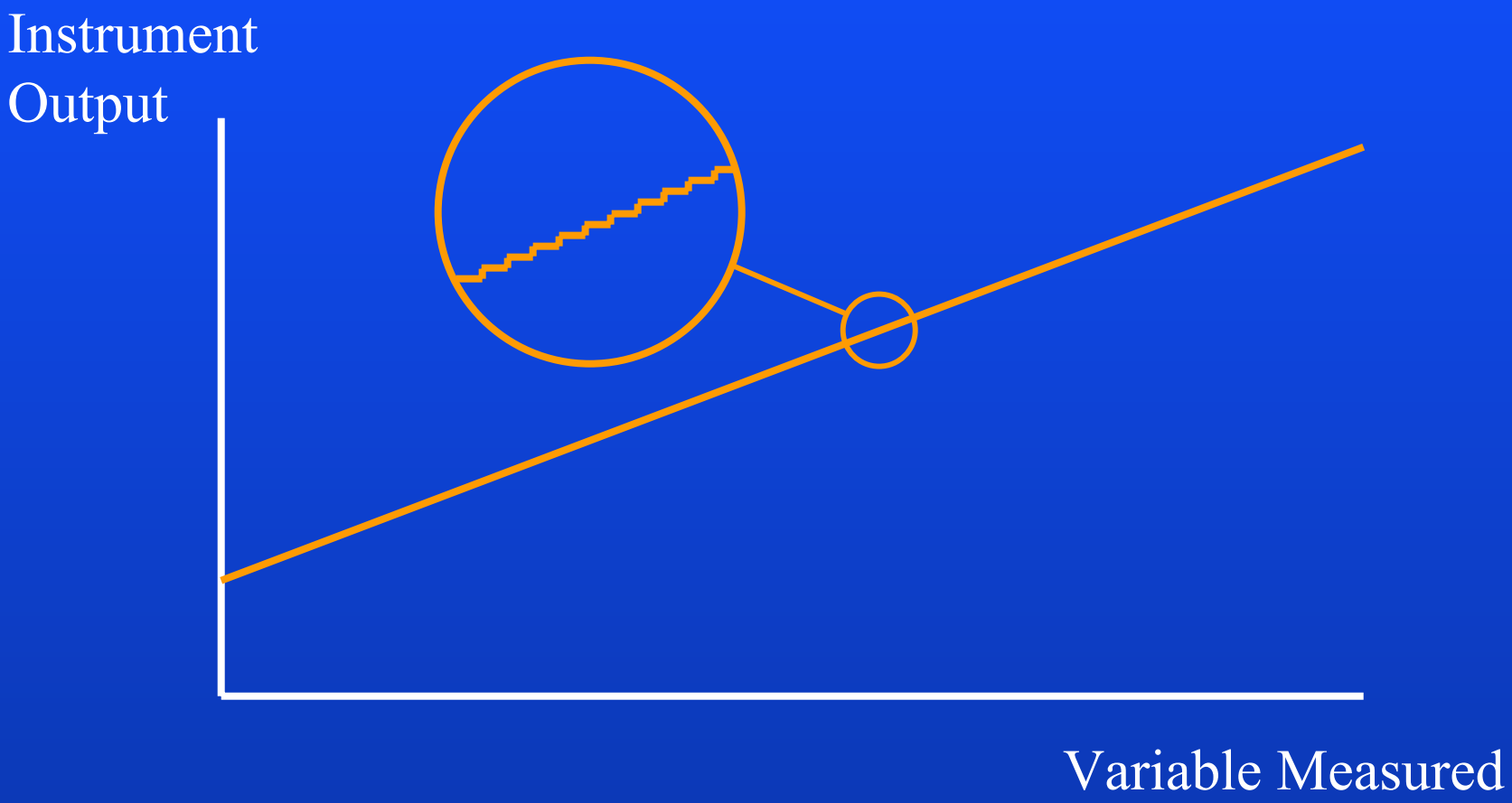
Stability - Consistency in output for a constant input



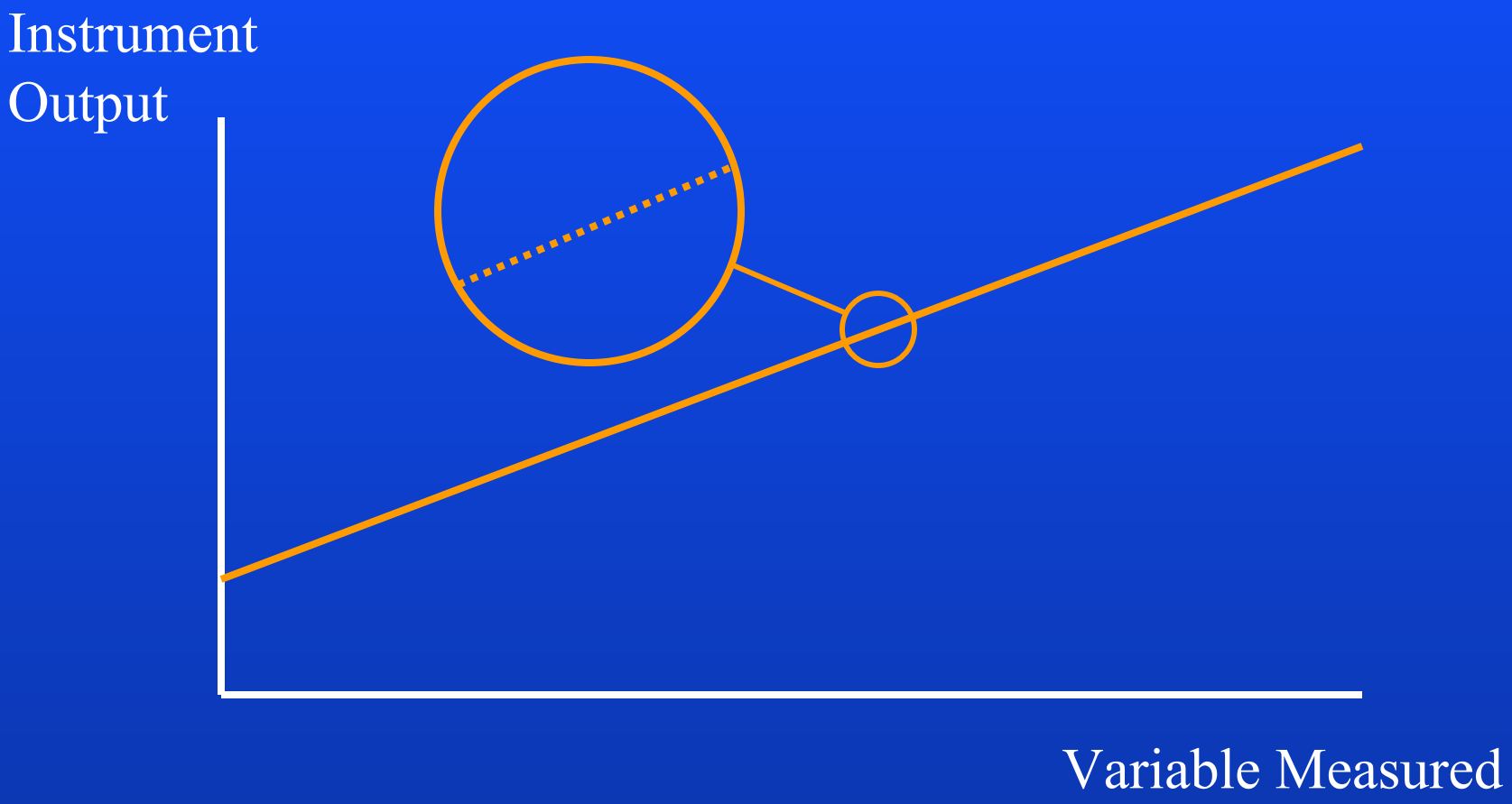
Specificity - Ability to distinguish desired variable from other competing variables



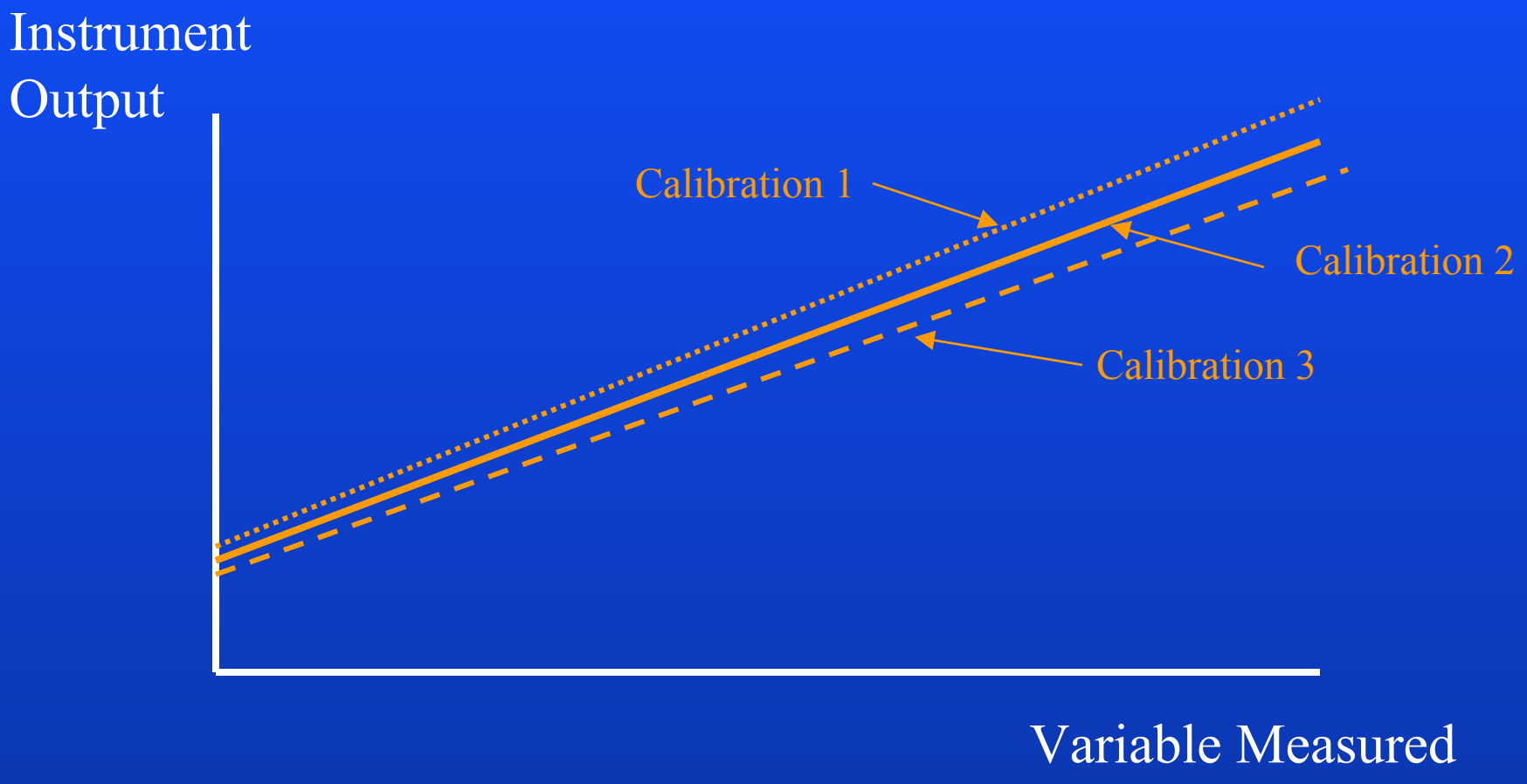
Accuracy - Difference between true value and measured value divided by the true value



Precision - Number of distinguishable alternatives from which a given result is selected. In other words: the smallest change in a variable that can be correctly measured

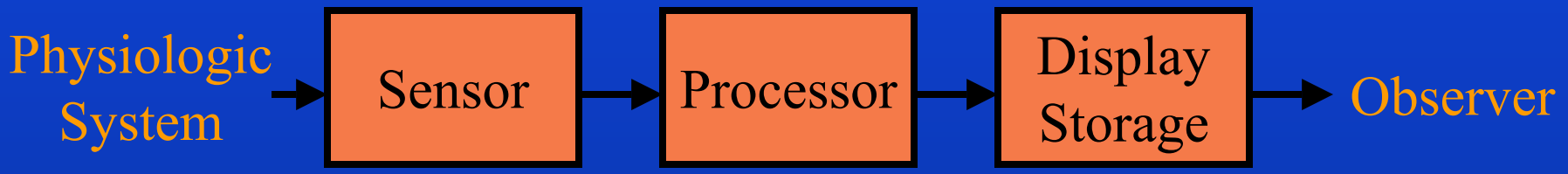


Resolution - Smallest increment that can be measured with certainty

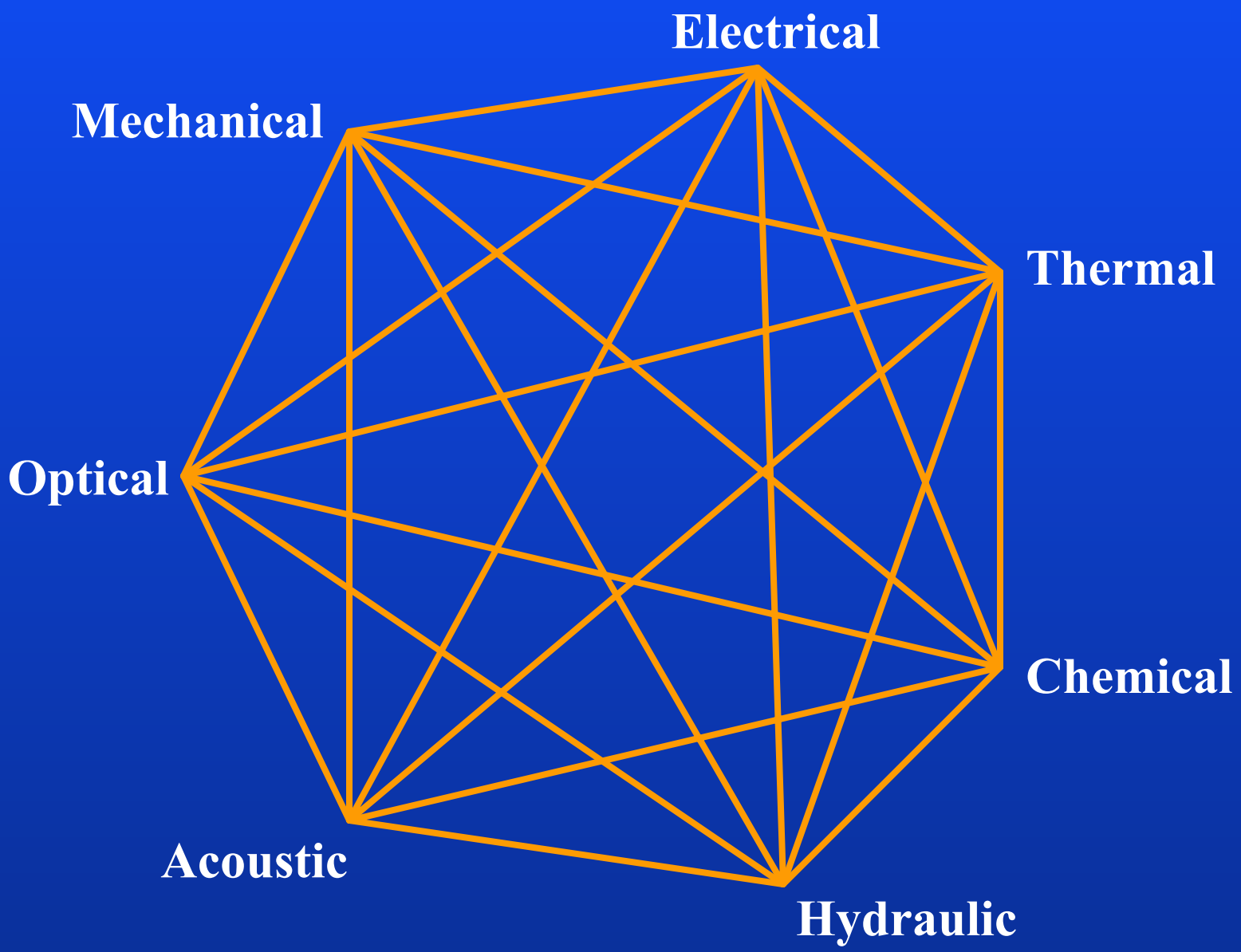


Reproducibility - Same output for the same input

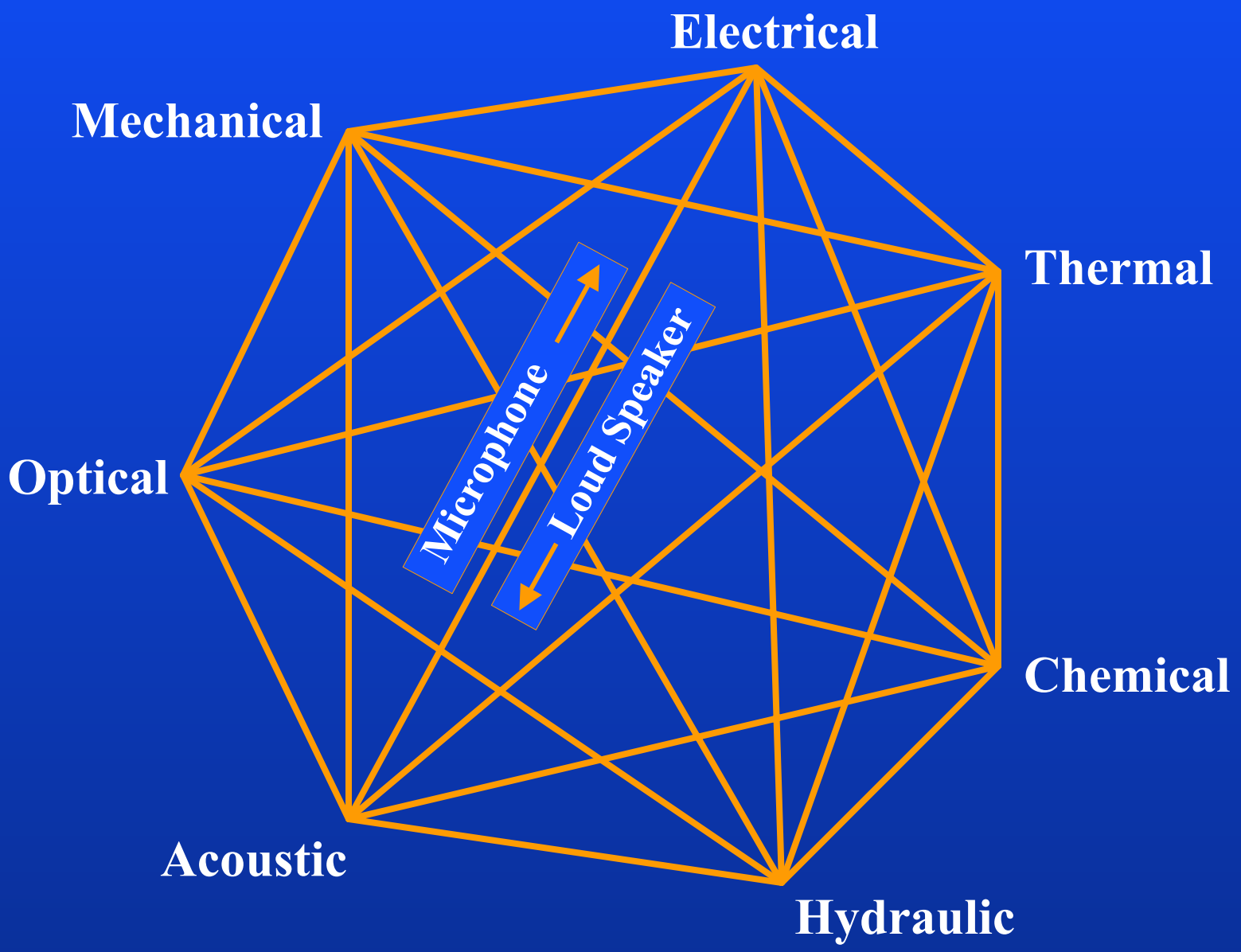
Basic Biomedical Instrument



Possible Types of Transducers



Possible Types of Transducers



Types of Sensors

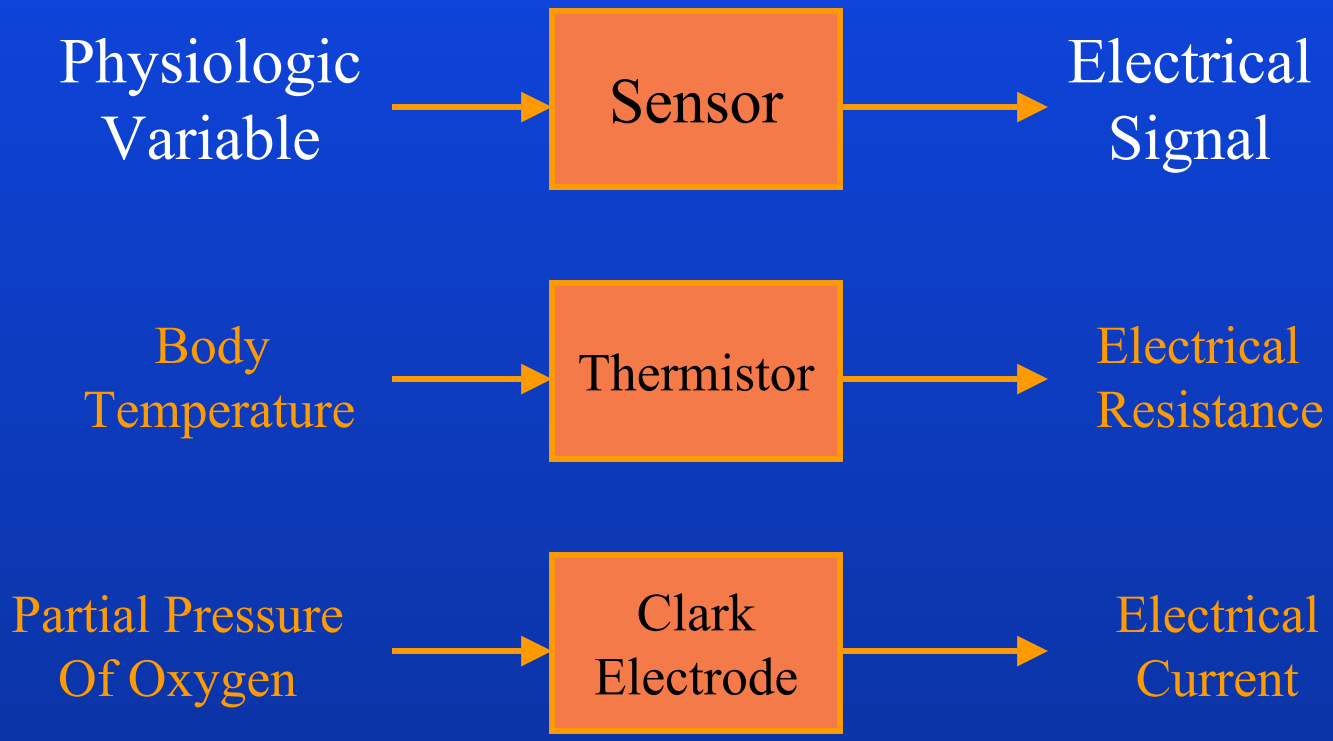
- Physical
- Chemical
- Bioanalytical

Types of Sensors

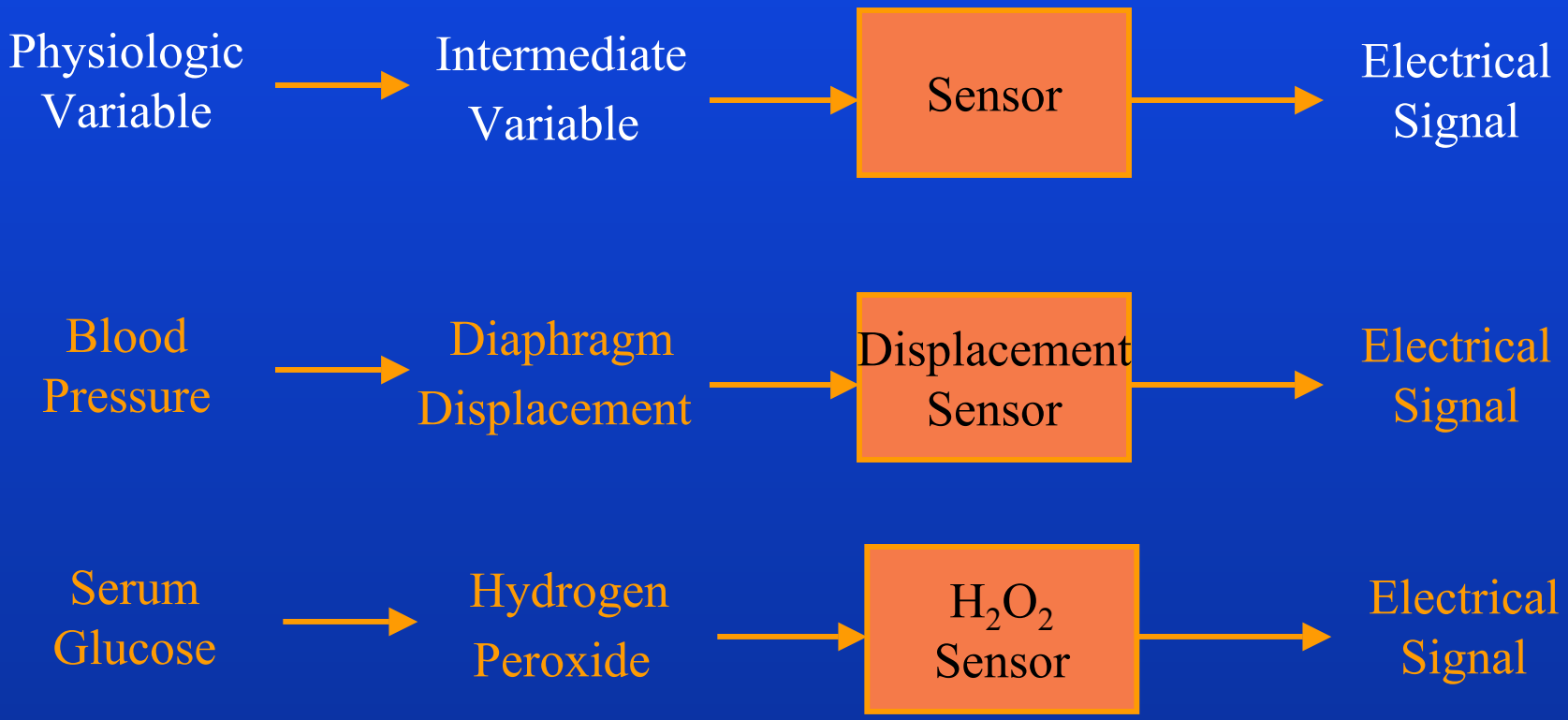
- Physical
  - Strain gauge
  - Accelerometer
  - Load cell (force)
  - Pressure sensor
  - Velocimeter
  - Thermistor
  - Metal resistance thermometer
  - Flow sensor
- Chemical
  - Oxygen electrode
  - Glass electrode (pH)
  - Ion-selective electrode
  - CO_2 sensor
- Bioanalytical
  - Glucose sensor
  - Lactate sensor

And so on …….

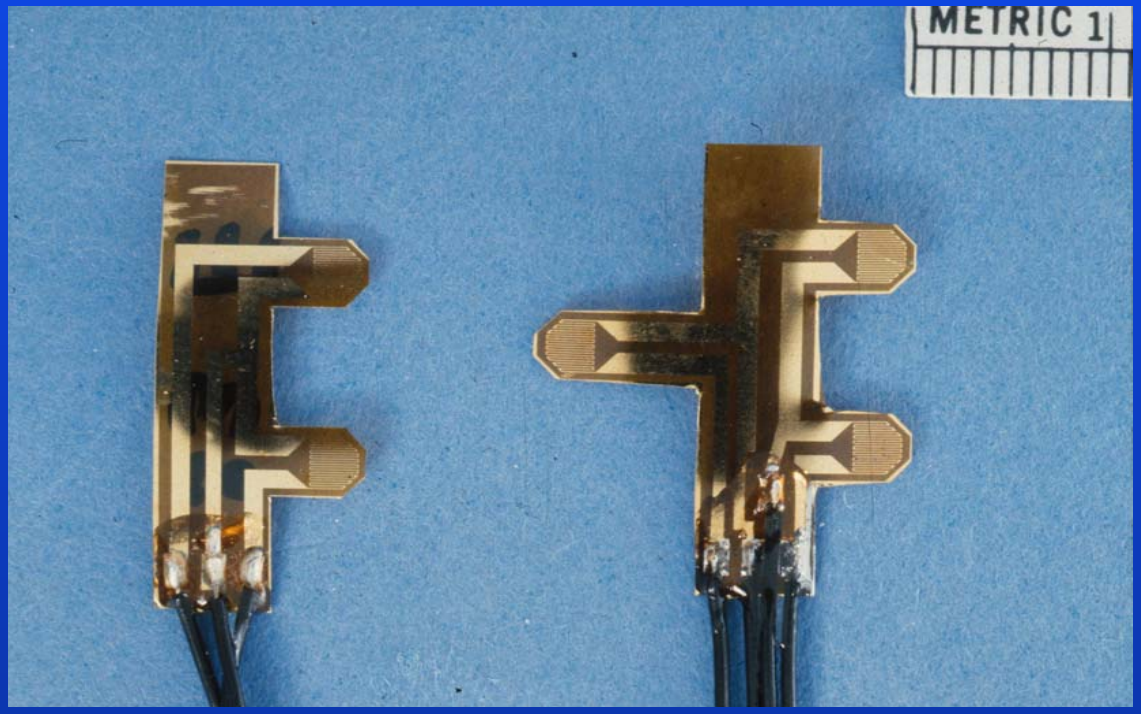
Single Conversion Sensor



Multiple Conversion Sensor



Thin-Film Gold Temperature Sensor



Nasal

Oral/Nasal

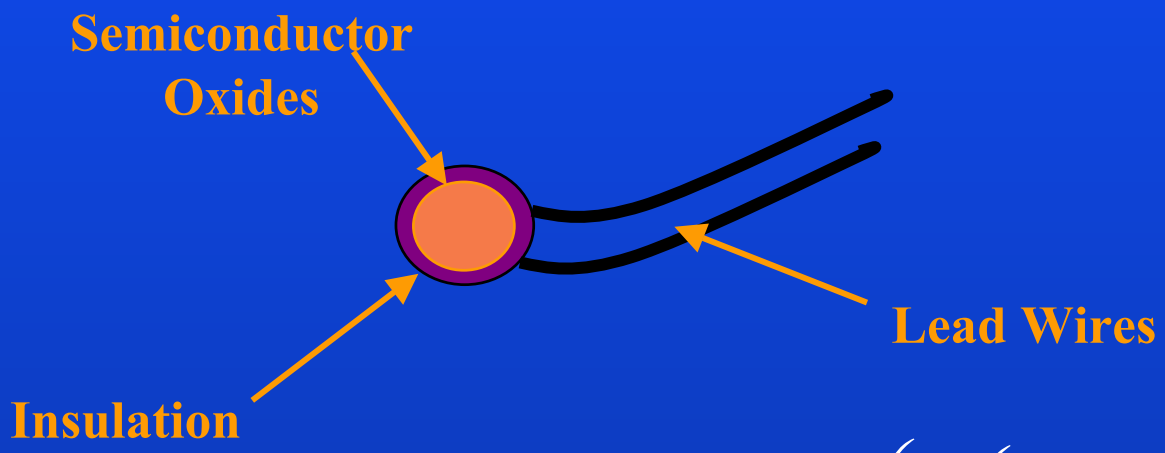
In place on an infant

$$R = R_0\left(1 + \alpha\left(T - T_0\right)\right)$$

R_0 is the resistance at temperature T_0

α Is the temperature coefficient of resistance

Thermistor (Temperature Sensor)



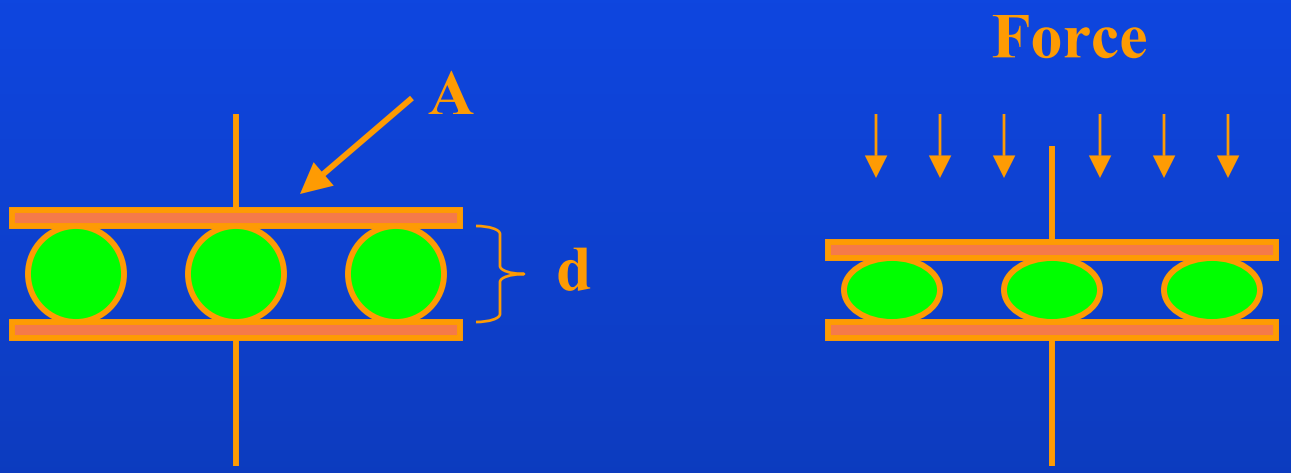
- **High sensitivity**
- **Inexpensive**
- **Non-linear**
- **Moderate stability**

$$R = R_0 \exp\left(\beta\left(\frac{1}{T} - \frac{1}{T_0}\right)\right)$$

R_0 is the resistance at absolute temperature T_0

β Is a constant

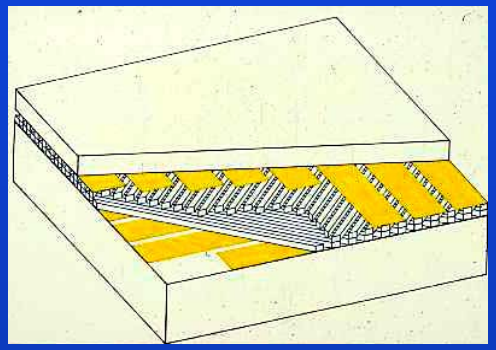
Capacitance Force Sensor



$$C = \varepsilon \frac{A}{d}$$

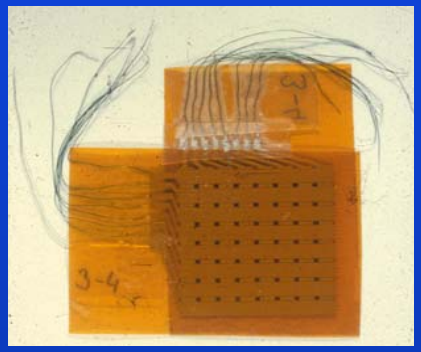
ε is the dielectric constant

Capacitance Force Sensor



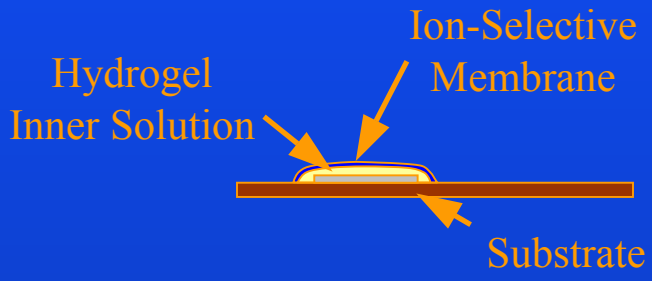
Cut-away structure of 64-element force sensor

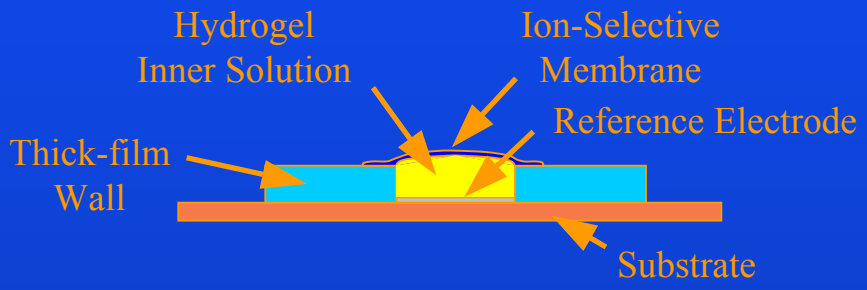
Micrograph of thick-film silicone dielectric strips



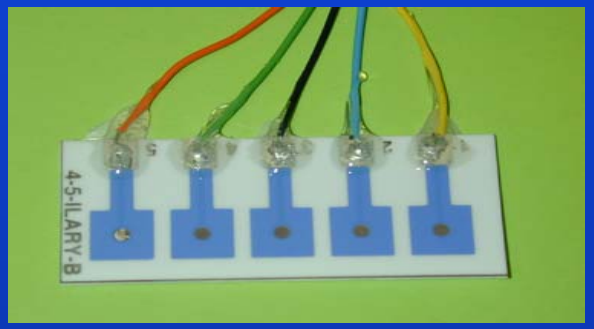
Assembled sensor

Ion-Selective Electrodes





Single thin-film basis ion-selective electrode



Ion-selective electrodes on a ceramic substrate with the inner chamber defined by 100 μm thick glaze films.