Mathematical Modelling

For Closed Loop Control

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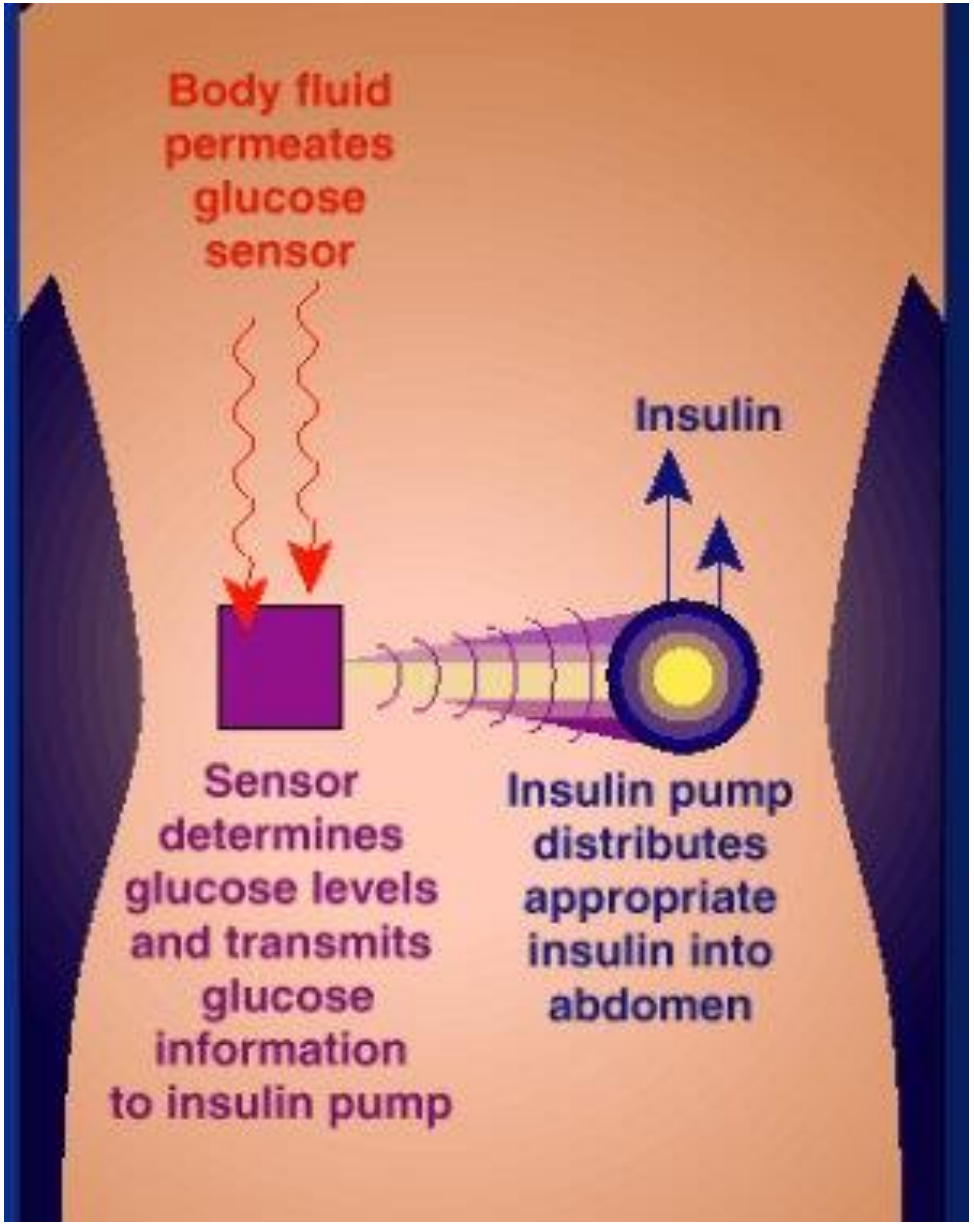
Closed-Loop Control: The Artificial Pancreas



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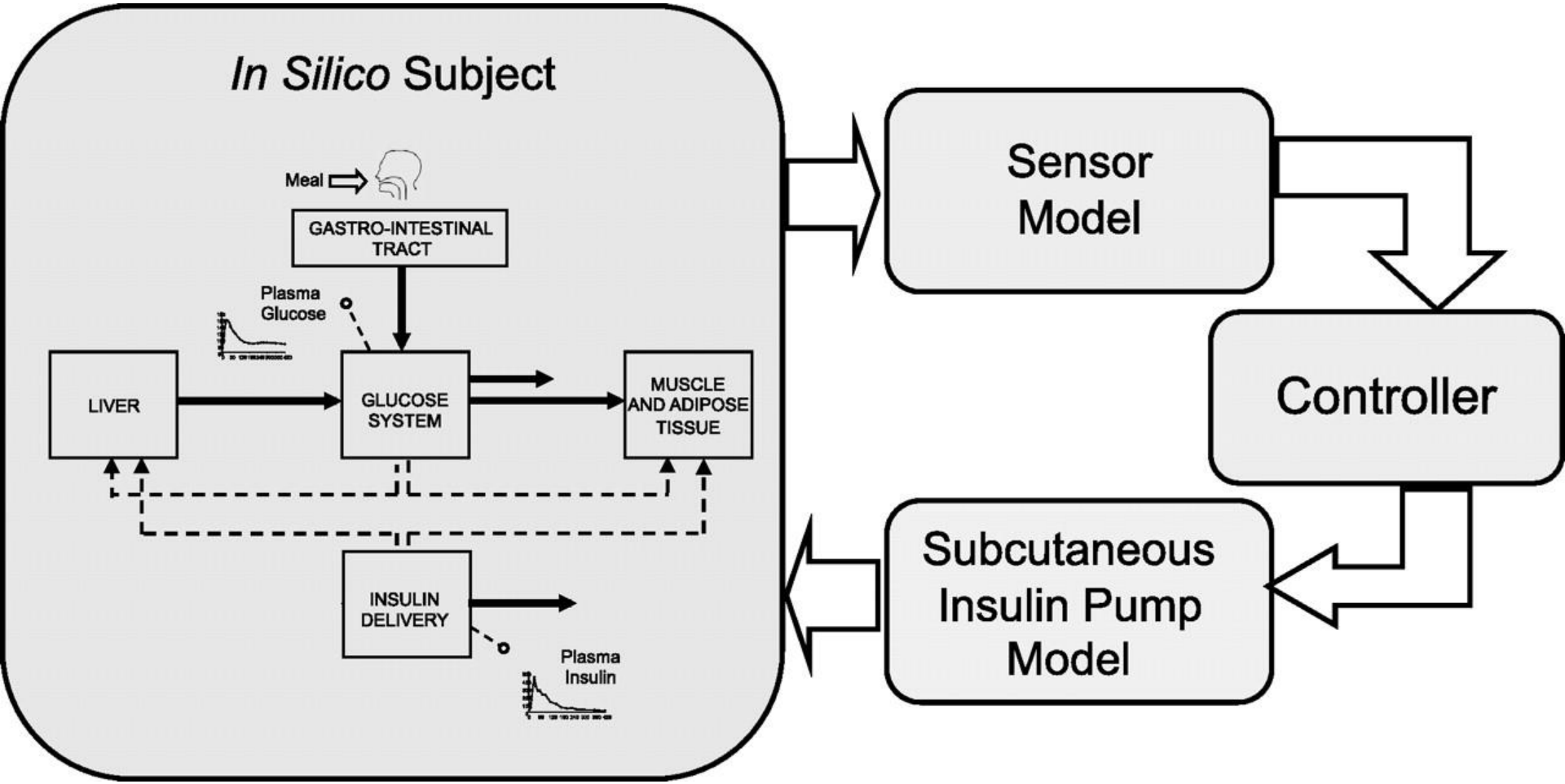
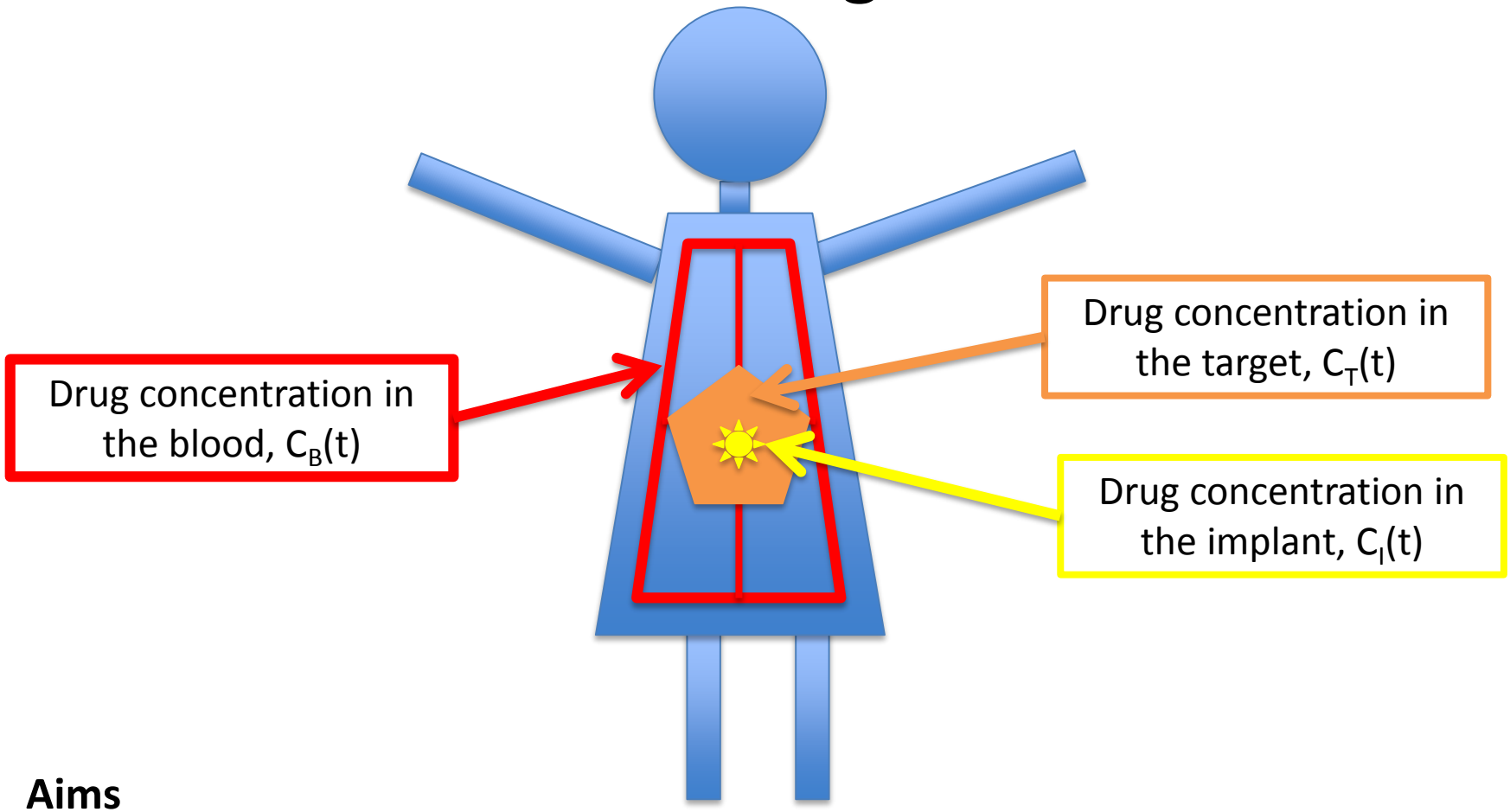


Closed-Loop Control:
How Do I Build A Mathematical Model?

- What are the **quantities of interest?**
- What are the **observables**?
- What are the **control parameters**?
- What are the **timescales of interest**?

A Simple Example:
Controlled Drug Release

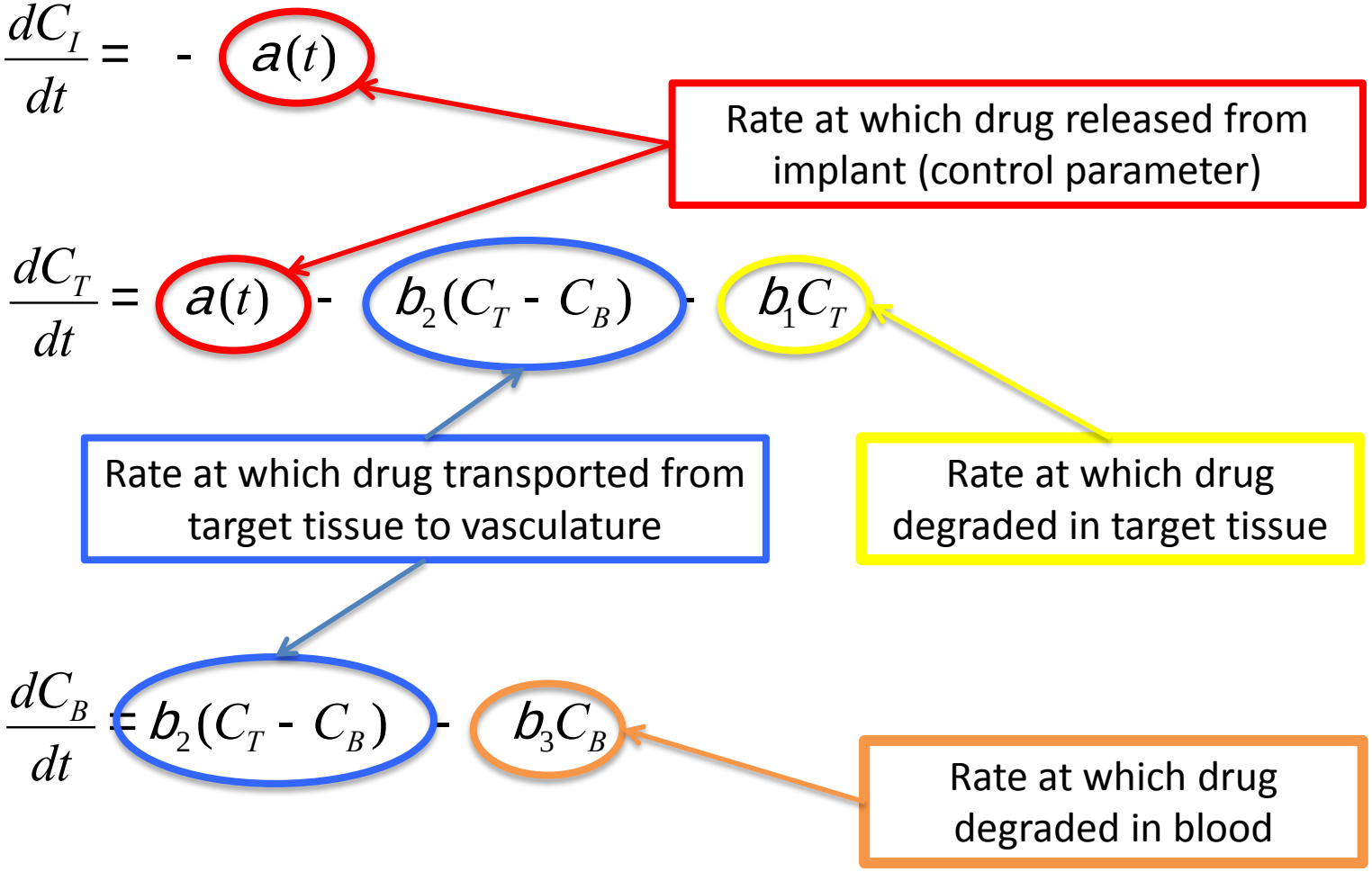


Aims

- **Control drug release** rate from implant to **maintain drug levels in target tissue** within **efficacious** and **non-toxic** levels
- **Signal** to change implant (eg **drug levels low, device malfunction**)

Controlled Drug Release:

A Prototype Mathematical Model



Controlled Drug Release:
Possible Control Strategy

$$a(t+\Delta t)=\begin{cases} a_{low} & \text{if} \quad C_T(t) > C_{\max} \\ a_{med} & \text{if} \quad C_{\min} < C_T(t) < C_{\max} \\ a_{high} & \text{if} \quad C_{\min} > C_T(t) \end{cases}$$

Controlled Drug Release:

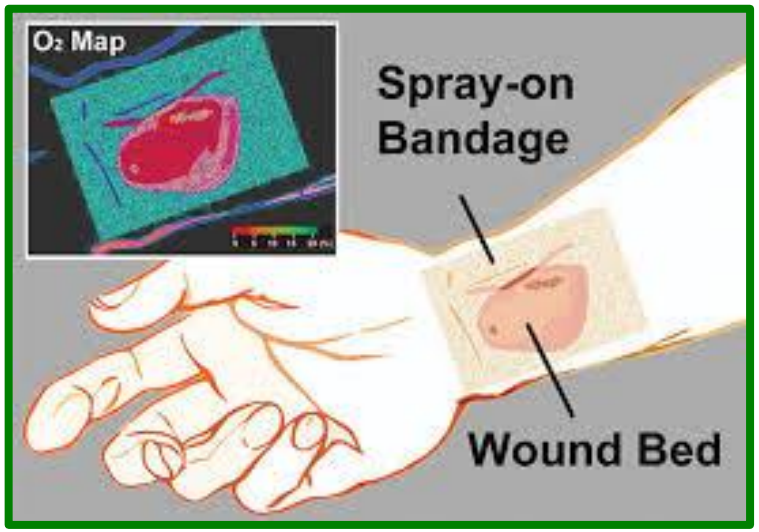
From Prototype to Practice

$$\frac{dC_I}{dt} = -a(t) \qquad \frac{dC_T}{dt} = a(t) - b_2(C_T - C_B) - b_1 C_T \qquad \frac{dC_B}{dt} = b_2(C_T - C_B) - b_3 C_B$$

Possible Model Extensions

- More detailed models of drug metabolism and control
- Account for drug action:
  - Halt treatment for non-responders
  - Increase drug levels for responders
- Smart(er) implant:
  - Multiple drugs
  - More sophisticated control system
  - Multiple observables (eg oxygen levels, pH, temperature)

Smart Bandages for Wound Healing



- **Quantitites of interest:**
  - wound size, degree of perfusion, signs of infection
- **Observables**:
  - temperature, pH, glucose, oxygen
- **Control parameters**:
  - antibiotics, pressure, warning signal
- **Timescales of interest**: days