

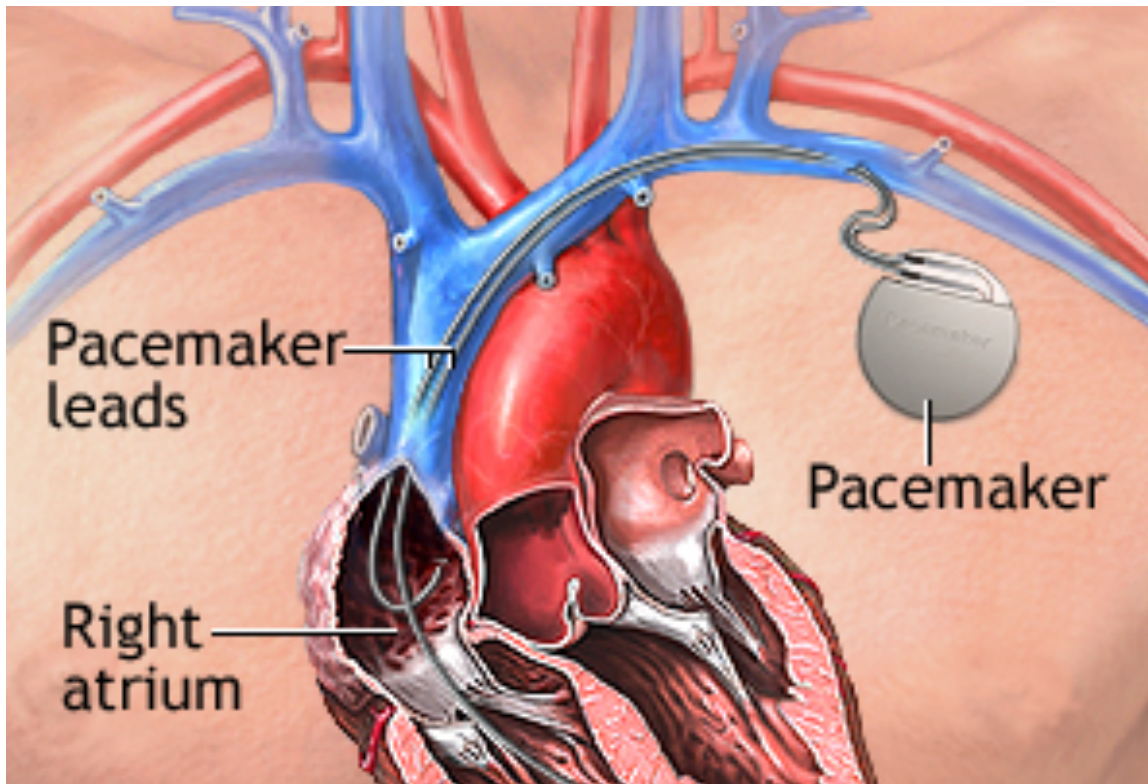
Cyber-Physical Systems

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Università degli Studi di Trieste
II Semestre 2020

Lecture 1: Introduction and Course Logistic

Medical Device



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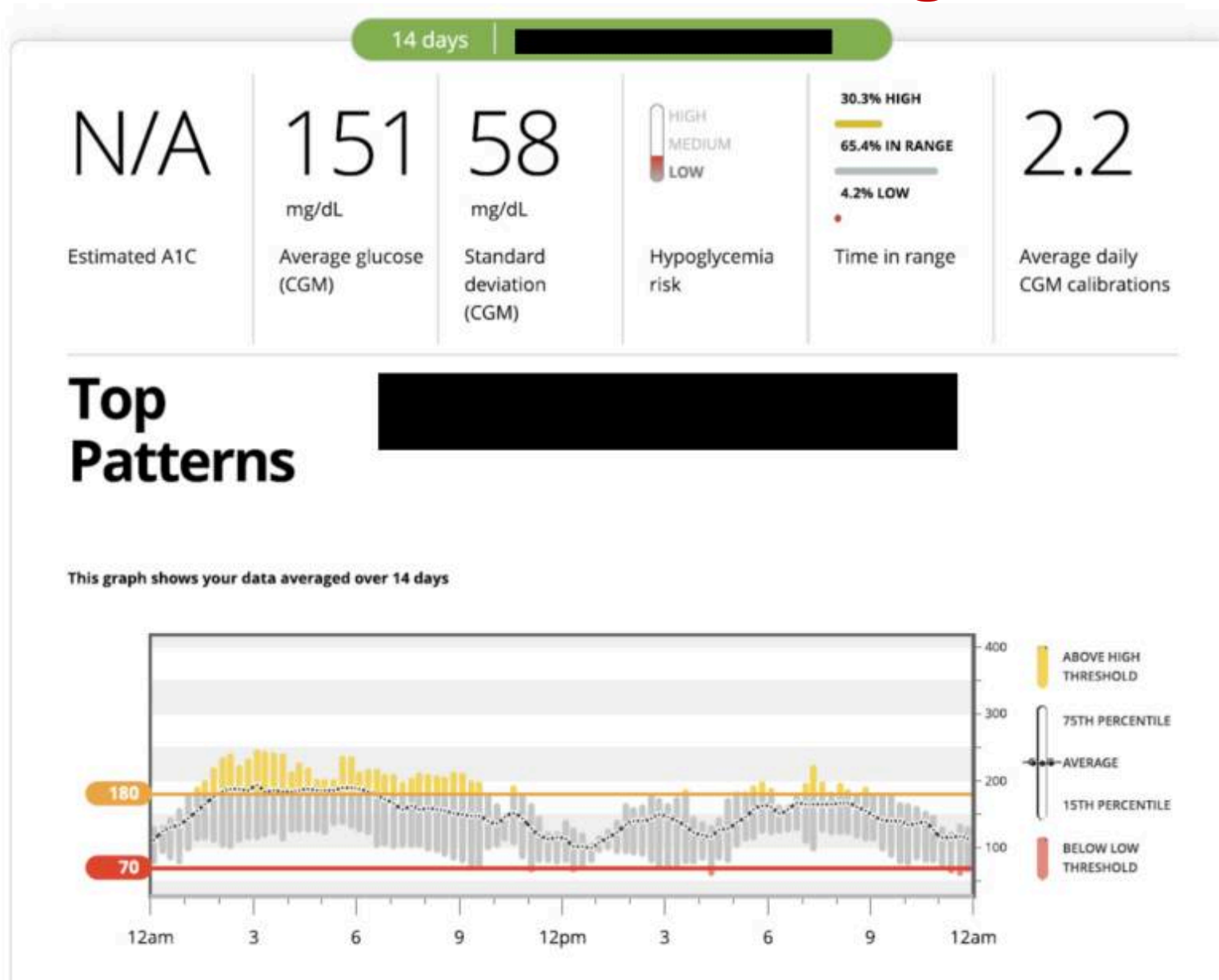
Artificial Pancreas

Type 1 diabetes occurs when the pancreas produces little or none of the insulin needed to regulate blood glucose

They rely on external administration of insulin to manage their blood glucose levels.

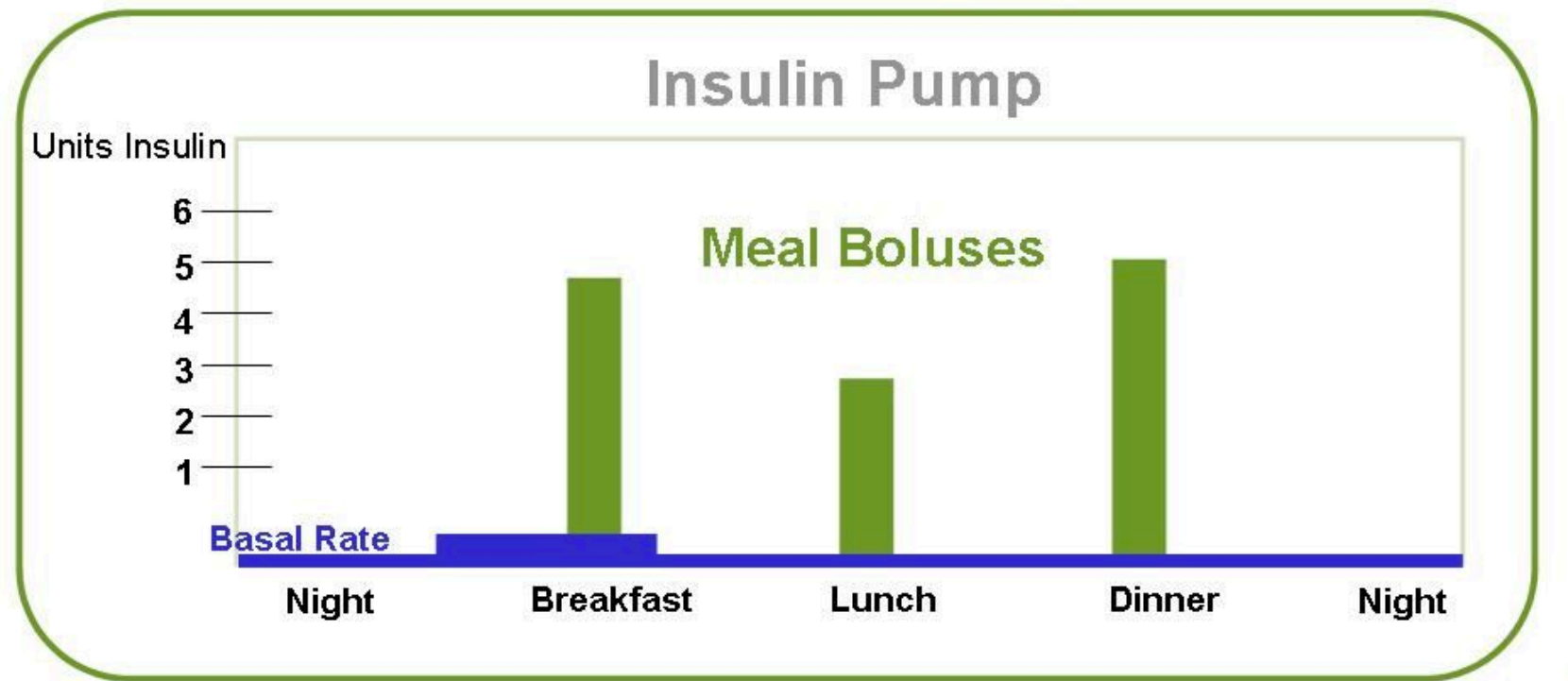


Continuous Glucose Monitoring



Insulin pumps

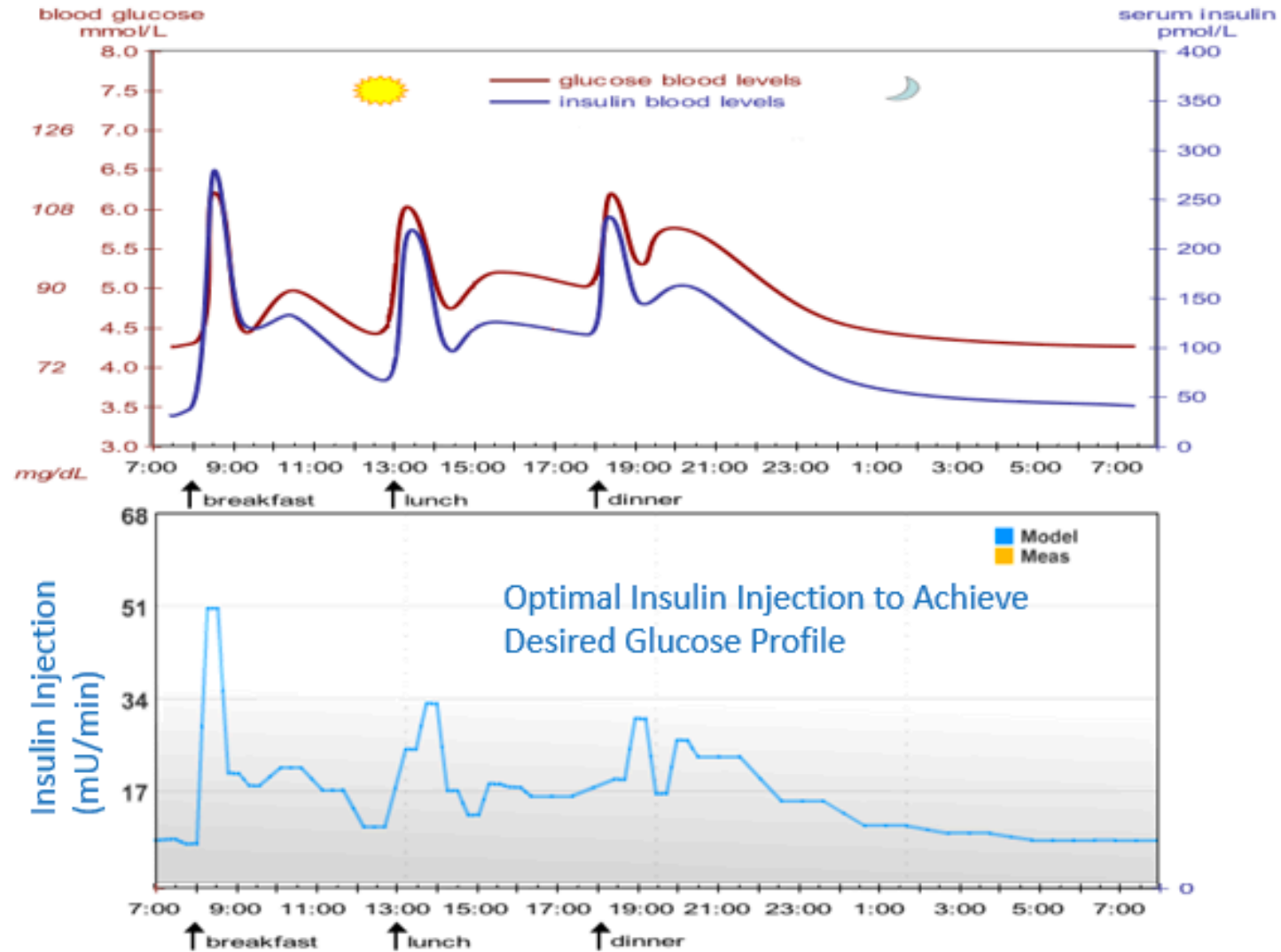
Carbohydrate counting matches your pre-meal bolus of insulin to the actual amount of food you plan to eat.



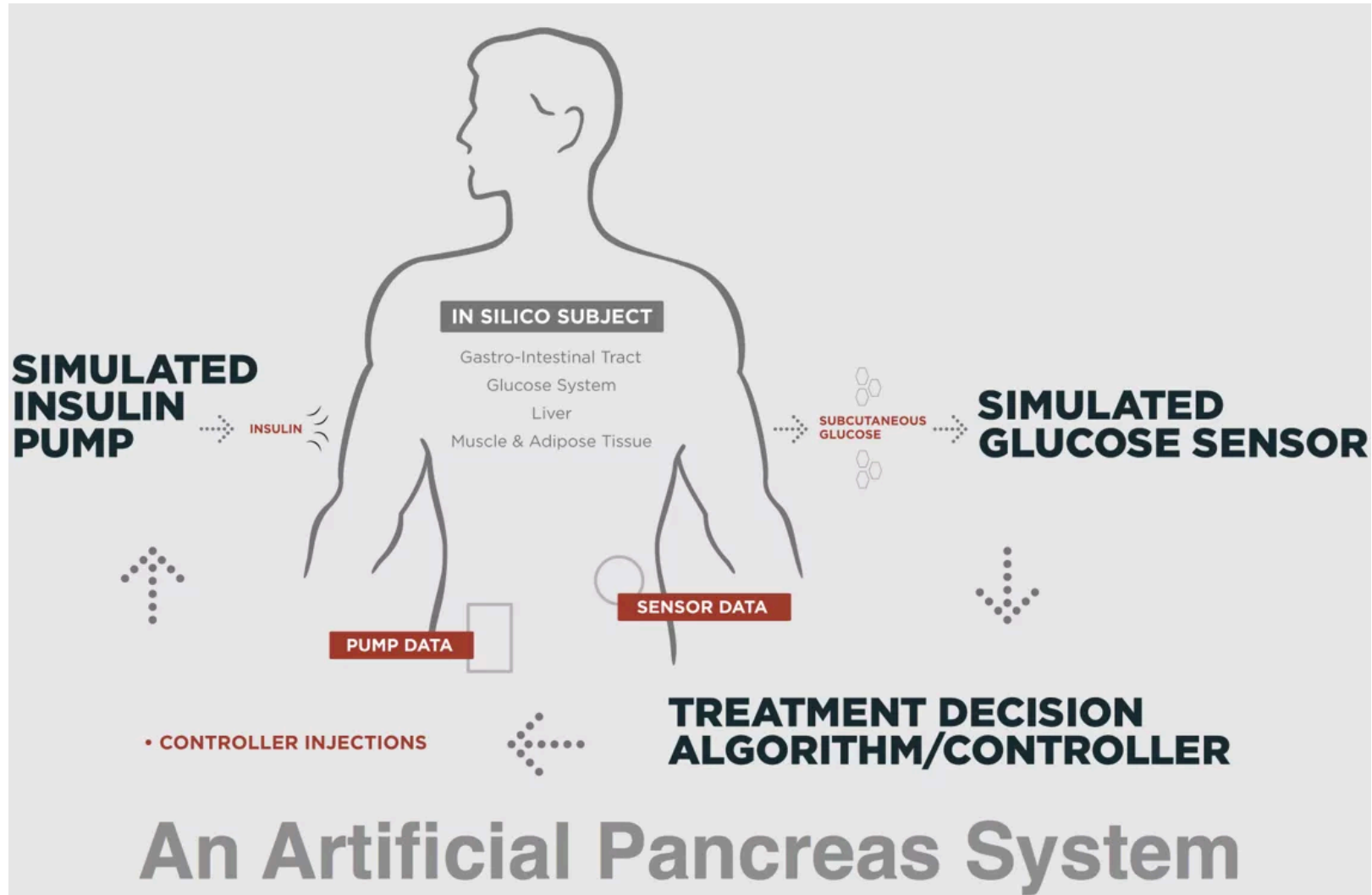
Schematic representation only.

REAL Diabetes Control

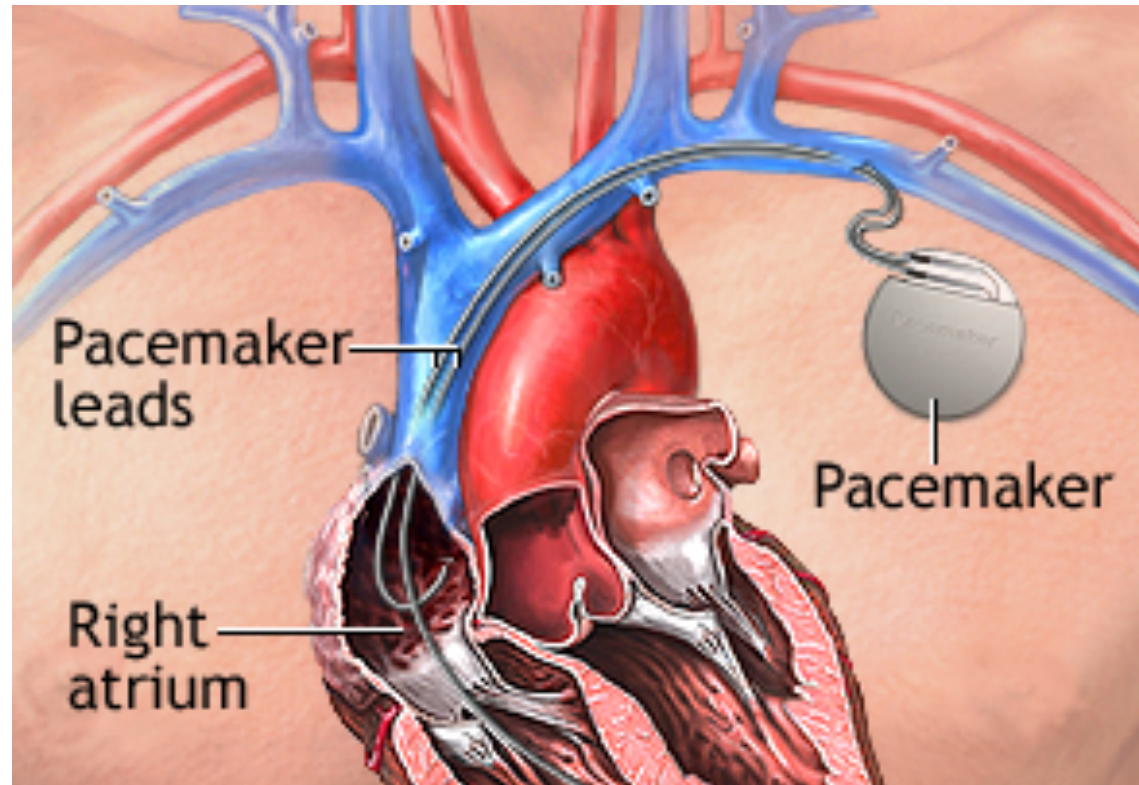
Artificial Pancreas



Artificial Pancreas

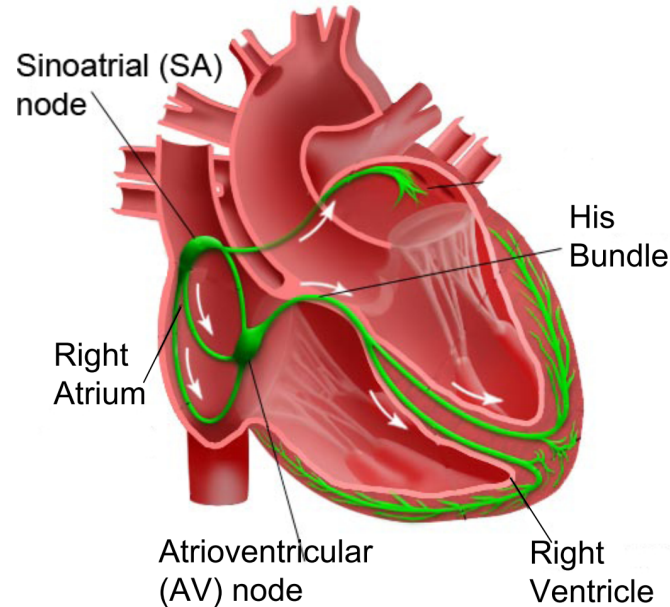


PaceMaker



Z. Jiang, M. Pajic, S. Moarref, R. Alur, R. Mangharam, *Modeling and Verification of a Dual Chamber Implantable Pacemaker*, In Proceedings of Tools and Algorithms for the Construction and Analysis of Systems (TACAS), 2012.

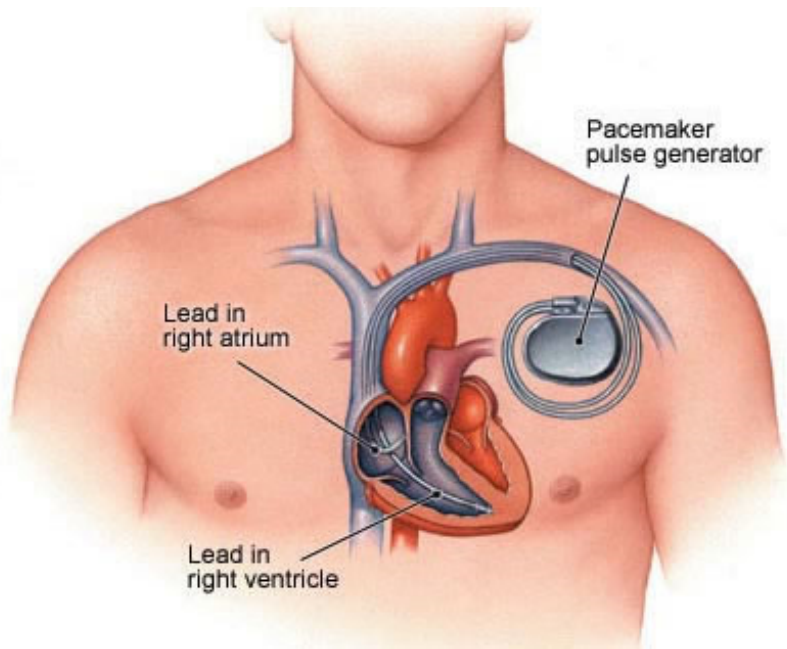
How does a healthy heart work?



- SA node (controlled by nervous system) periodically generates an electric pulse
- This pulse causes both atria to contract pushing blood into the ventricles
- Conduction is delayed at the AV node allowing ventricles to fill
- Finally the His-Pukinje system spreads electric activation through ventricles causing them both to contract, pumping blood out of the heart

Z. Jiang, M. Pajic, S. Moarref, R. Alur, R. Mangharam, *Modeling and Verification of a Dual Chamber Implantable Pacemaker*, In Proceedings of Tools and Algorithms for the Construction and Analysis of Systems (TACAS), 2012.

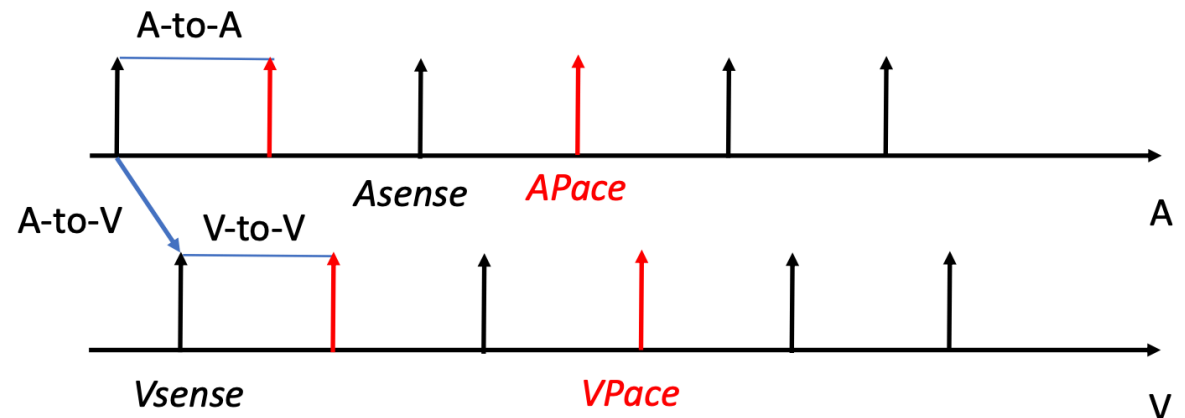
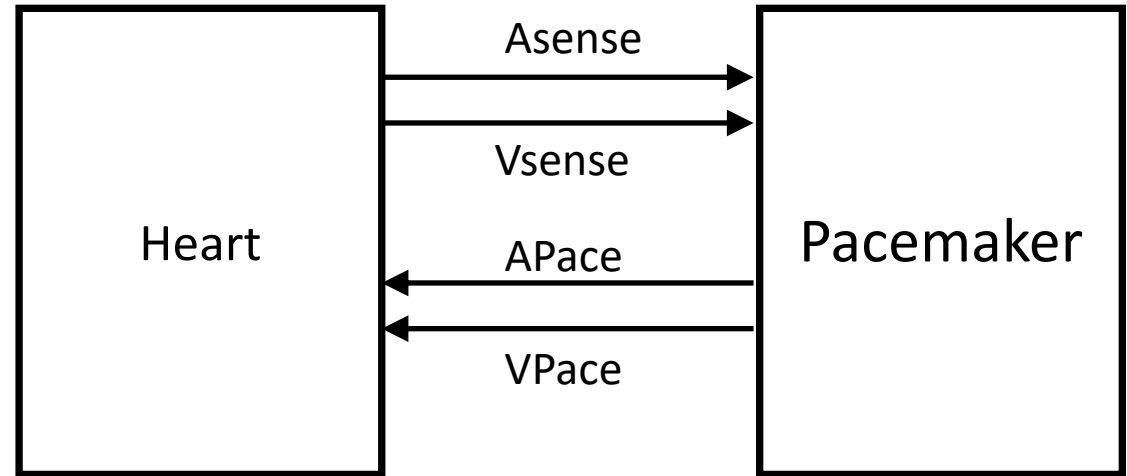
PaceMaker



- Aging and/or diseases cause conduction properties of heart tissue to change leading to changes in heart rhythm
- Tachycardia: faster than desirable heart rate impairing hemo-dynamics (blood flow dynamics)
- Bradycardia: slower heart rate leading to insufficient blood supply
- Pacemakers can be used to treat bradycardia by providing pulses when heart rate is low

How dual-chamber pacemakers work

- Activation of local tissue sensed by the leads (giving rise to events Atrial Sense and Ventricular Sense)
- Atrial Pace or Ventricular Pace are delivered if no sensed events occur within deadlines



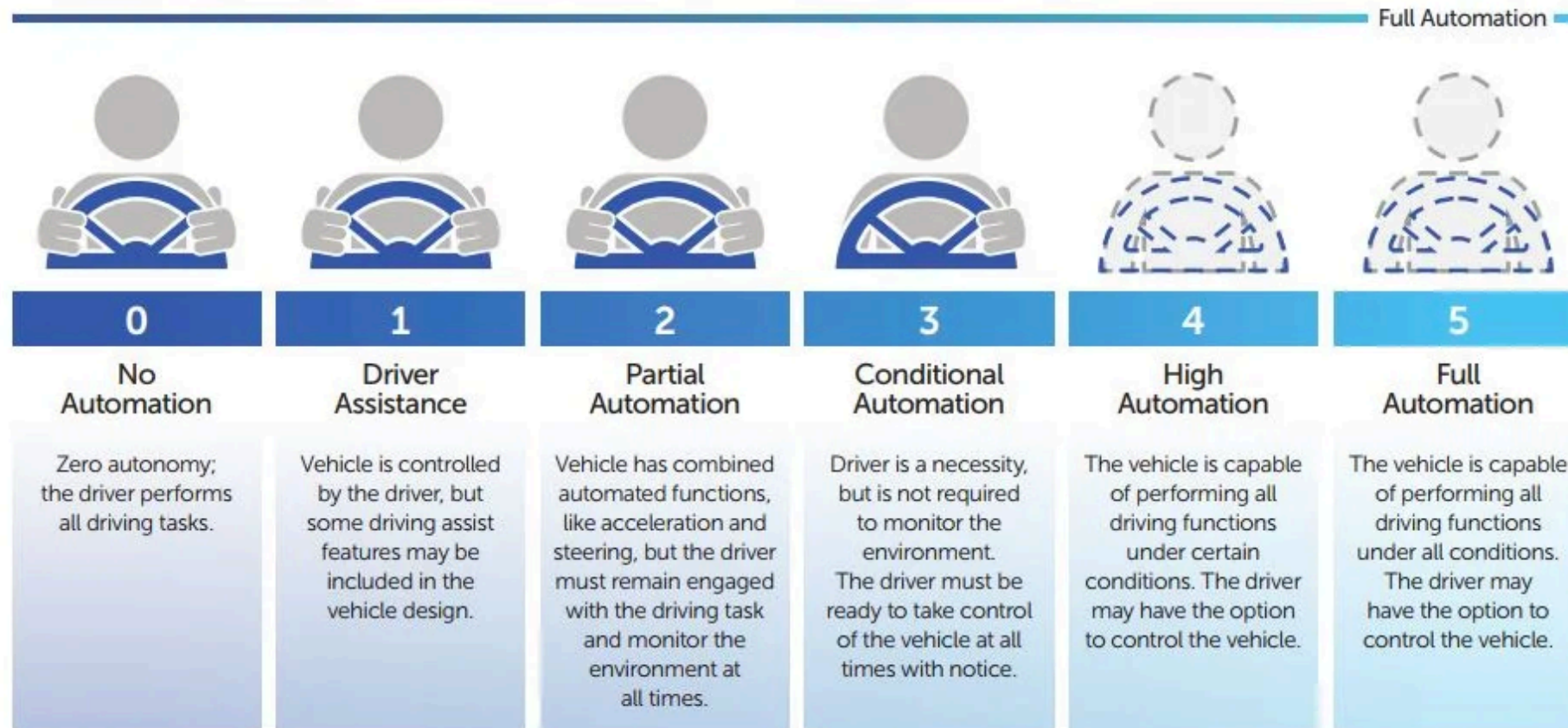
Transportation CPS

Everything that moves will become autonomous

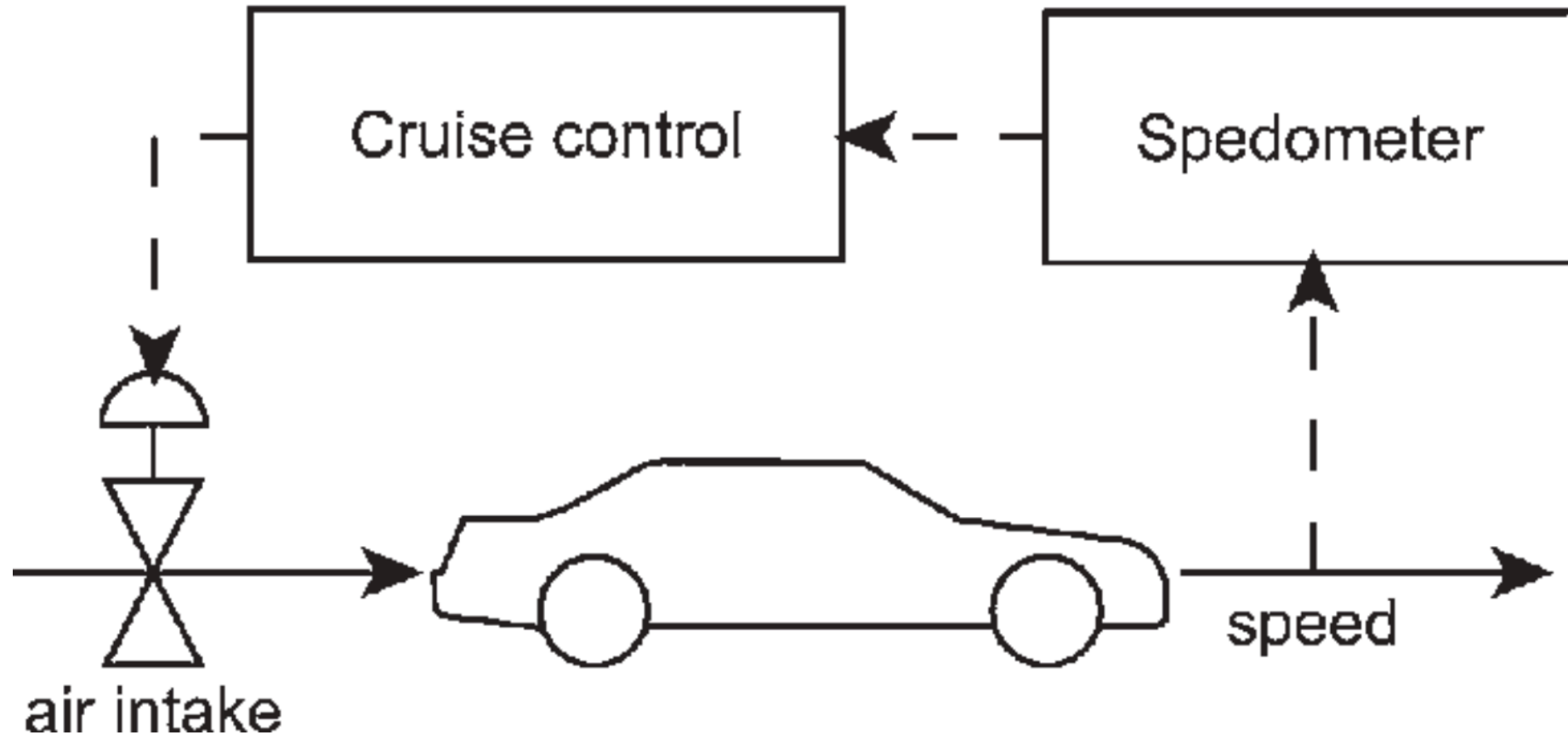


Automotive Car

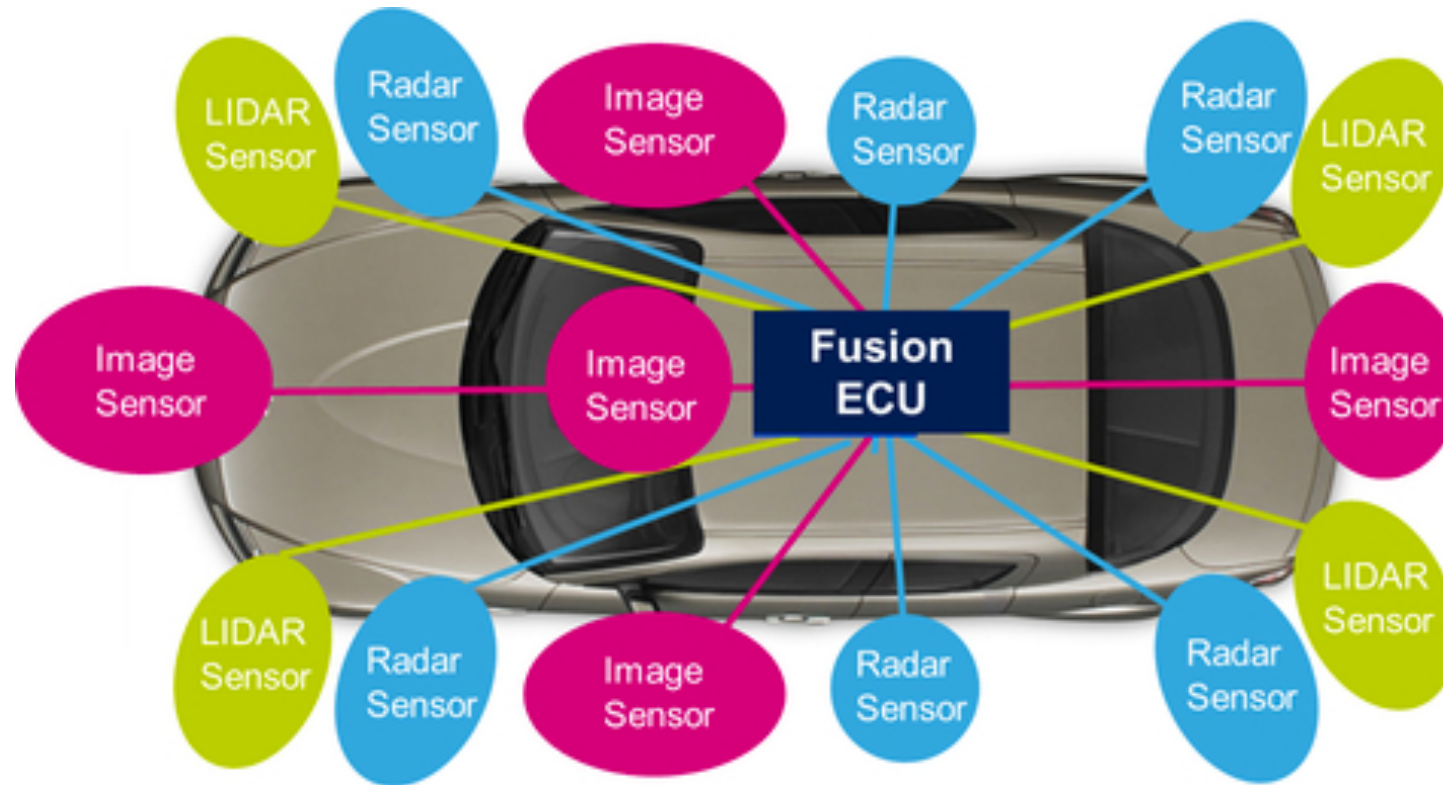
SAE AUTOMATION LEVELS



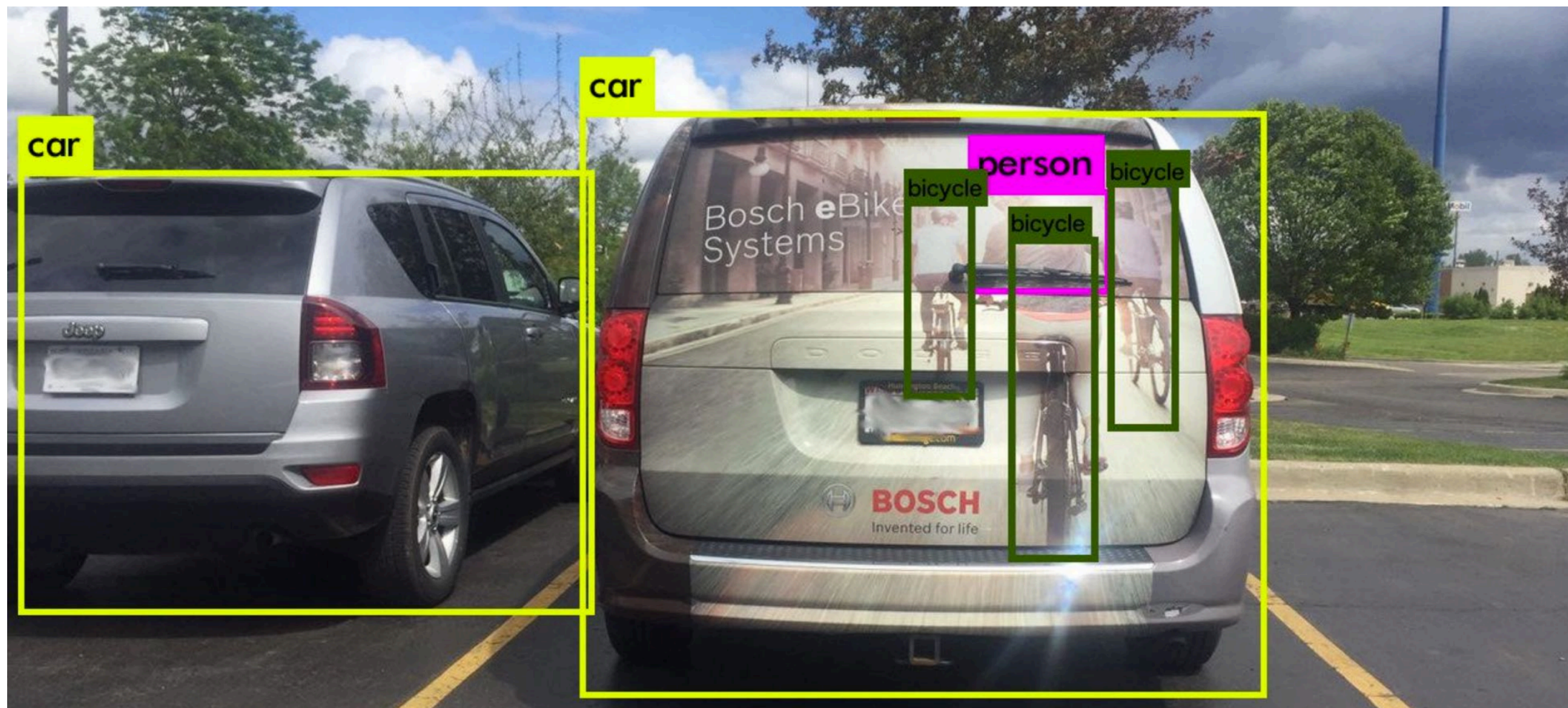
Automotive Car



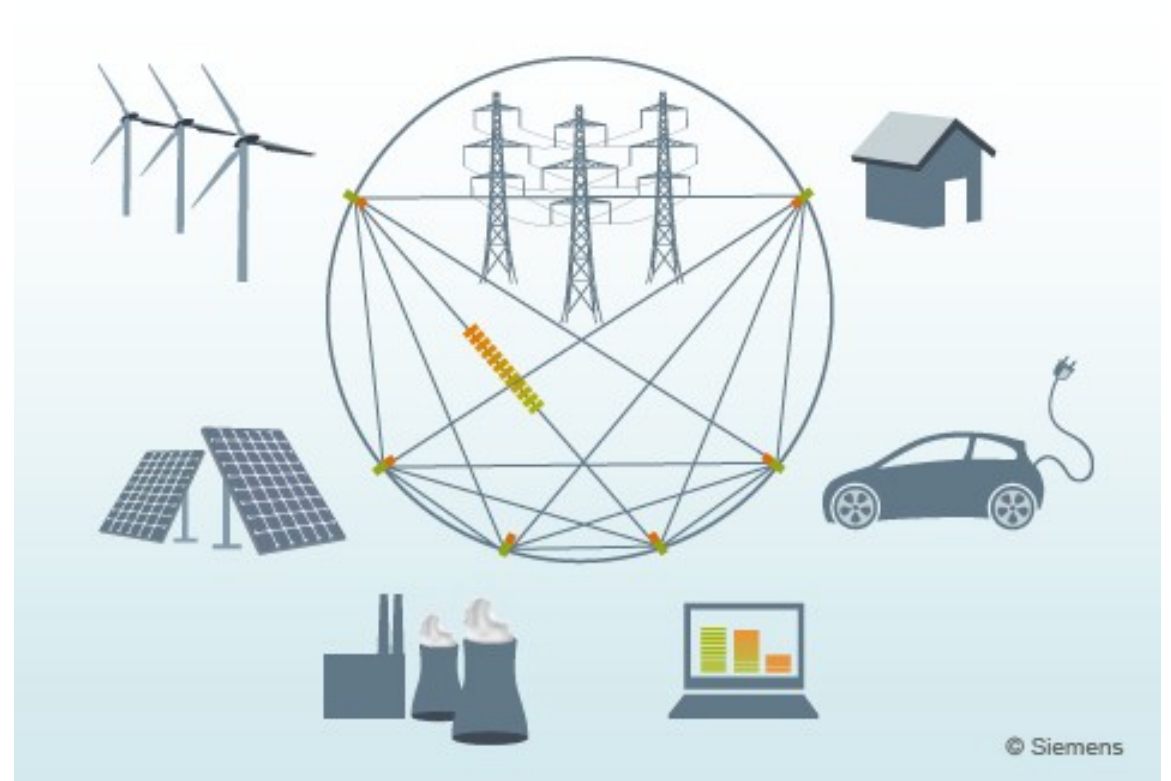
Automotive Car



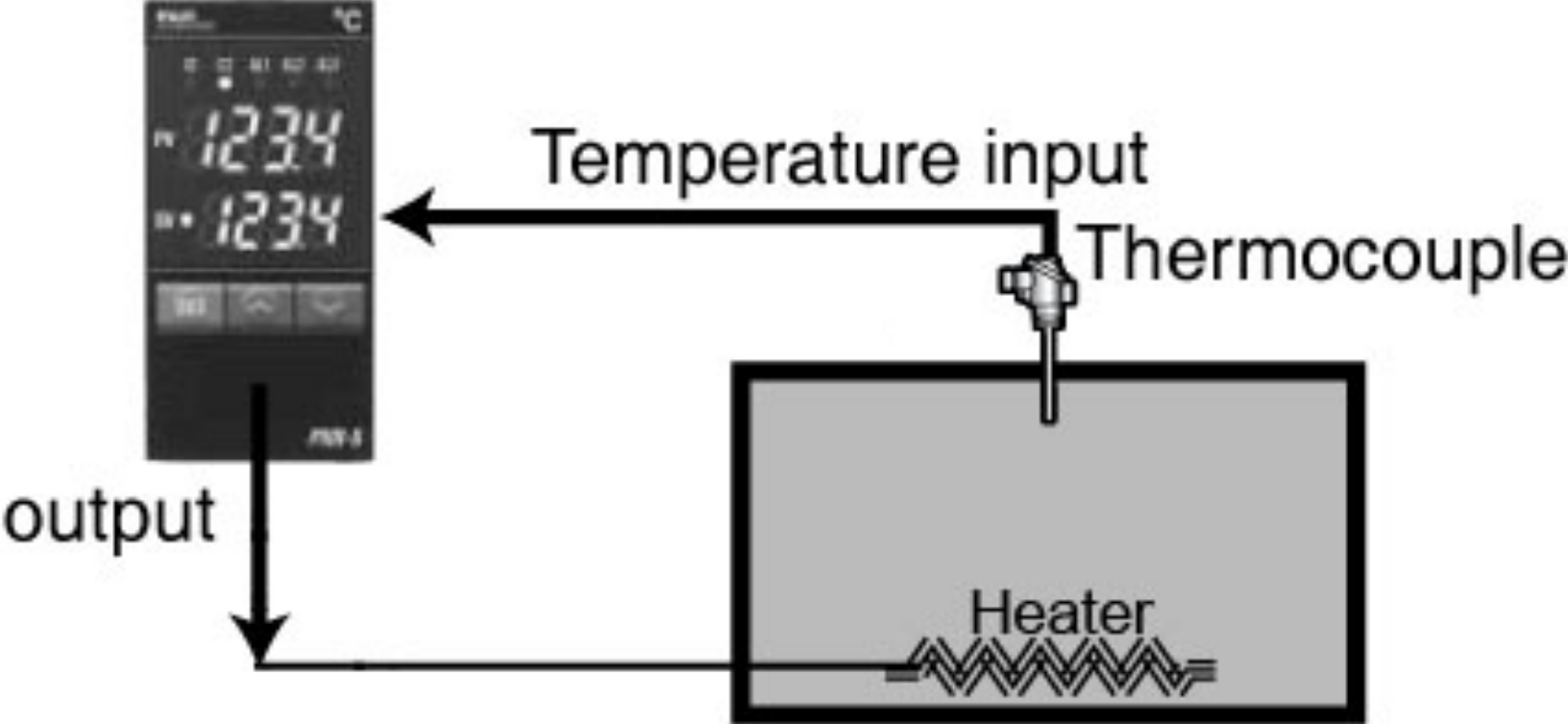
Automotive Car



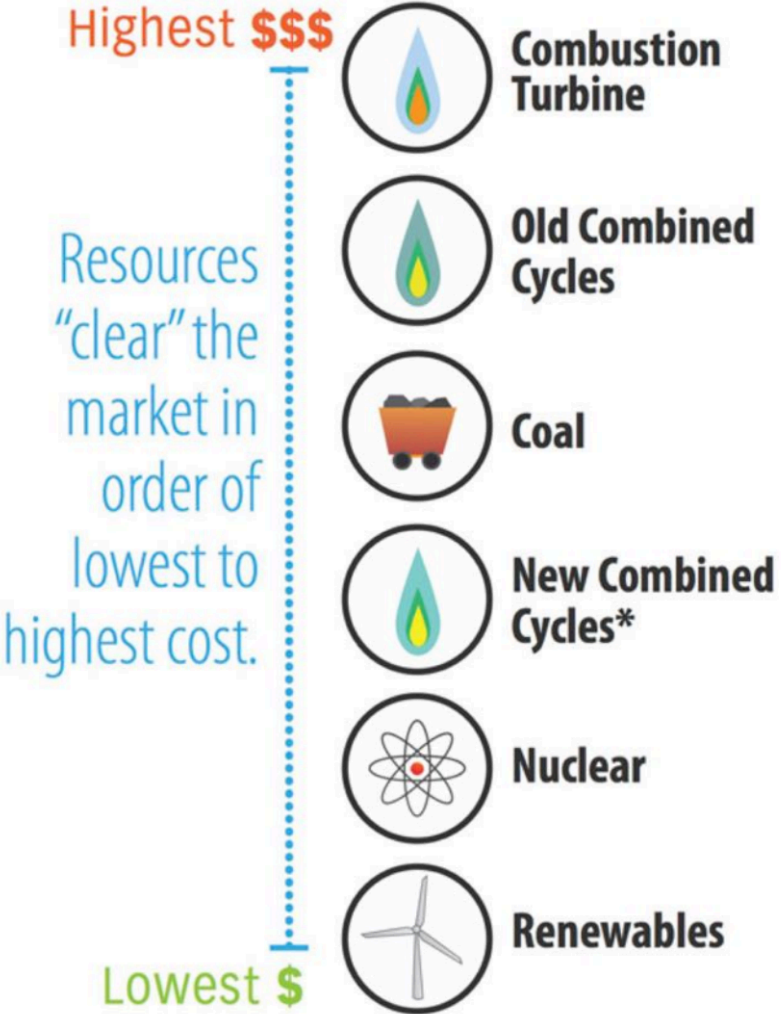
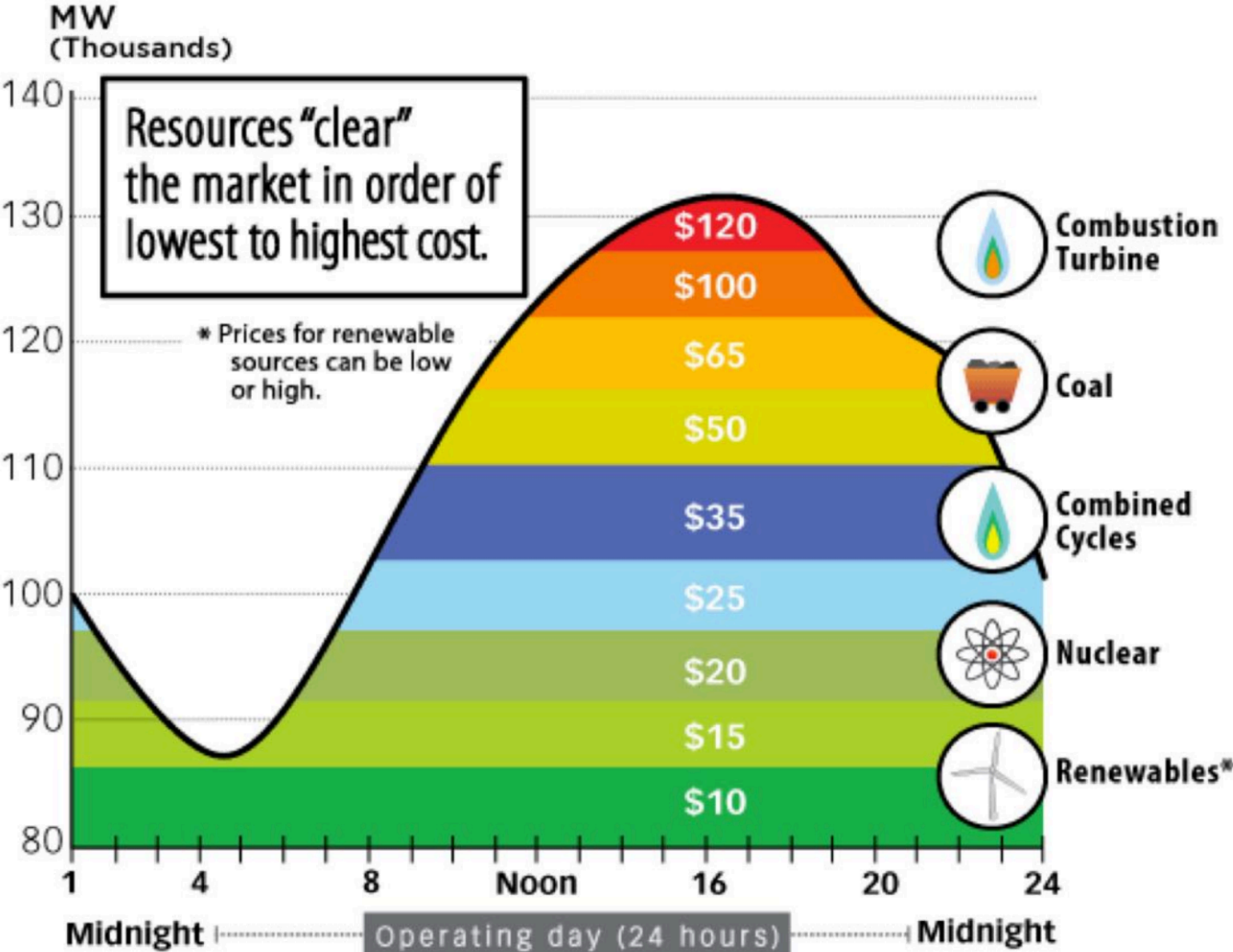
Energy



Temperature Control



Energy Control



Model-Based control for buildings

Traditional rule-based building control

- Sequence of operations or planned steps.
- Pre-defined rules set by building engineers.
- Purely reactive.
- Equipment-level controllers (PID) ensure reference tracking.



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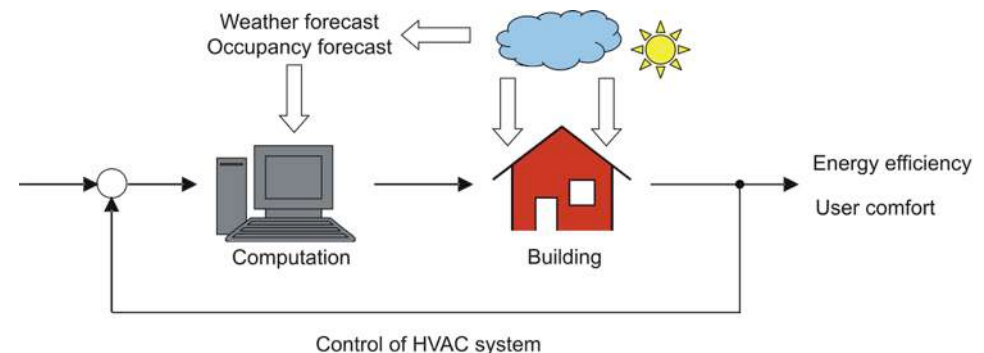
Took 23 min yesterday

22

Took 42 min today
(but price increased !)

Model-based building control

- Model how the building will response to disturbances (weather, occupants etc.)
- Predictive
- Control design:
 - Energy-efficiency
 - Demand flexibility
 - Fault handling
- Okay to use equipment level PID control



Model Predictive Control (MPC)