



POLITECNICO
MILANO 1863

DIPARTIMENTO DI CHIMICA,
MATERIALI E INGEGNERIA CHIMICA
GIULIO NATTA



COMPUTATIONAL METHODS FOR TRANSLATIONAL MEDICINE

Sezione di Ingegneria Biologica

Christian Vergara

Laurea in Ingegneria Biomedica
PhD in Ingegneria Matematica

Settore disciplinare: MAT08 – Analisi Numerica



TRANSLATIONAL MEDICINE

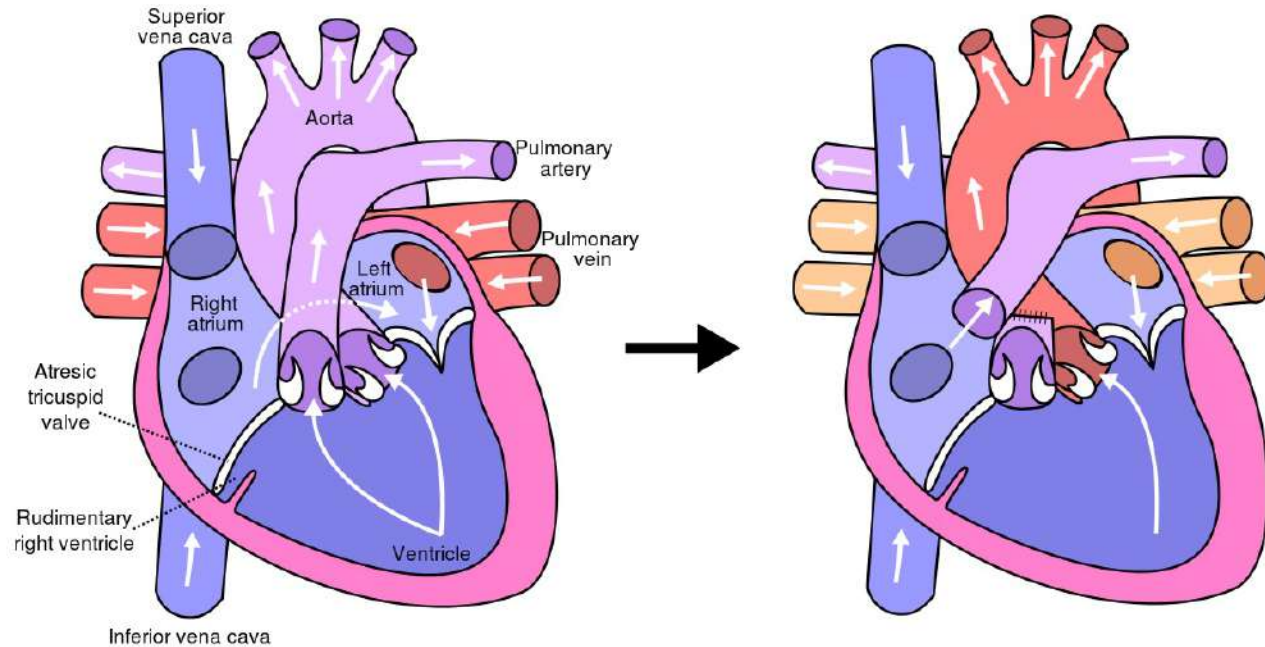
It is supported by three main pillars
”**benchside, bedside and community**”

It combine disciplines, resources, expertise, and techniques to promote enhancements in
prevention, diagnosis, and therapies

We would add also the interaction with a fourth synergistic pillar: ”**computerside**”, that is the predictions made by computational models

WHO ARE THE PIONEERS?

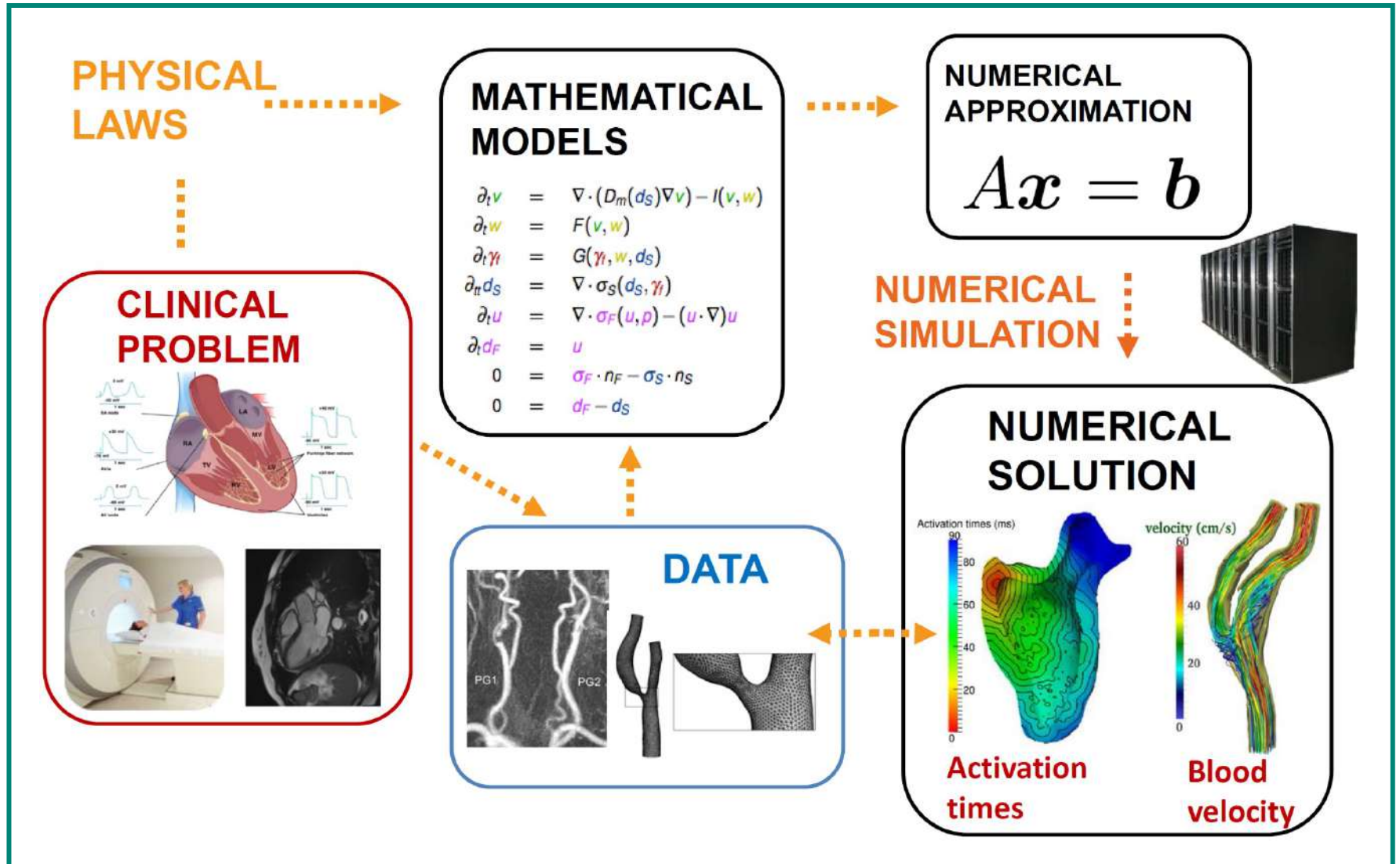
In late '90s, **F. Migliavacca**, **G. Dubini** and **G. Pennati** together with cardio-surgeons at *Great Ormond Street Hospital for Children NHS Trust, London*, studied computationally the blood dynamics in the **Fontan procedure**



Anastomosis of the pulmonary artery onto the inferior vena cava in children with only one ventricle



A GENERAL (SIMPLIFIED) OVERVIEW



Main advantages:

- ▶ Non-invasive
- ▶ Virtual scenarios
- ▶ Complete information

A HIGHLY MULTIDISCIPLINARY RESEARCH

Clinicians

Bio-engineers

Applied
Mathematicians

HPC/Computer scientists

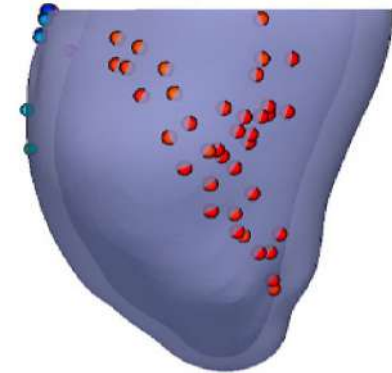
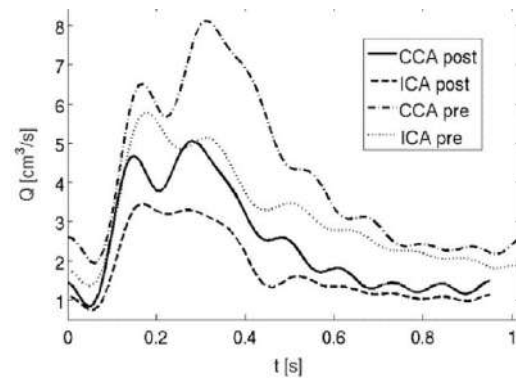
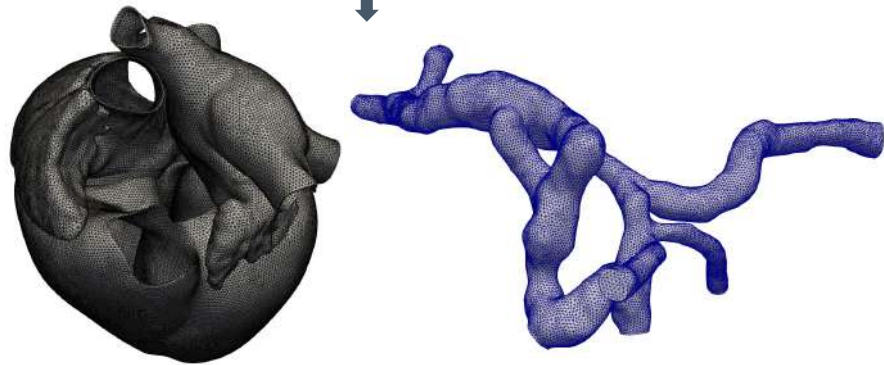
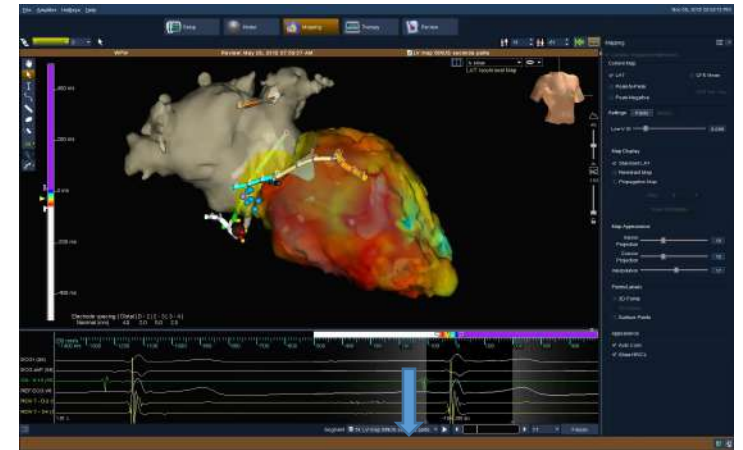
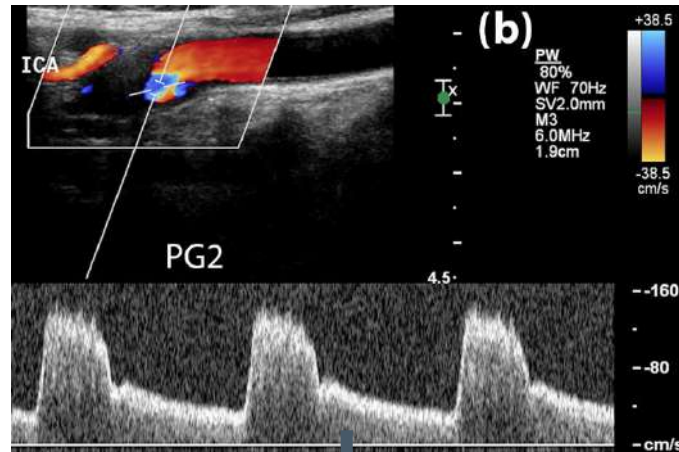


- ▶ Define a common language
- ▶ Define suitable aims
- ▶ Exchange of big data and results



Pieter Bruegel (il vecchio) – Torre di Babele - 1563

THE ISSUE OF DATA



- ▶ Geometry reconstruction
- ▶ Boundary conditions/input

- ▶ Calibration of parameters
- ▶ Validation of the results

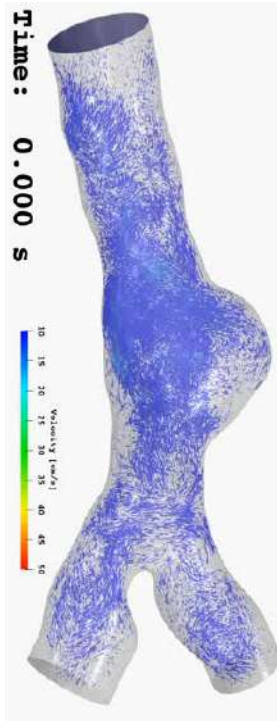
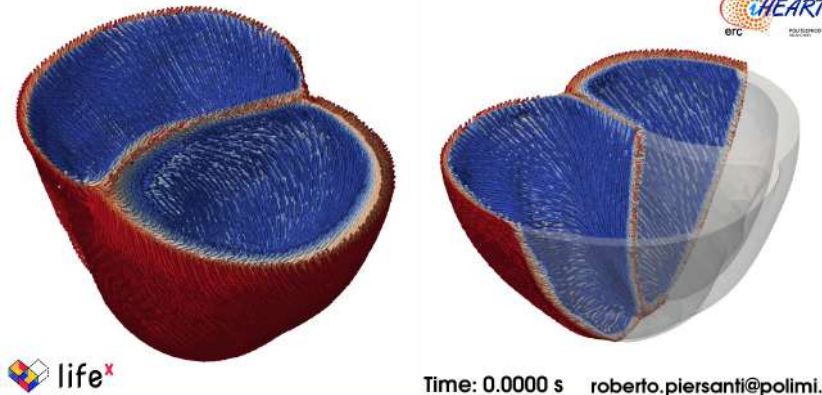
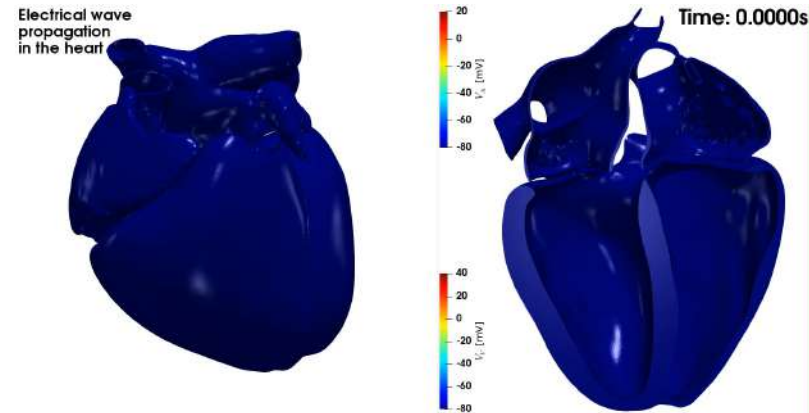
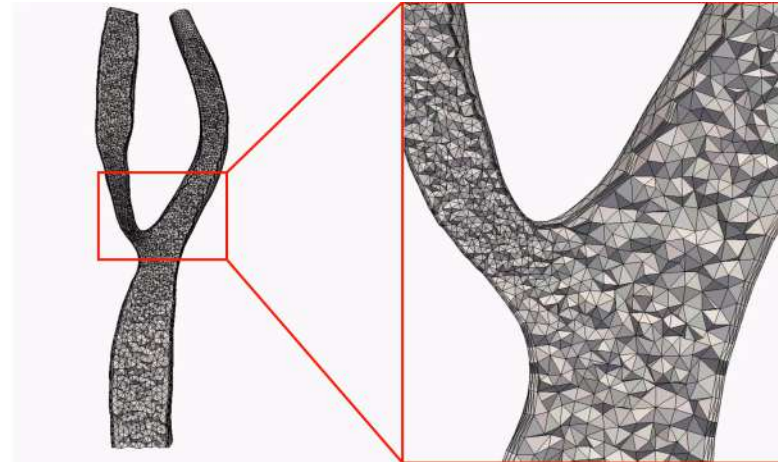
OTHER CRITICAL ISSUES

- ▶ **Choice of the mathematical model**
Ex: - Rigid walls vs compliant vessel
- Electro-physiology vs electro-mechanical
- ▶ **Choice of the numerical model**
- ▶ **Implementation in an efficient algorithm/software**



al-Khwarizmi,
Persia, IX sec

CPU times could be of
the order of
days/weeks!



A (THERAPEUTIC) EXAMPLE: CARDIAC RESYNCHRONIZATION THERAPY

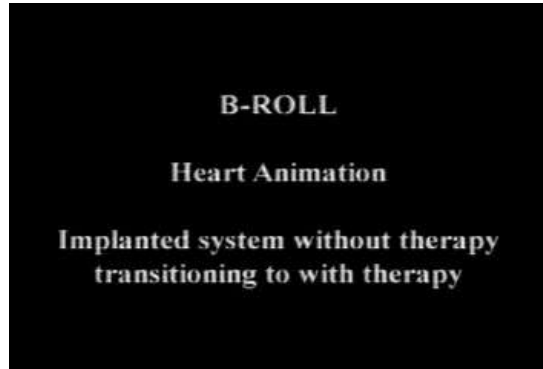
CRT allows to restore synchronized heart contraction in presence of dyssynchrony



Azienda Provinciale
per i Servizi Sanitari
Provincia Autonoma di Trento

In collaboration with Ospedale S. Maria del Carmine, Rovereto (TN)

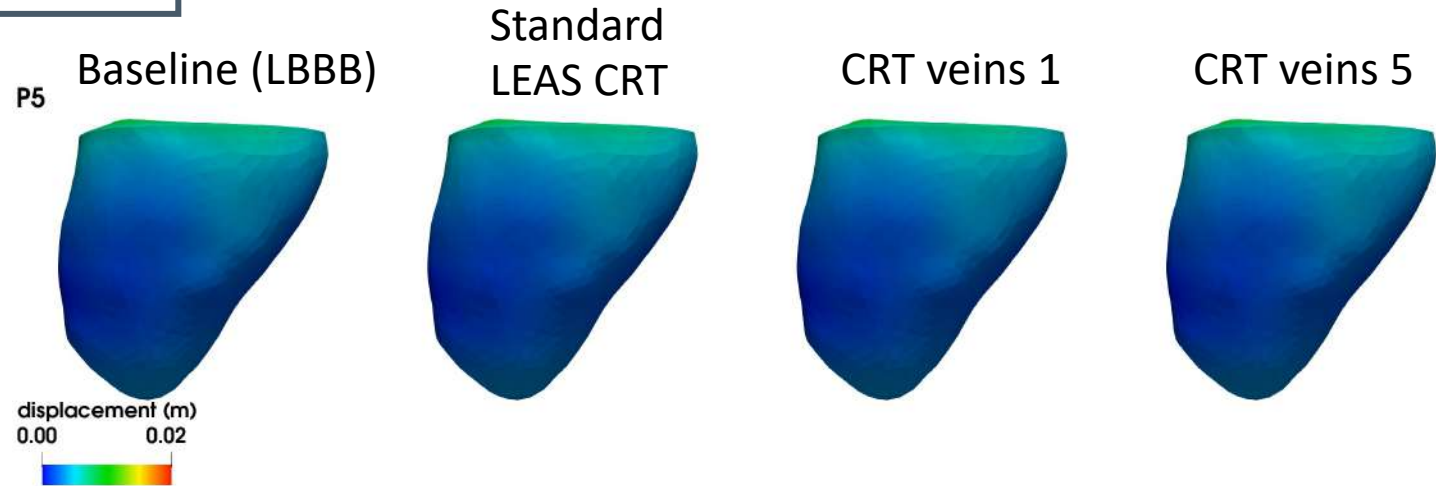
PhD work of Simone Stella (18-21)



Left pacing:
endocardial veins

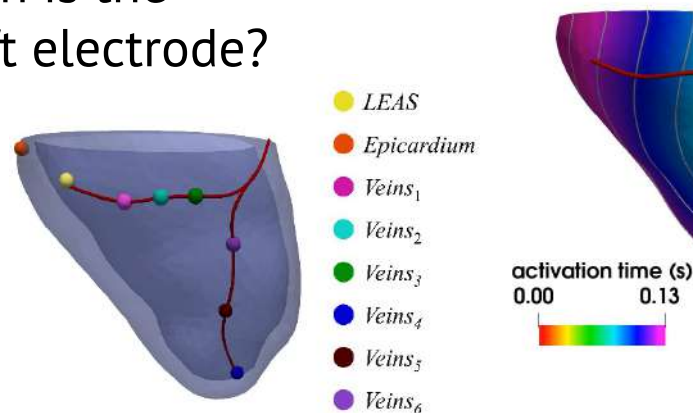


Right pacing: At the apex/septum



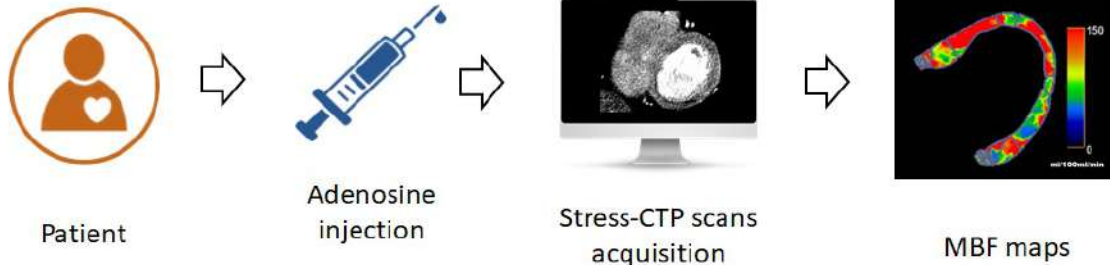
Clinical question: which is the optimal site for the left electrode?

Comparison among virtual scenarios

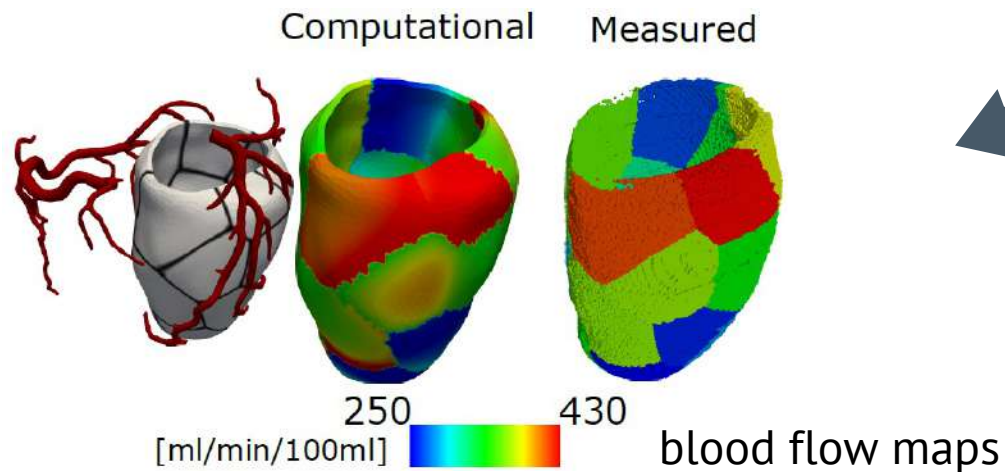


A (DIAGNOSTIC) EXAMPLE: MEASURING CARDIAC PERFUSION

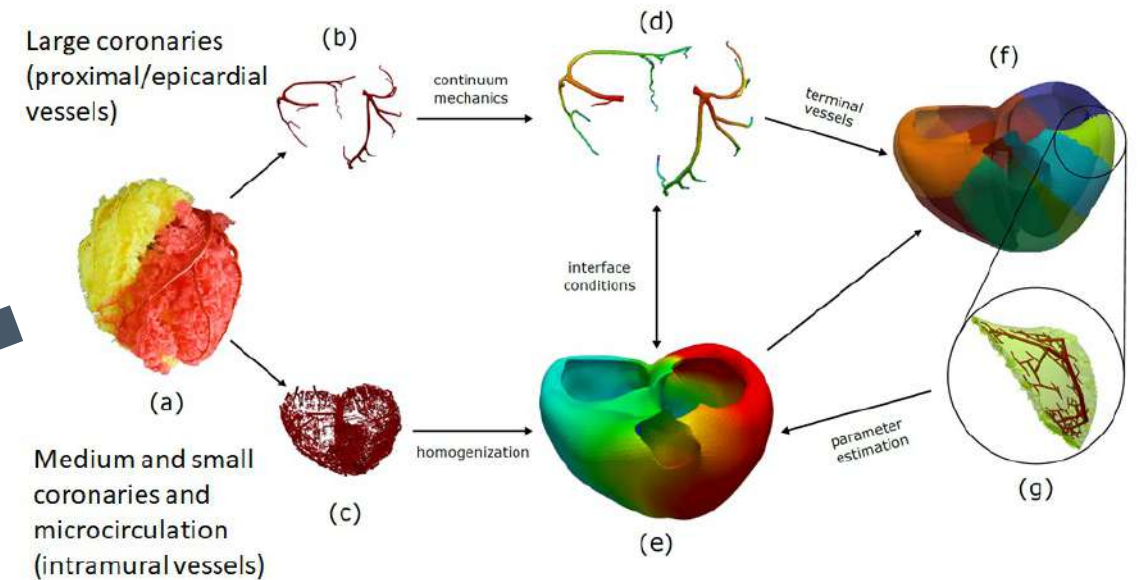
Maps of myocardial perfusion give a **direct** information of the support of oxygen



Clinical question: Is it possible to measure MBF maps under non-stress conditions?



Coupling between large coronaries (3D fluid-dynamics) and microcirculation (fluid in porous medium)



COMPUTATIONAL TRANSLATIONAL MEDICINE IN THE FUTURE

Artificial intelligence for:

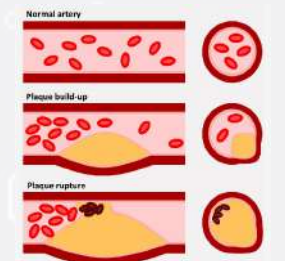
- ▶ Calibration of parameters
- ▶ Accelerating the CPU times (physics informed neural networks)



Computational techniques for real time simulations



Computational models for diseases development





GRAZIE

christian.vergara@polimi.it

POLITECNICO MILANO 1863