BB 101 : Biomedical Engineering

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BSBE, IITB

Lecture 1 : Introduction to BME, concept of non-invasive monitoring of the human body.

14-02-2022

Quiz, Exams, Text books ….!

- 1 Quiz (MCQ via moodle) of total 5 marks and final exam for 20 marks (MCQ).

- Part 1: Biomedical Engineering and medical imaging

1. [Kak] Principles of Computerized Tomographic Imaging, Avinash Kak and Malcolm Slaney (free online)

   Chapters 1,2 and 3 (up to section 3.3).

2. Biomedical Optics :Principles and imaging : Hsin-i Wu and Lihong V. Wang : chapter 1st and 5th.

3. [Enderle] Introduction to Biomedical Engineering : John Enderle, Joseph D. Bronzino, and Susan M. Blanchard Chapters 3,9, 10, 11, 12.

- Part 2: Origin of Biopotentials

1. [Guyton] Guyton and Hall Textbook of Medical Physiology : Chapters 1, 2 , 4, 5, 9, 10, 11, 45 and 46.

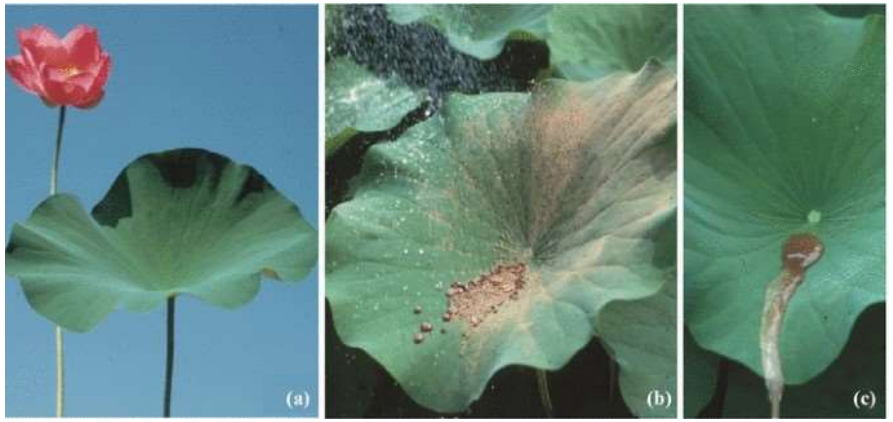
What is Biomedical engineering ?

- Basics Physiology + clinical physiology and anatomy + Engineering
- Physiology : Biology + chemistry + physics } mathematics
- Engineering : physics + chemistry + math (once upon a time)
- Engineering solutions to basic/clinical biomedical requirements.
- Concepts are often taken in both directions
- BIE :Bio inspired engineering
- EIB: Engineering principles used to inspire new hypothesis in Biological world: eg: “Synthetic Biology” : From wiki: "the use of a mixture of physical engineering and genetic engineering to create new (and, therefore, synthetic) life forms“ eg: making artificial cells.

Ref : Biology-Inspired Engineering and Engineering-Inspired Biology | Frontiers Research Topic (frontiersin.org)

Bio inspired engineering (BIE) and Engineering inspired Biology (EIB)

Ornithopter: Otto is going to fly - Ornithopter - Wikipedia



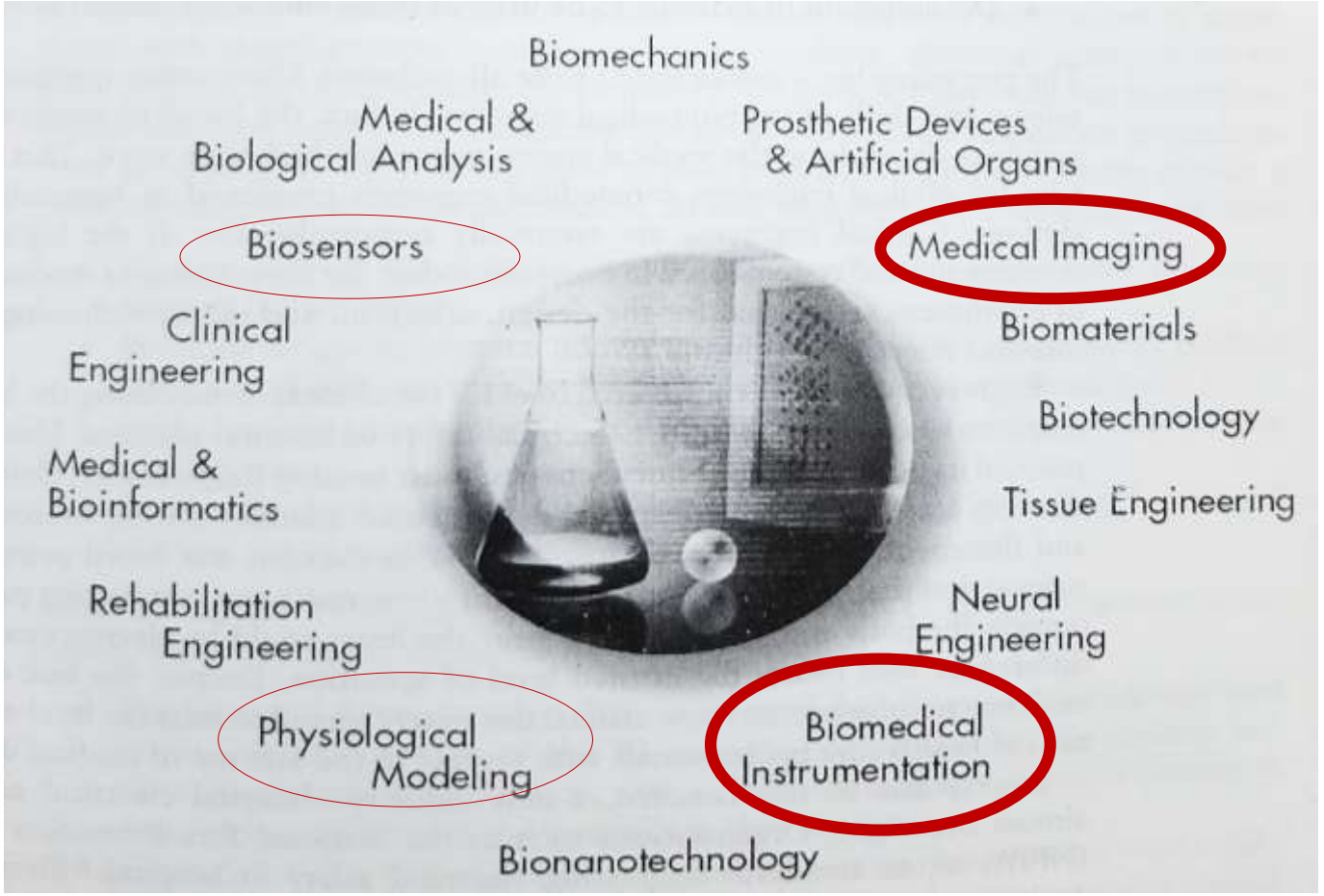
Plant Surfaces: Structures and Functions for Biomimetic Innovations | SpringerLink

Box fish inspired.
Bioniccar_11.jpg (3200×2119) (wikimedia.org)

Sticky Science: the Evolution of Spider Webs - Scientific American

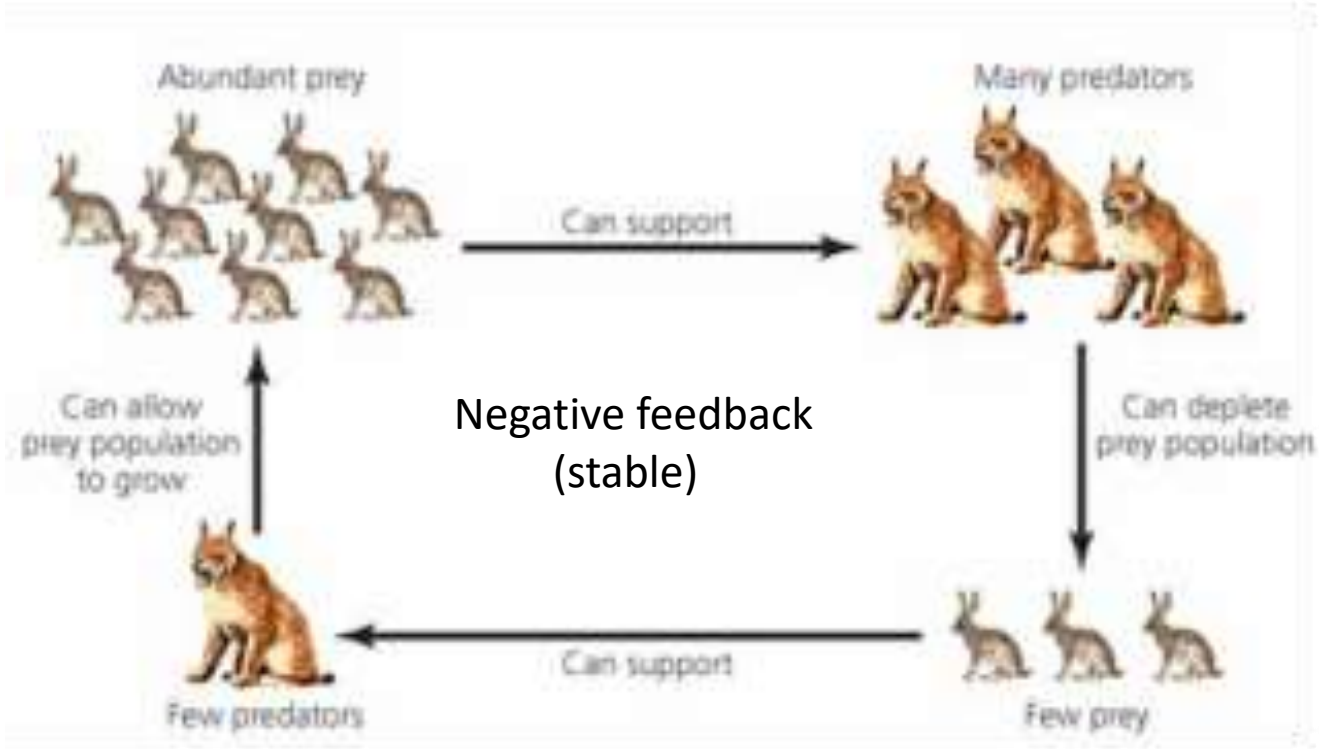
BIRDS hitting the glass and dying (infact though rarely some humans as well): Birds are more sensitive to UV than visible light: glass made of UV invisible coating (human can see through) which birds can see and hence avoid collision. Inspired by: spider web with a silk material capable of reflecting the UV and hence warn the birds of hitting.

Branches of Biomedical Engineering



Introduction to Biomedical Engineering **[Enderle]**

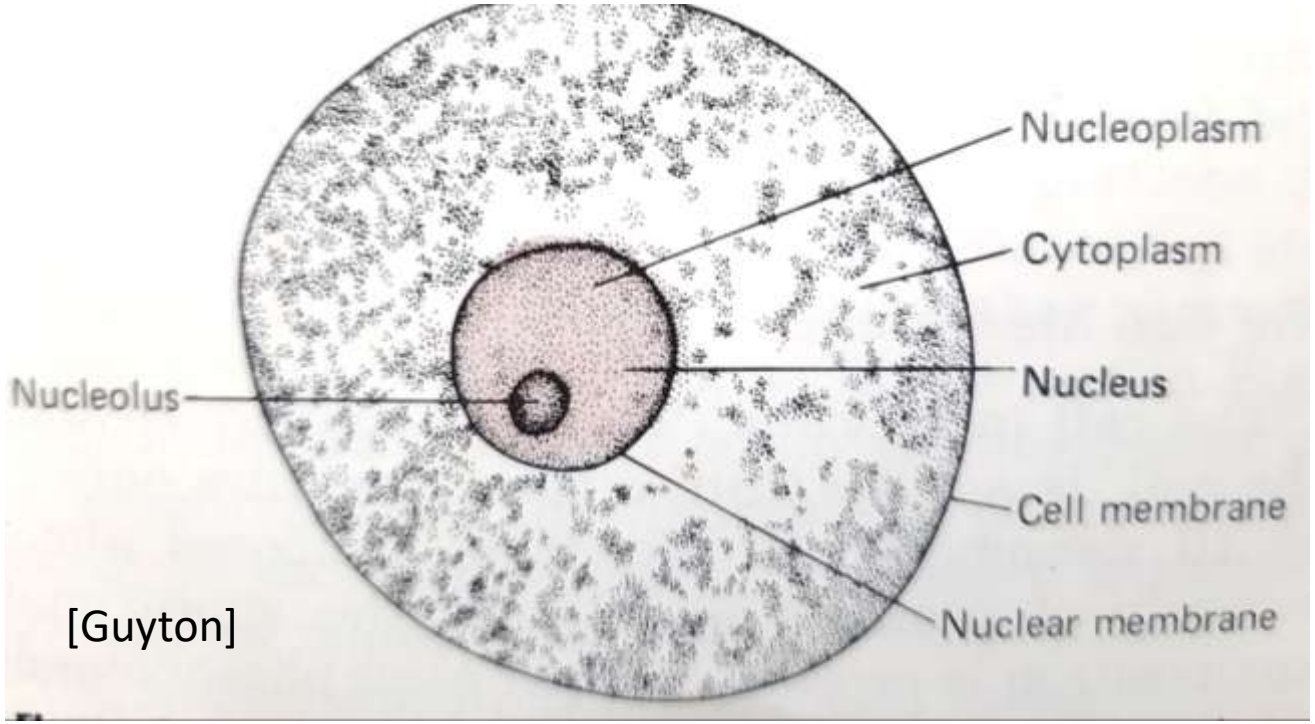
Overlap of engineering principles and physiology : Stability and feedback.



ESS Topic 1.3: Energy and Equilibria - AMAZING WORLD OF SCIENCE WITH MR. GREEN (mrgscience.com)

The Systems Thinker – Selecting Variable Names for Causal Loop Diagrams - The Systems Thinker

Cell : structure and some functions.



[Guyton]

- Maintenance of static conditions on the internal environment is important for stability : **Homeostasis**.
- Organs maintains homeostasis: in fact physiology learns how different organs maintain homeostasis.

Eg: kidneys : ion concentration ; Lungs : provides oxygen to extracellular fluid which is consumed by cell as needed. Gastro intestinal system provides nutrients.

- Cell: basic living unit with specific task.
  Roughly 75x10^12 cells in body
  Eg: Red blood cell (RBC)
- Organ : aggregate of many cells.
- A common function of all cells:

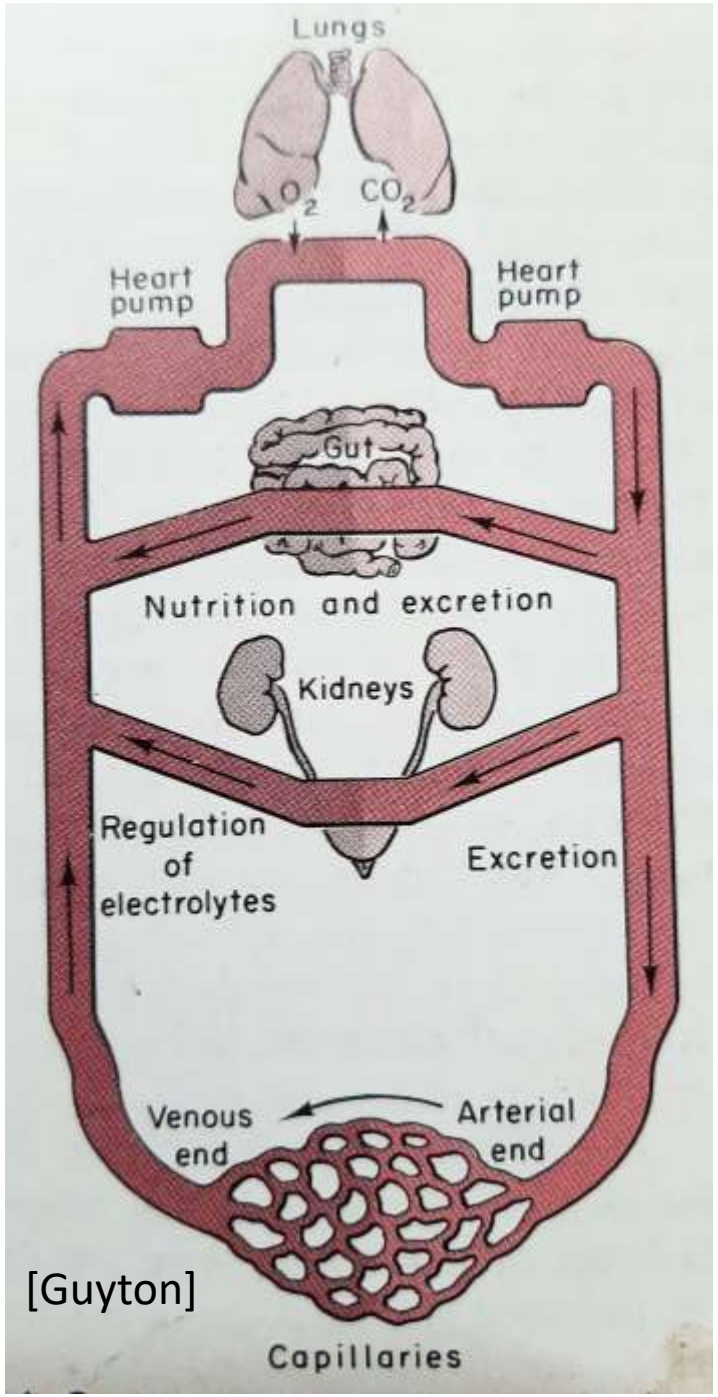
  a. Energy synthesis:

  Oxygen + (fat, carbohydrate, protein) = Energy

  b. Reproduction : Mitosis.

Structure of cell:

- 56% human body fluid: extracellular (1/4th) and intracellular ($3/4^{th}$).
- Extracellular fluid floats in body: blood transport it.
- Intracellular: eg. K, Na and Phosphate ions.
- Extracellular: ions (Na, Cl) and nutrients (i.e., oxygen, glucose, fatty acids, amino acids).
- **Extracellular fluid is called internal environment** of the body as it creates same environment for all cells.



[Guyton]

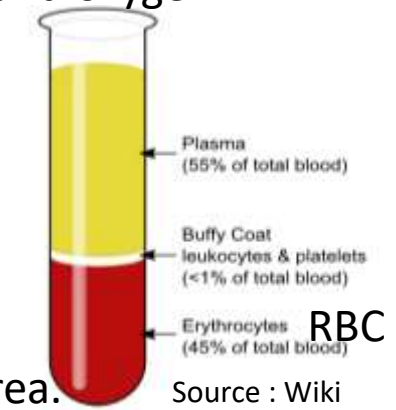
The circulatory system : extracellular fluid transport

- **Heart** : two separate pumps. One pumps blood through the lungs and the other to the body (systemic circulation).
- **Extracellular fluid** : **blood plasma + interstitial fluid,** lymph + transcellular fluid.

blood plasma : 92% water (blood volume) + salts (Ph) + glucose and amino acids (nutrients to cell) + Urea (to be excreted in kidney) + various hormones and plasma proteins (eg. Albumin pulls water and keep it there by osmosis etc).

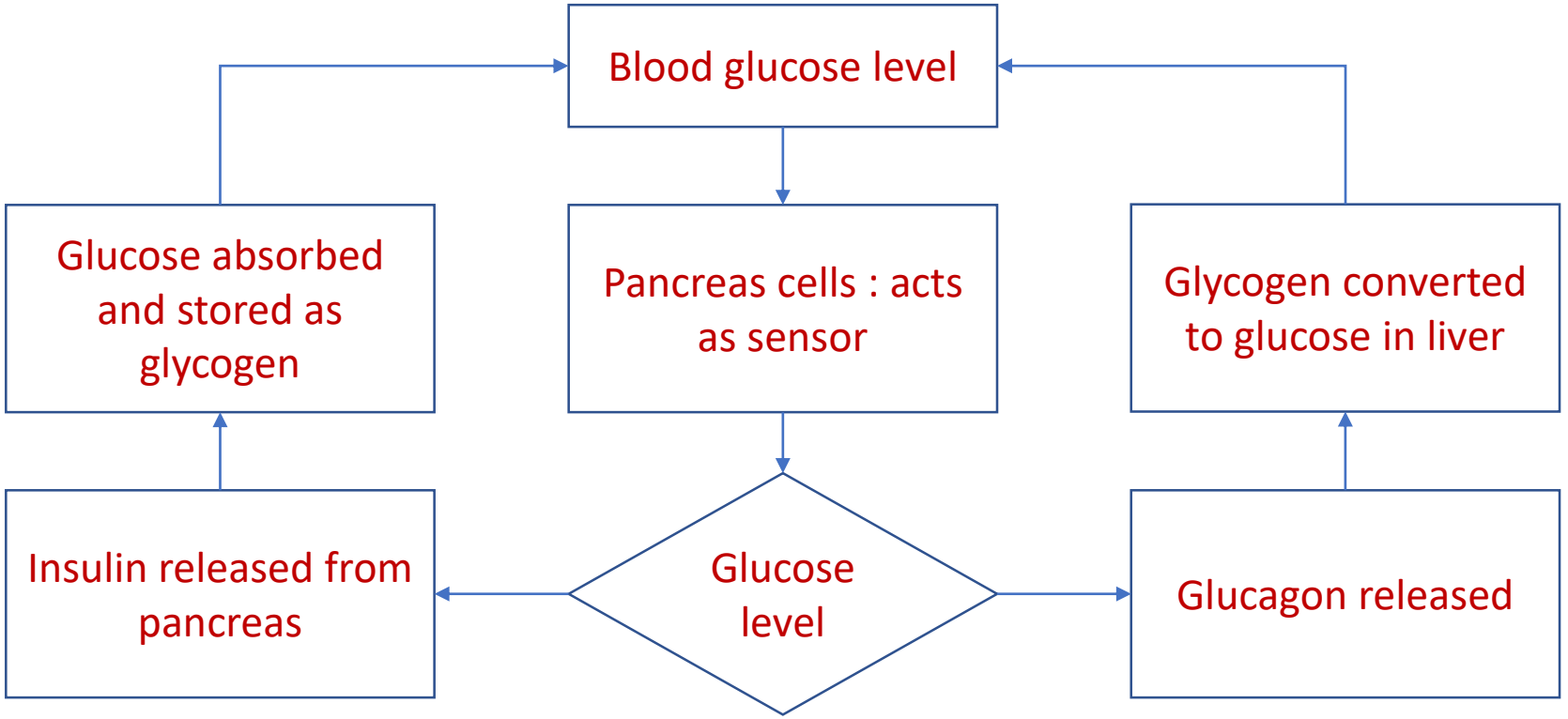
Interstitial fluid : water, amino acids, sugar, **neurotransmitters ,** fatty acids, hormones etc **. Role: delivery material to cell, intercellular communication and removal of metabolic waste**. **Diffusion of materials** to cells from capillaries via interstitial fluid happens. Plasma can diffuse to interstitial fluid while RBC and platelets are too big for it.

- **Lungs :** Heart pumps blood to lungs and in the pulmonary capillaries. The alveoli of the lungs and capillaries are separated by a membrane and oxygen **diffuses to blood** via this. CO2 is released out in the same way.
- **Gastro Intestinal Tract (GUT) :** blood absorbs nutrients here : carbohydrates, fatty acids, amino acids etc.
- **Liver :** Modifies the absorbed nutrients from GUT to new form to be used by cells and also stored for future. Eg: glucose Is converted to glycogen and stored.
- **Kidneys :** removes unwanted materials in extracellular fluid eg: urea.



Source : Wiki

Homeostasis: roles of each organ and their concerted efforts to maintain homeostasis: **Control systems in human body**

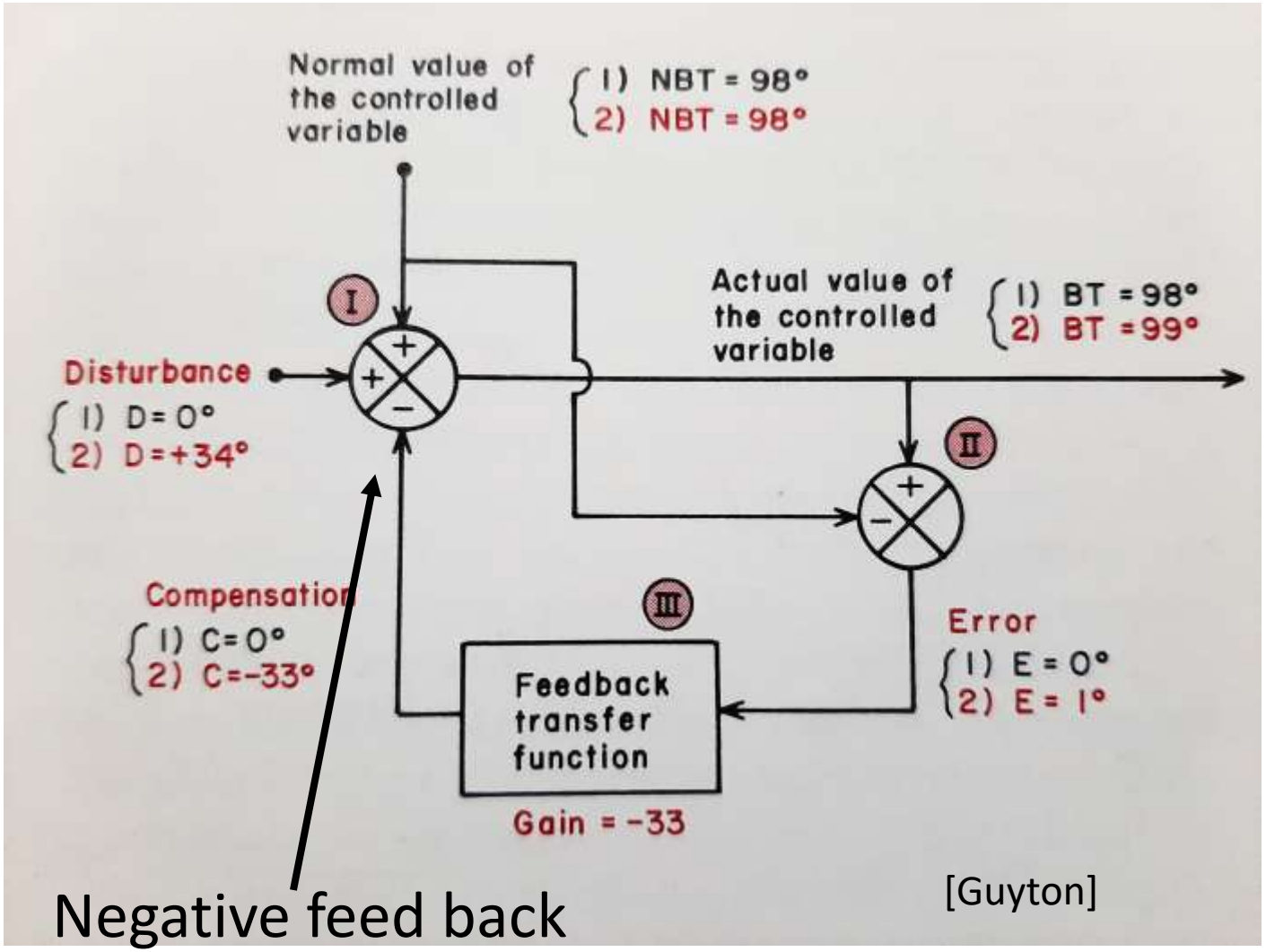


Negative feed back

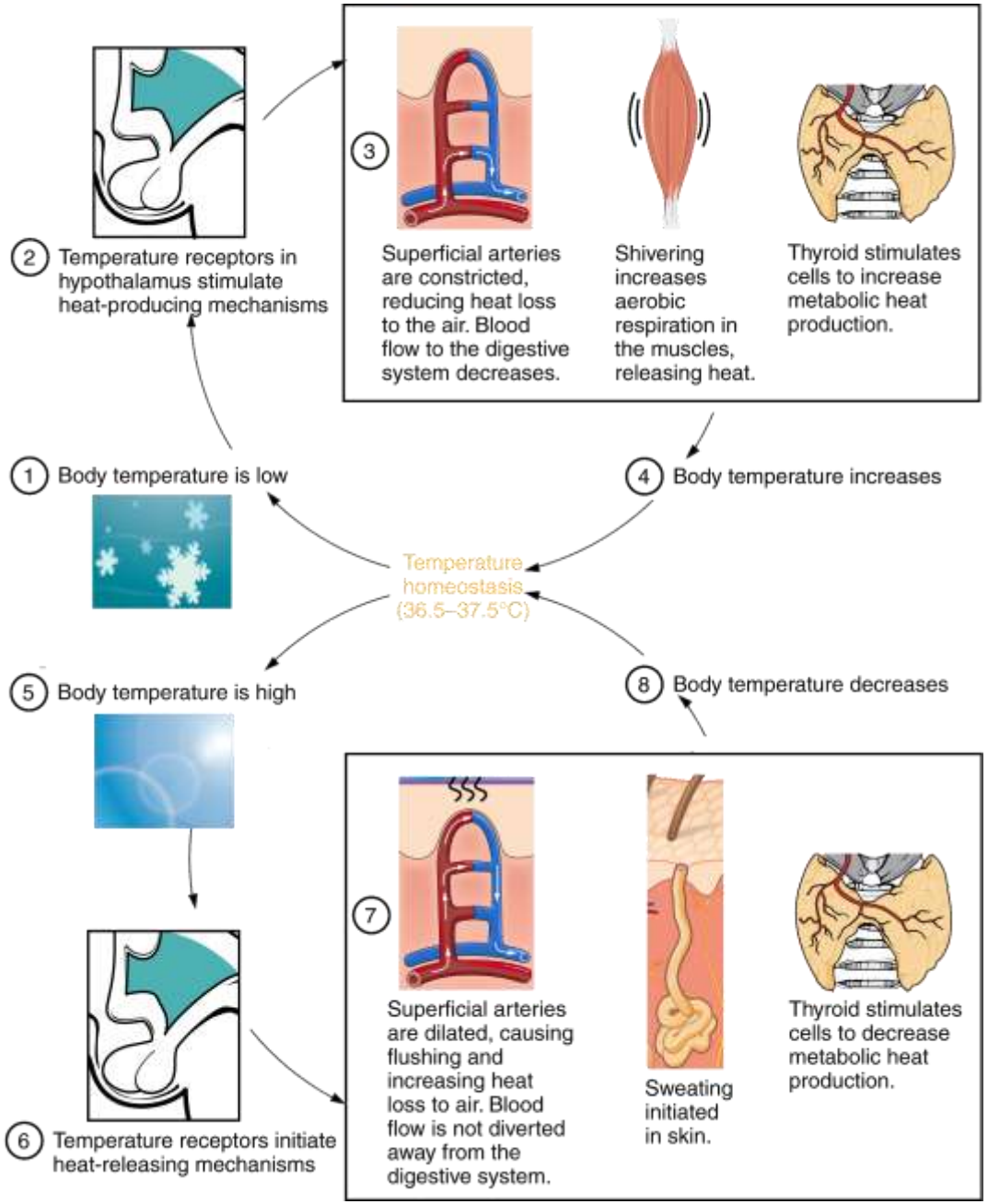
Sugar regulation

- Controlled variable : Blood glucose level
- Sensor : pancreas
- Feedback control : pancreas +insulin.
- Disturbance or initiator of blood glucose changes :disease or uncontrolled appetite.

General control system : Body temperature



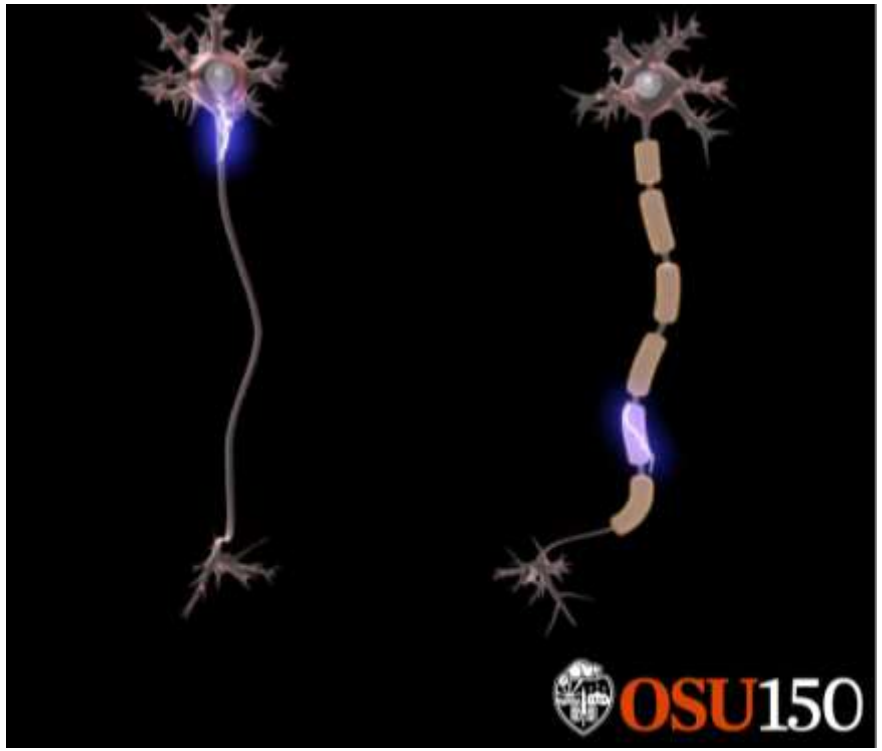
- Will show only overall mechanism without details.
- Normal Body temperature (BT) = 98.
- Suppose Homeostasis and no disturbance. i.e., Actual value of controlled variable (AVC) = disturbance + normal value of BT + error * Gain = 0+ 98 + 0 =98.
- Suppose a disturbance of +34.
  we need the AVC = 99 (i.e., just 1 degree error from normal BT)
  Compute the gain required:
  Error = 1; Gain = AVC-disturbance – Normal BT = 99-34-98 = - 33.
- This is only steady state analysis and no dynamics are taken into consideration : eg:. The compensation signal cannot act abruptly to maintain the controlled variable with less error.



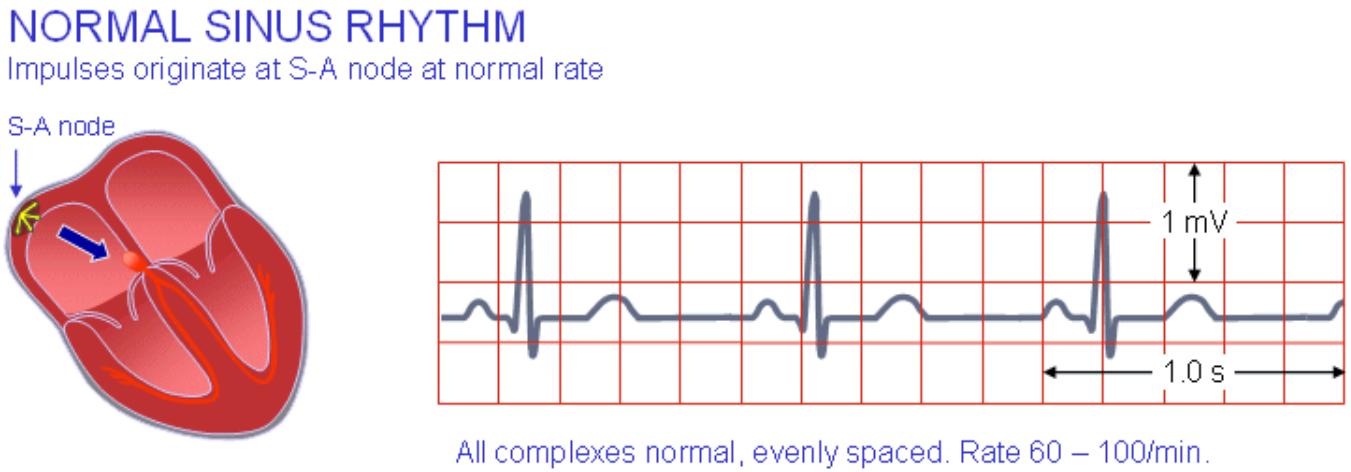
- Body temperature regulation : thermo regulation : Normal BT = 37 degree Celsius.
- Hypothalamus helps to main Homeostasis by means of conduction, convection, radiation and evaporation.
- Cold weather raised heart rate: we can measure this using a simple pulse oximeter.

https://iastate.pressbooks.pub/curehumanphysiology/chapter/body-temperature-homeostasis/

EXAMPLE OF POSITIVE FEED BACK :unstable



Action potentials in Neurons : Hodgkin cycle is a positive feedback loop



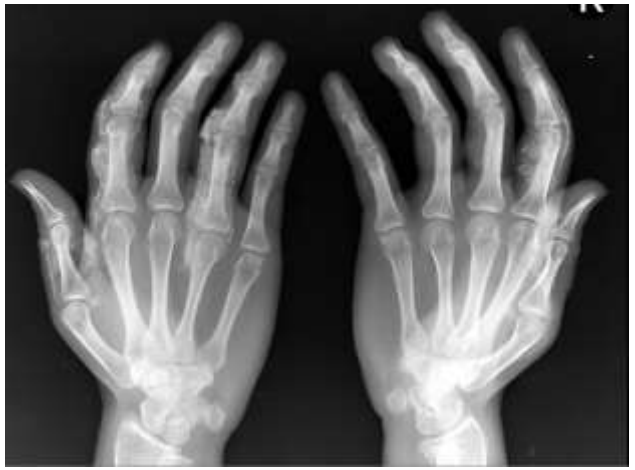
Sino Atrial node produces the impulses which makes the heart pump. : positive feedback or oscillator action

[Finding a Cure for ALS | Neurons transmit electrical signals… | Flickr]

[File:Normal ECG 2.svg - Wikimedia Commons]

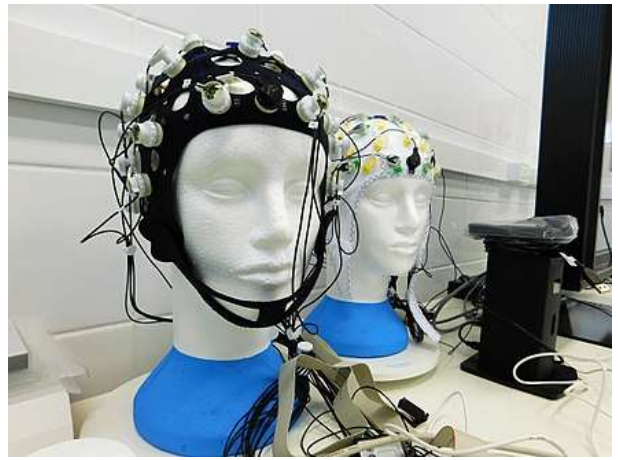
Biomedical instrumentation and measurement.

- We will look at the measurements that can be made in the body for accessing the status of physiological or anatomical situation of human body.
- Eg: physical inspection by a physician, Chest X-ray, MRI etc : anatomical information.
- Eg: EEG, ECG, Ultrasound, NIRS (pulse oximeter, Perfusion MRI) : physiological information.



Dermatomyositis x ray - wikidoc

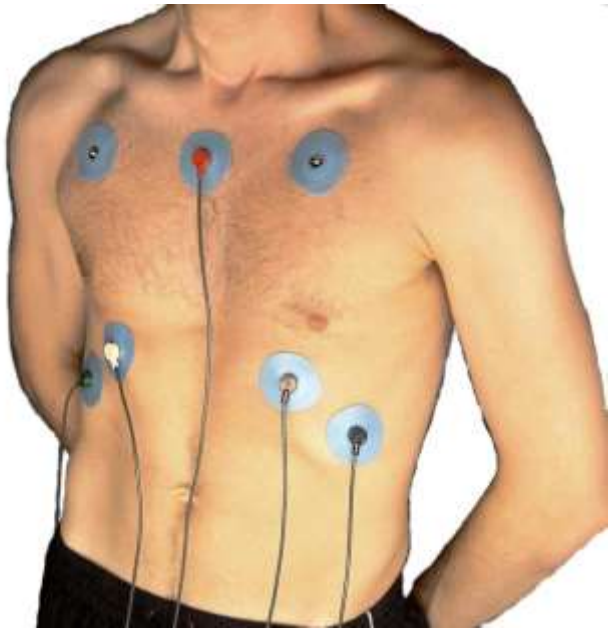
Fichier:Wrist-oximeter.jpg — Wikipédia (wikipedia.org)



Eletroencefalografia – Wikipédia, a enciclopédia livre (wikipedia.org)

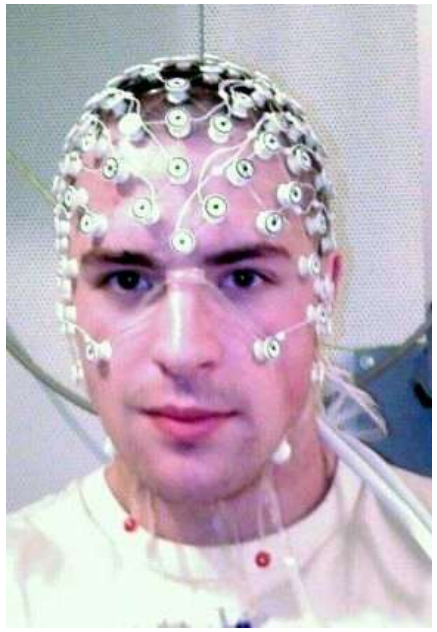
Looking into the body non-invasively.

A medical procedure is defined as *non-invasive* when no break in the skin is created and there is no contact with the mucosa, or skin break, or internal body cavity beyond a natural or artificial body orifice. : Non-invasive procedure - Wikipedia



Biopotential: electrical signal

14101766166_c78919676e_b.jpg (850×760) (staticflickr.com)



Biopotential: electrical signal

EEG_cap.jpg (289×423) (wikimedia.org)

Sound signal

Finding the Error Activity: Infant Apical Pulse – Answer – Vital Sign Measurement Across the Lifespan – 1st Canadian edition (pressbooks.pub)

Looking into the body non-invasively.

https://en.wikipedia.org/wiki/CT_scan

https://en.wikipedia.org/wiki/Ultrasound

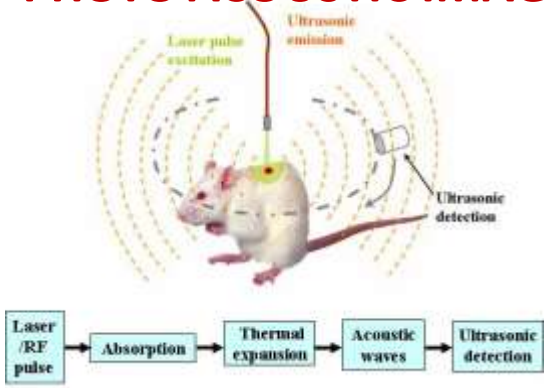
https://en.wikipedia.org/wiki/Magnetic_resonance_imaging

NIR IMAGING

https://www.wikiwand.com/en/Near-infrared_spectroscopy

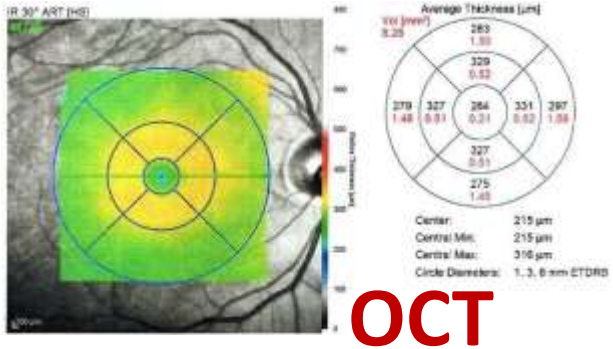
https://en.wikipedia.org/wiki/Photoacoustic_imaging

PHOTO ACOUSTIC IMAGING



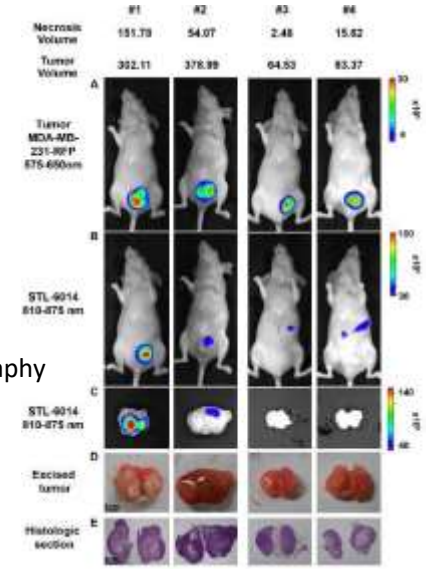
https://en.wikipedia.org/wiki/Positron_emission_tomography

PET SCAN



OCT

https://en.wikipedia.org/wiki/Optical_coherence_tomography



FLOURESCENCE IMAGING

https://commons.wikimedia.org/wiki/File:Fluorescence_Imaging_07.jpg

- **Different imaging modalities have different underlying physical principles.**
- **Look for common features of each imaging modalities.**
- **A common platform or theory to many imaging modalities.**