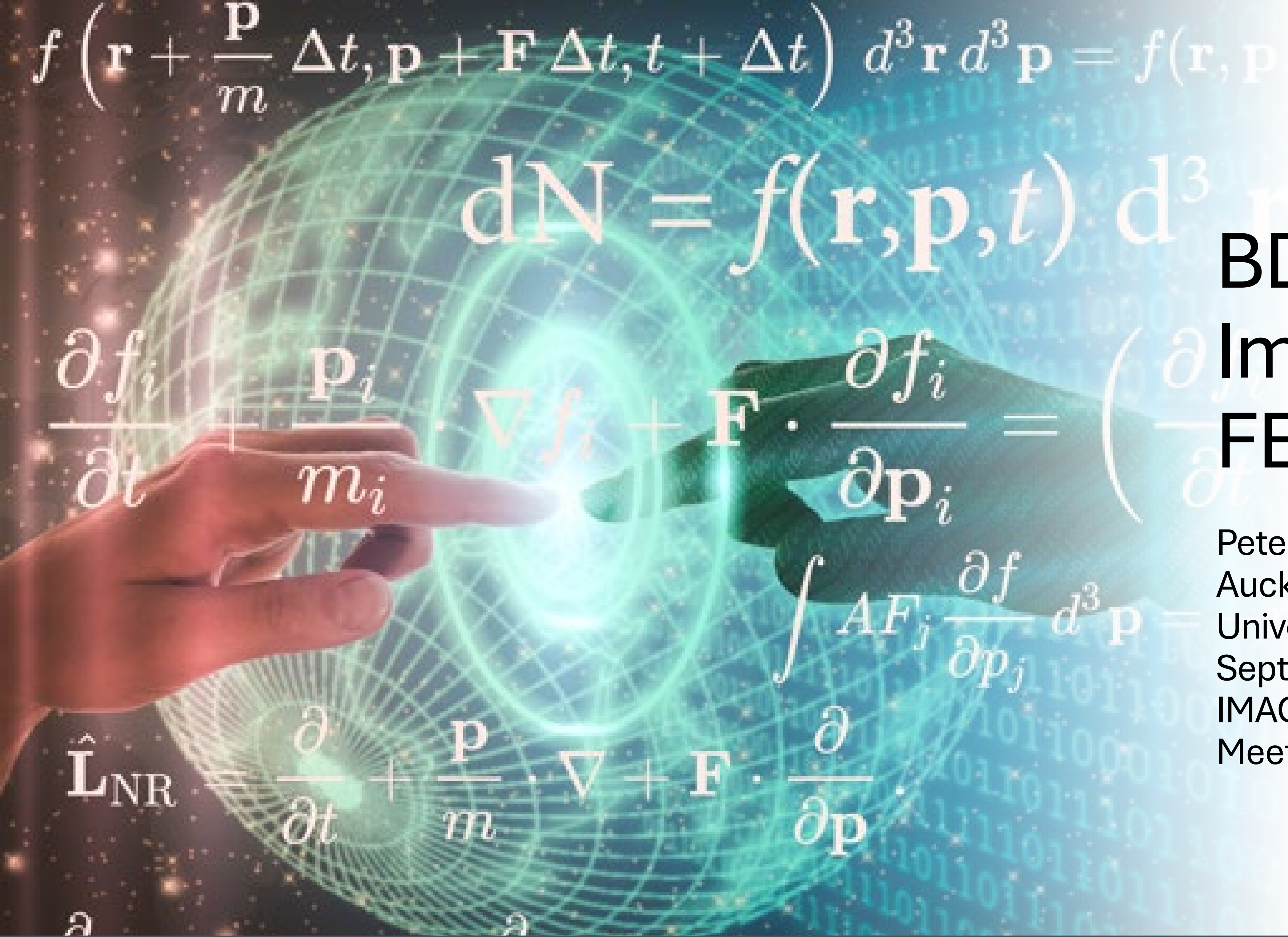


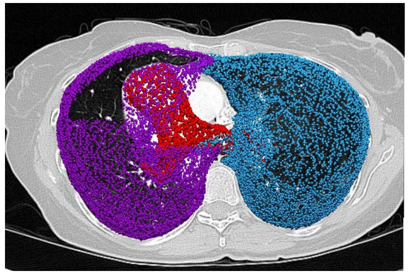
BDT Project: Image-based FE modelling

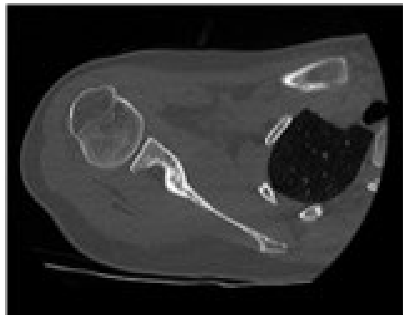
Peter Hunter
Auckland Bioengineering Institute
University of Auckland, NZ

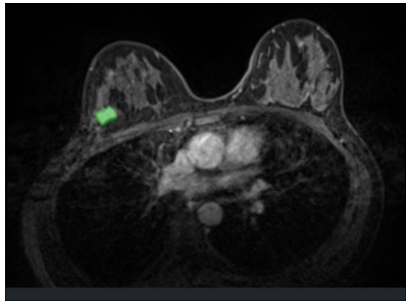
September 30, 2024
IMAG/MSM Teaming4BDT Meeting

NASEM Loop: Image-based FE modelling

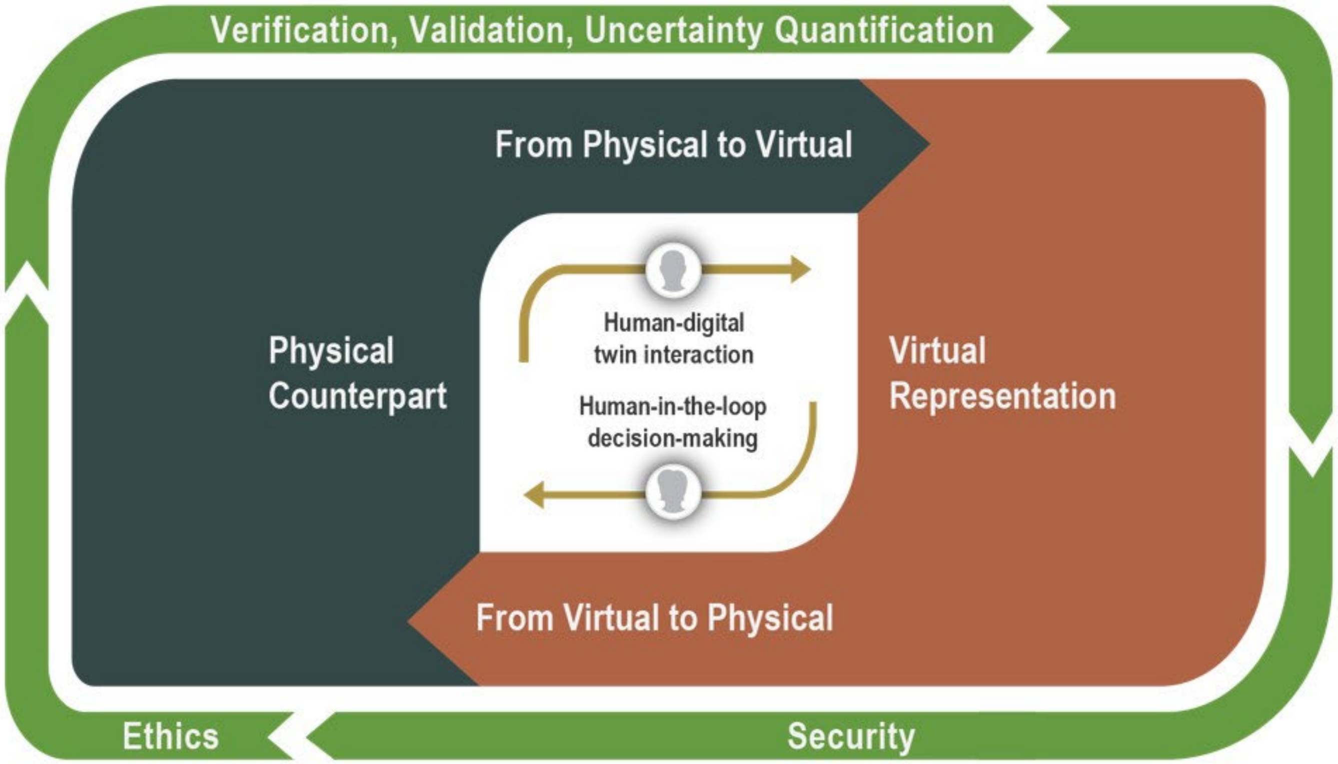
Clinical images





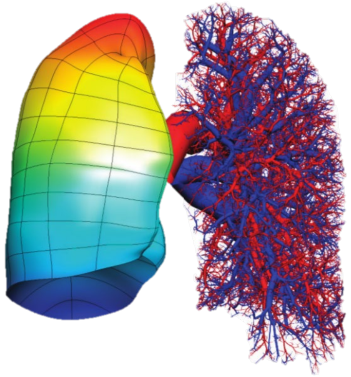


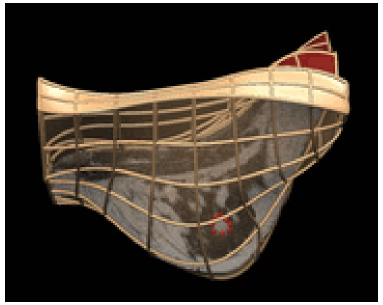
The FE models are personalised and, with appropriate boundary conditions, are used to solve the eqns of continuum mechanics



The output of the modelling are clinical reports

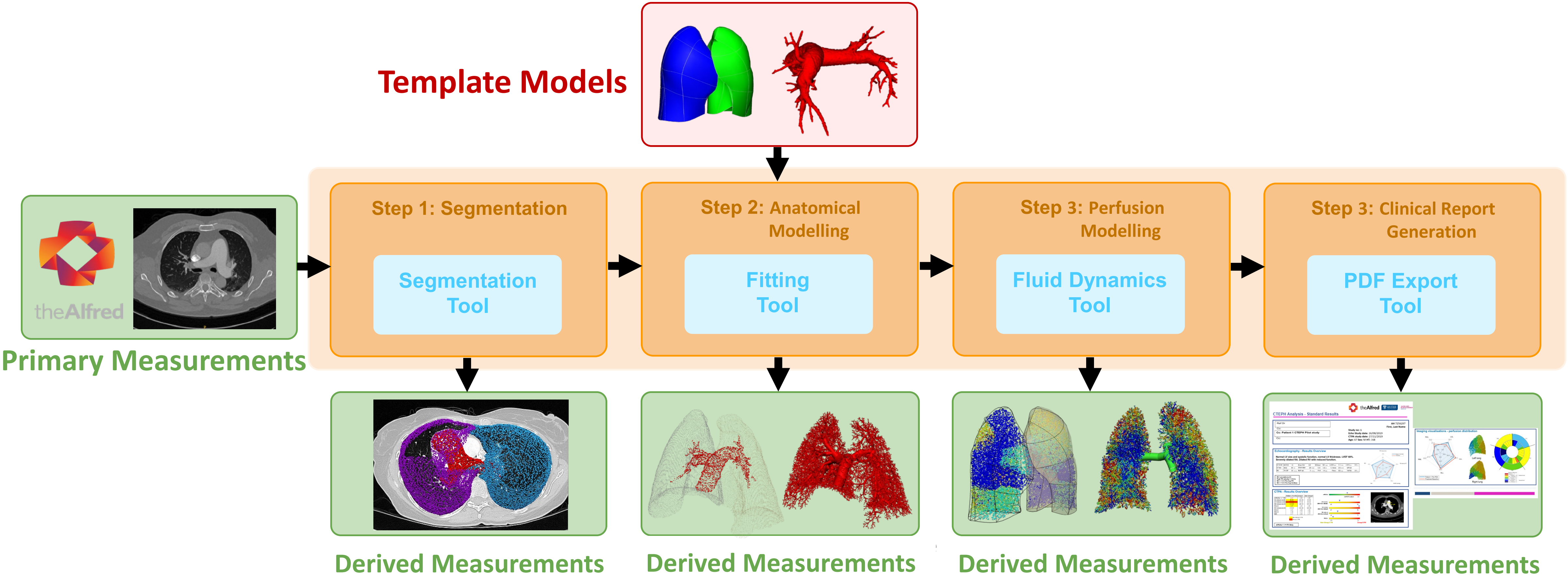
FE models





Physical and Virtual Assets and Their Interaction

The physical asset is the clinical image (3D and time varying). The virtual asset is the FE model. The model is fitted to the images for each individual patient and used to predict outcomes of treatment strategies.



Problem and BDT Solution

The FE models are personalised and are currently used to help clinicians diagnose pathologies and development treatment strategies.
The problem is that they are not yet multiscale – we would like to include information on tissue biopsies, blood biomarkers and genetic testing to improve the clinical utility of the models when these additional data are available.

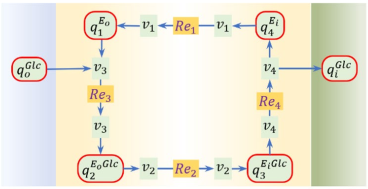
The next slides illustrate our approach to physics-based multiscale modelling.

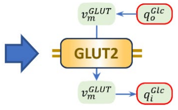
Multiscale modelling with bond graphs

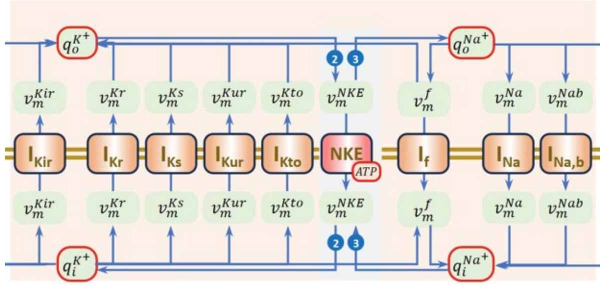
1. BG protein templates

(full) (reduced)

- Metabolic enzymes
- SLC transporters
- ATPase pumps
- ABC transporters
- Ion channels
- Contractile proteins
- Receptors: GPCR, TRK
- Signal transduction
- Immune cytokines
- Cell cycle
- Gene transcription & translation

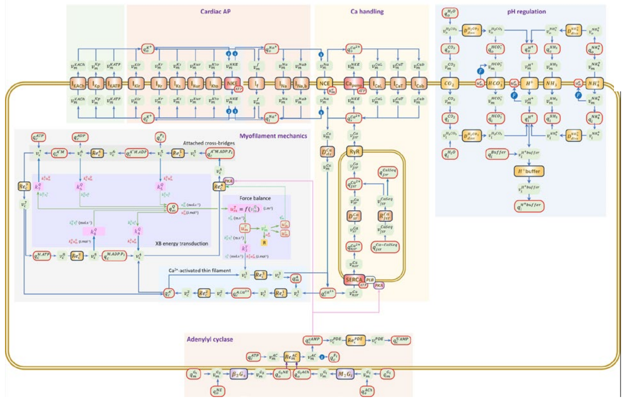






2. FCUs

- Metabolism
- Action potentials
- Calcium handling
- pH regulation
- Myofilament mechs
- Receptors & signaling
- Glucose transport
- Na/K regulation
- Cell cycle
- Cell adhesion
- Gene regulation
- …



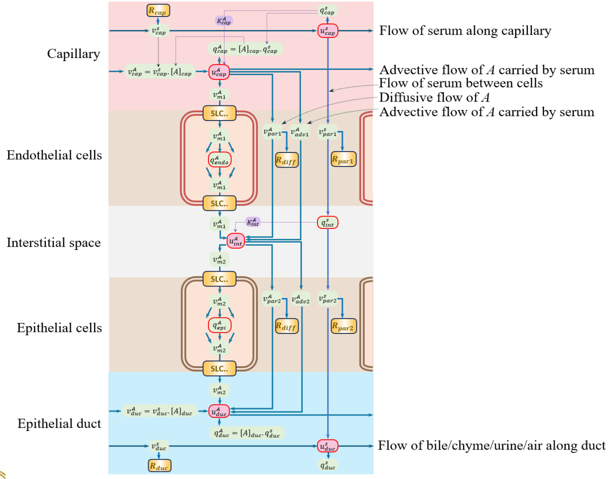
3. Cells

- Endothelial cell
- Epithelial cell
- Cardiomyocyte
- Muscle fiber
- Fibroblast
- Smooth muscle cell
- Osteocyte
- Enterochromaffin cell
- Hepatocyte
- Goblet cell
- Red blood cell
- …

4. FTUs

(including 3D structure)

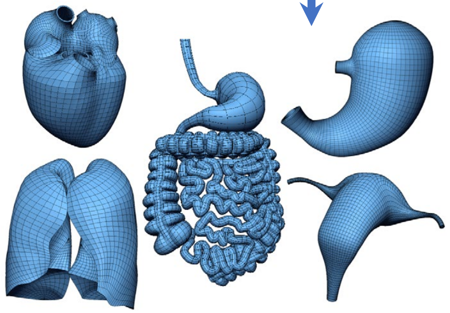
Glomerulus, …	nephron
Lung alveoli	acinus
Myocardial sheet	block
Liver lobule	lobules
Bone osteon	osteon
Fibre, etc	fascicle
…	…



5. Organs

● =surrogate

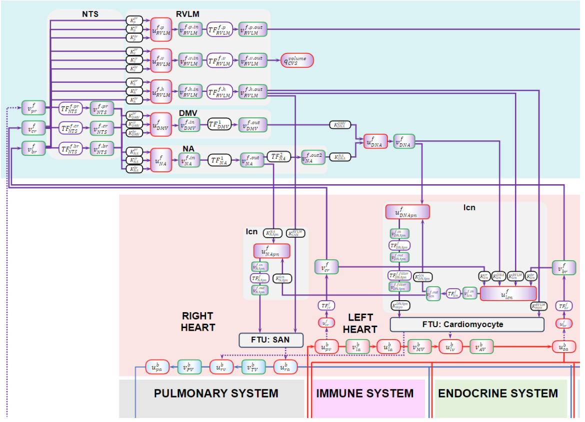
- Kidney
- Lung
- Heart
- Liver
- Bone
- Muscle
- …



6. FPUs

(3D anatomical model of the body)

- Regulation of fluid volume
- Regulation of arterial blood pressure
- Regulation of pH
- Regulation of electrolyte balance
- Regulation of glucose
- Regulation of O_2 and CO_2
- Regulation of calcium
- Regulation of phosphate
- Regulation of body temperature
- …



Finite element models that are subsequently reduced (with AI methods) to surrogate models.

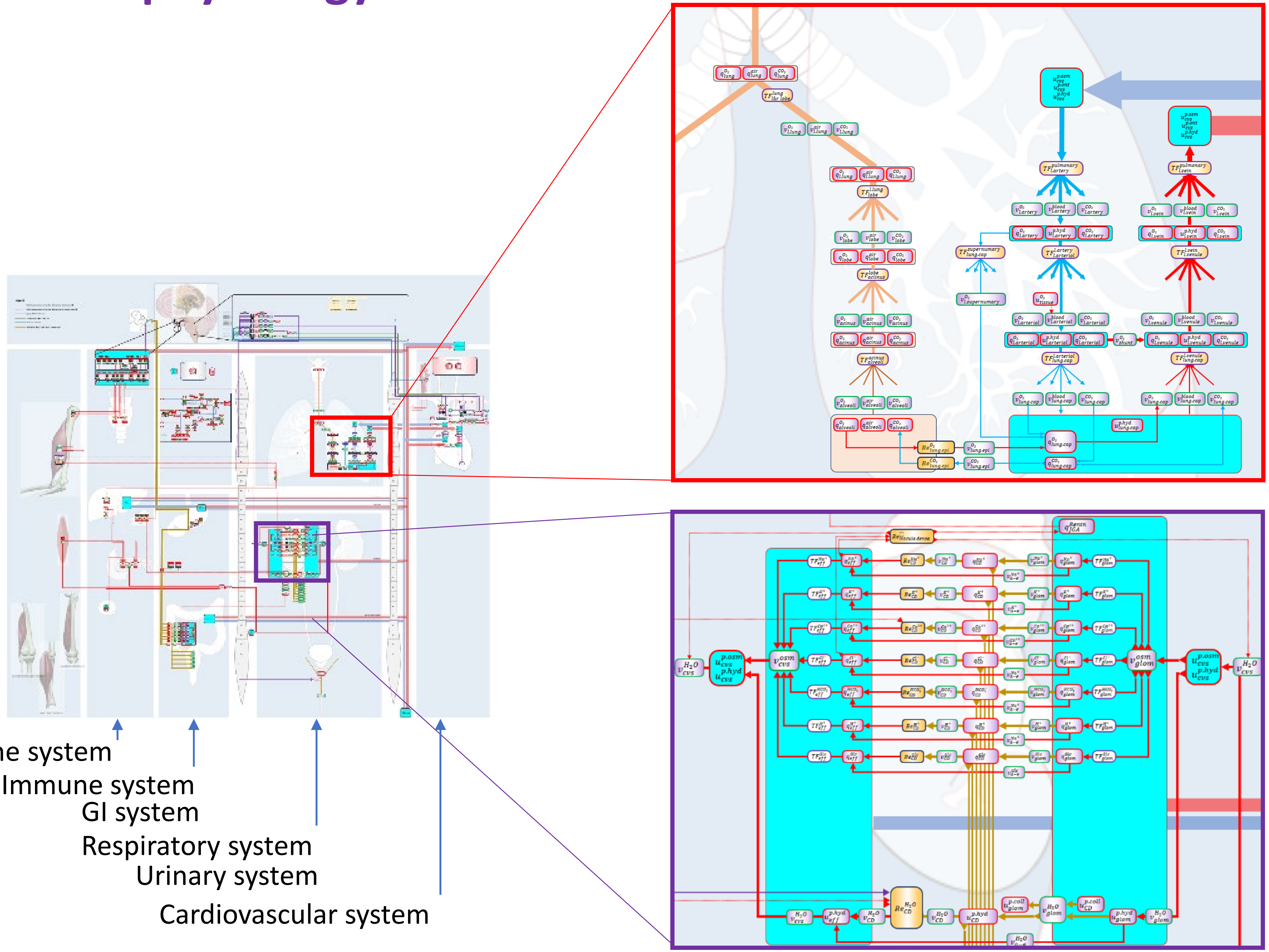
Linking systems physiology with molecular mechanism

Food intake and glucose control
Control of BP: Baroreceptors and RAAS
Control of blood volume
Control of metabolism
Calcium homeostasis
Circadian rhythms
Growth regulation
...

Nervous system →

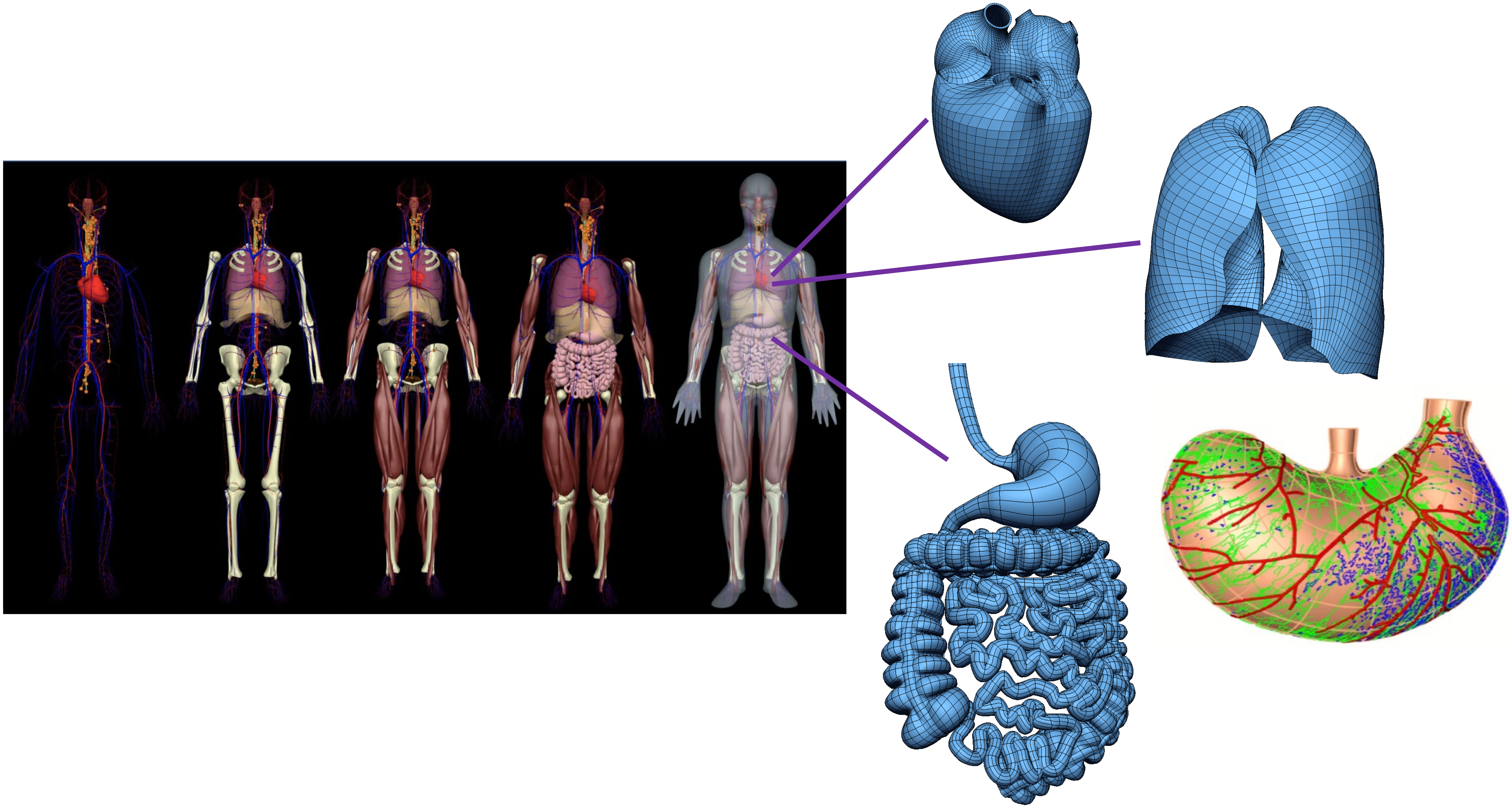
MSK system →

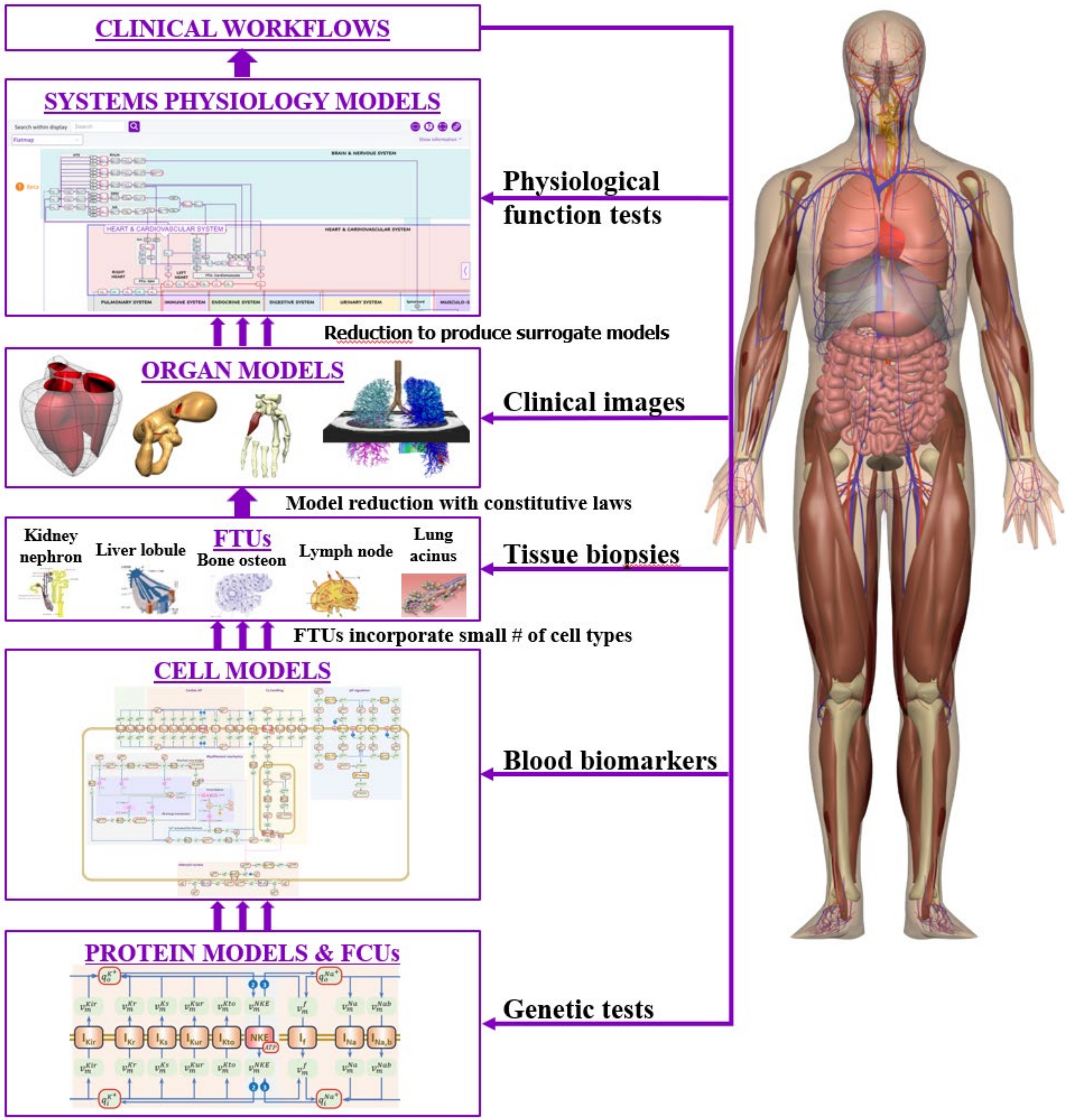
Not shown: reproductive systems and integumentary system (skin)



Endocrine system
Immune system
GI system
Respiratory system
Urinary system
Cardiovascular system

Scaffolds for spatial mapping





Constrained by observed behaviour

Model parameters

Constrained by physics and genetics

Questions

Contact me

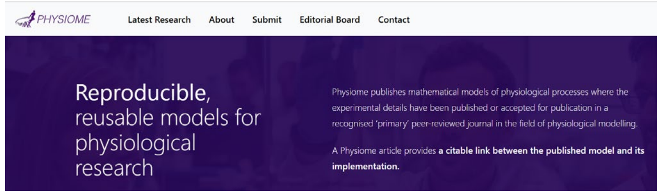
Email: p.hunter@auckland.ac.nz

Lab: Auckland Bioengineering Institute: https://www.auckland.ac.nz/en/abi.html

Resources:

CellML homepage https://www.cellml.org/

OpenCOR software https://opencor.ws/



https://journal.physiomeproject.org/

Mapping tools https://docs.sparc.science/docs/map-core-scaffold-mapping-tools