Imaging whole-body biological circuits with total-body PET

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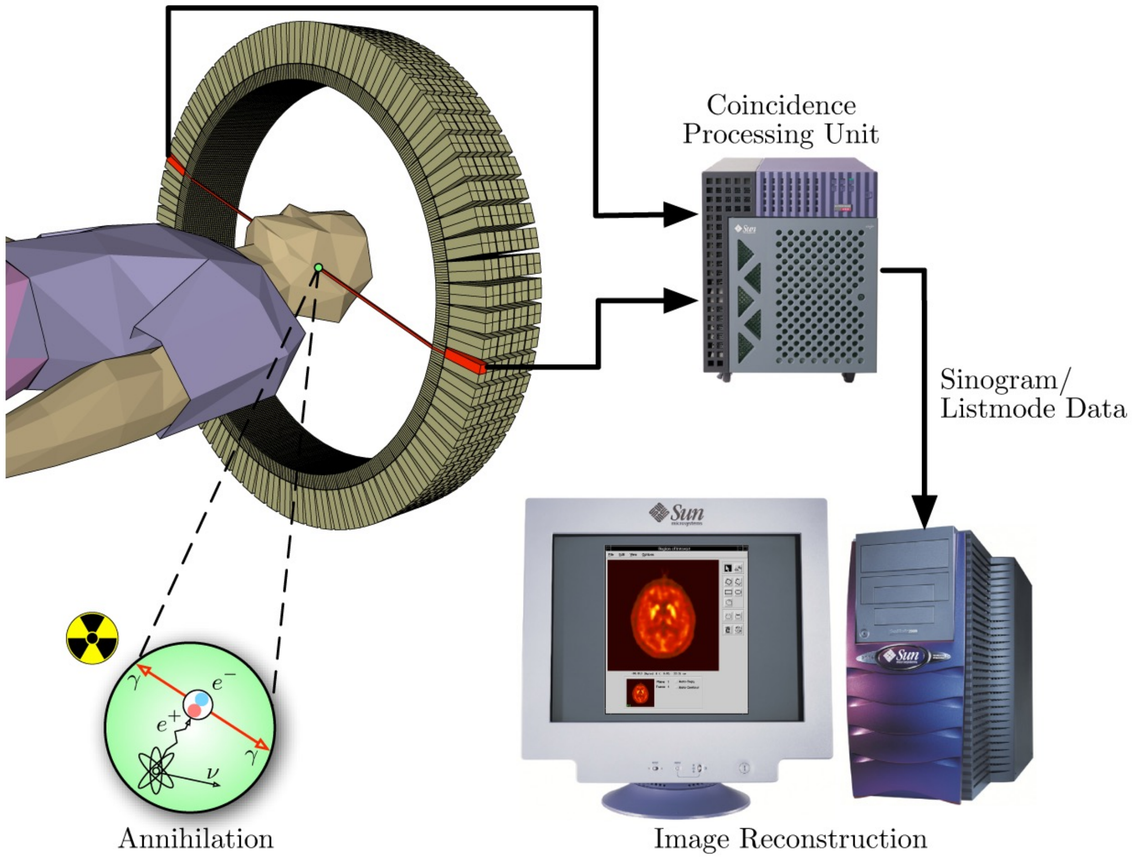
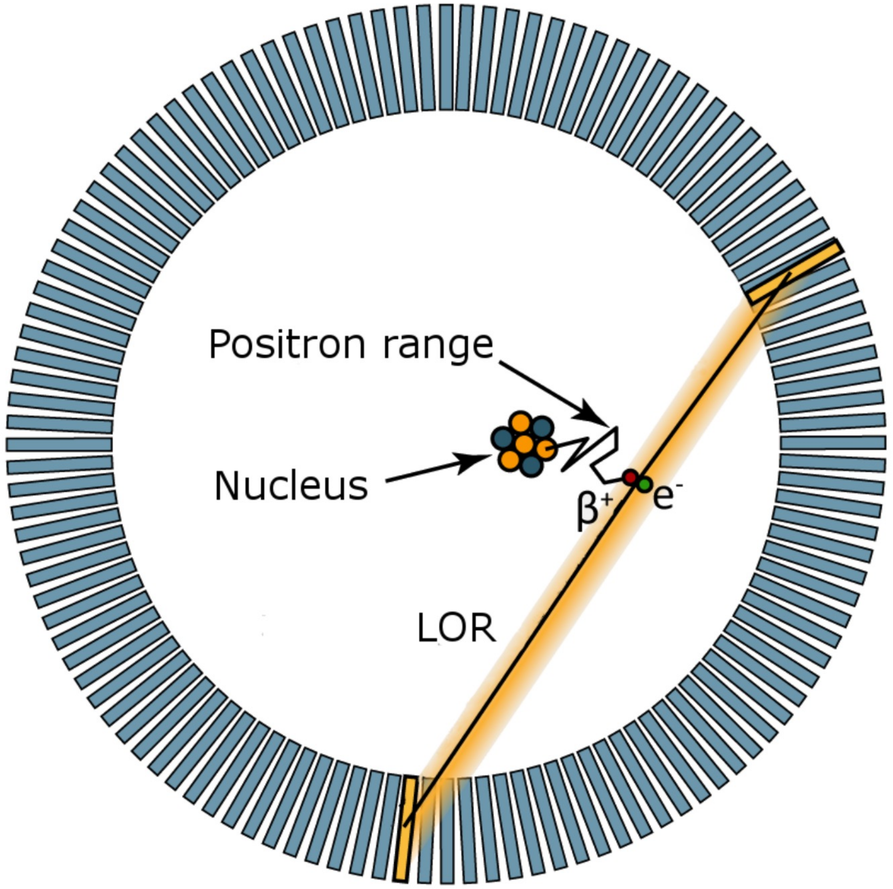
PET is great because…

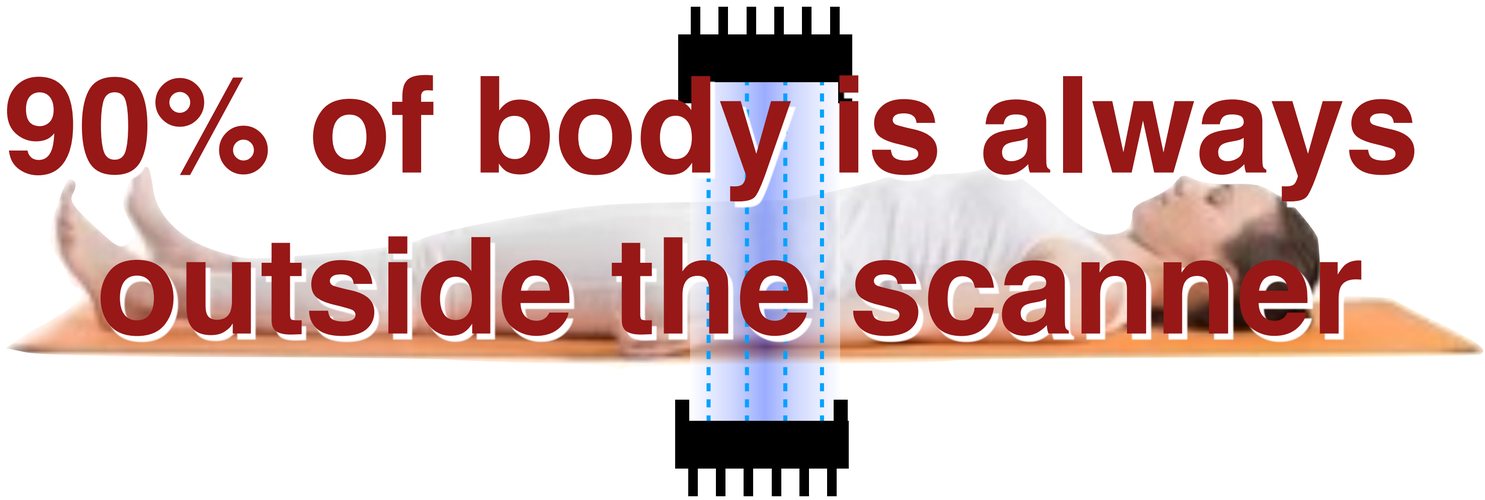
- …it has high biological specificity
- …its targets are limited only by physics and the imagination of the radiochemists
- …unlike MRI, it provides truly quantitative measurements

Why conventional PET sucks?

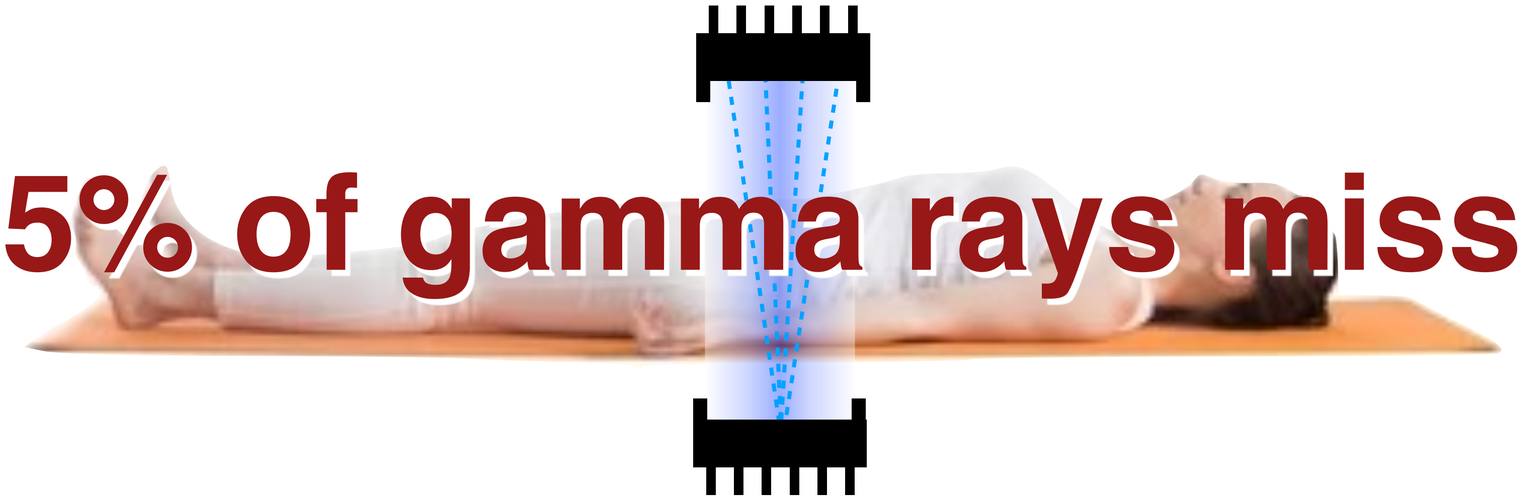


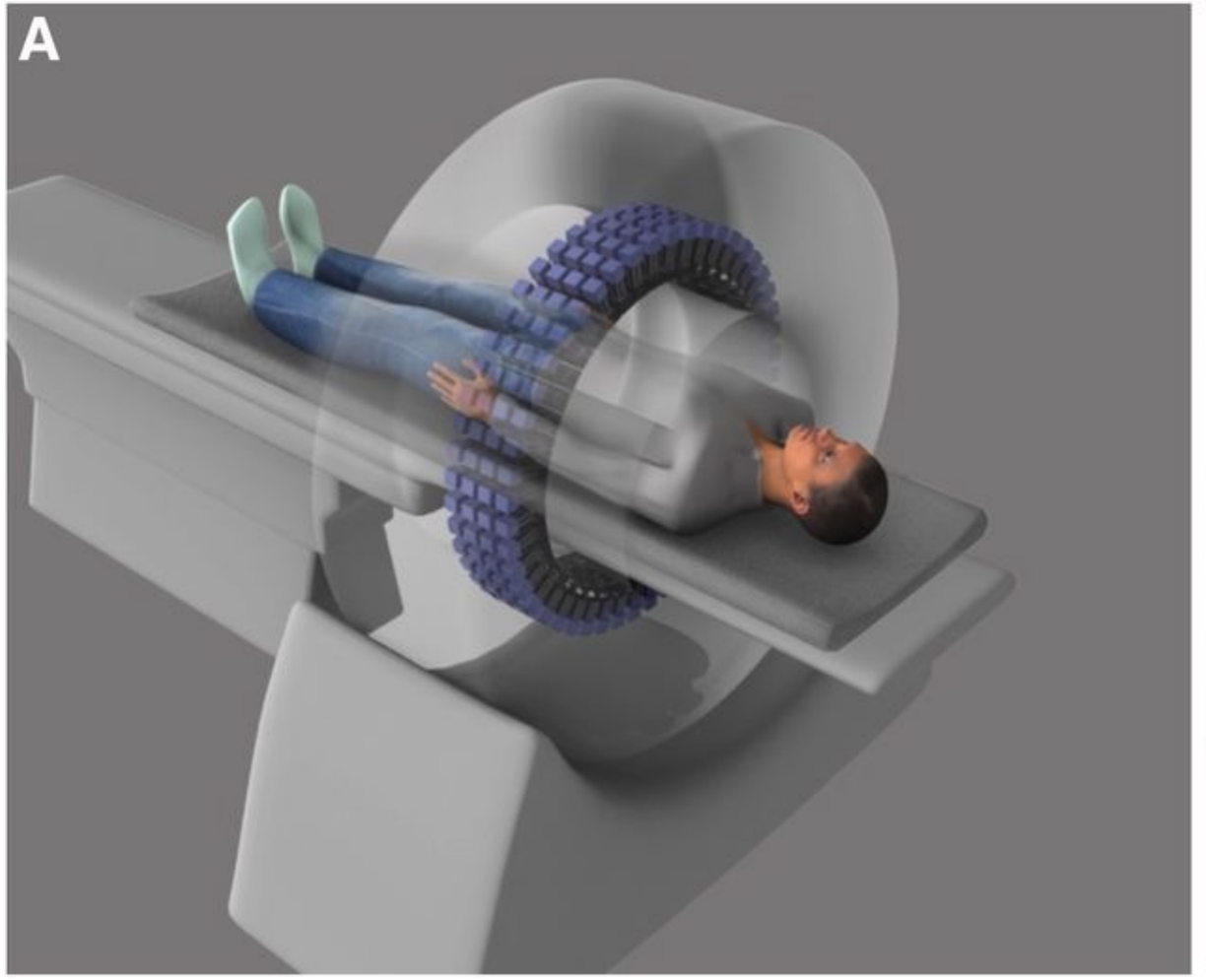


A) Linear lines of response



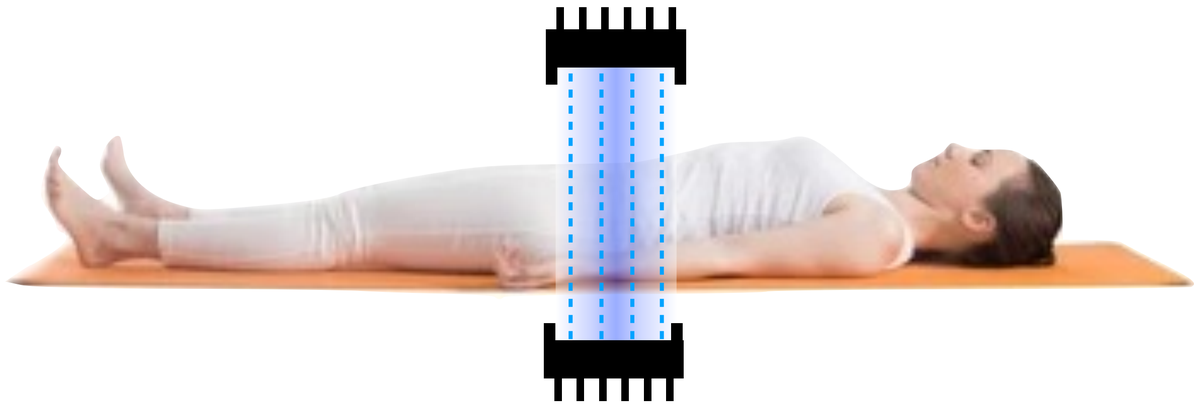
B) Angular lines of response



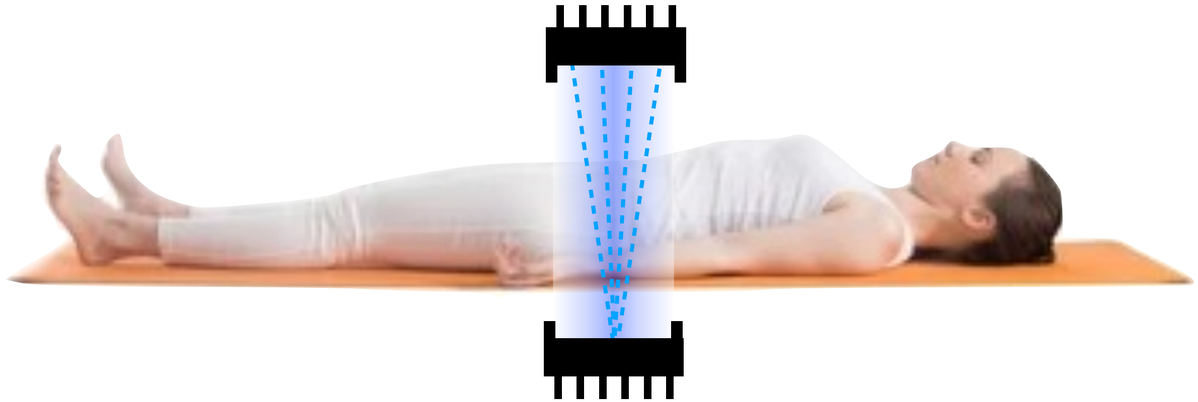


Cherry et al (2018)

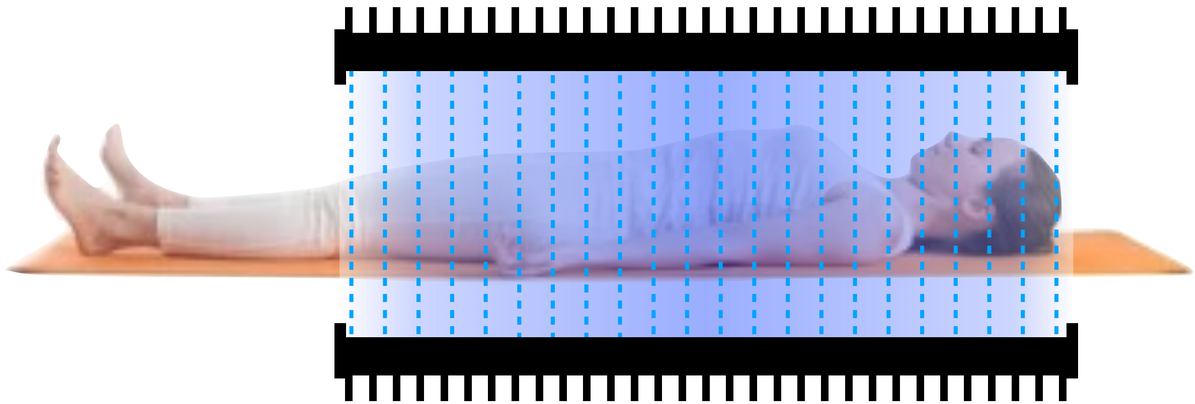
A) Conventional PET: linear lines of response



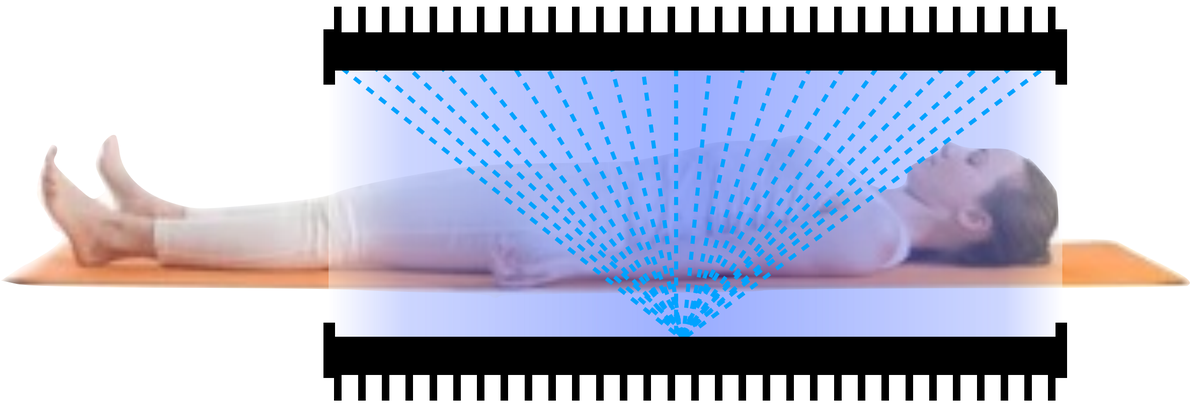
B) Conventional PET: angular lines of response

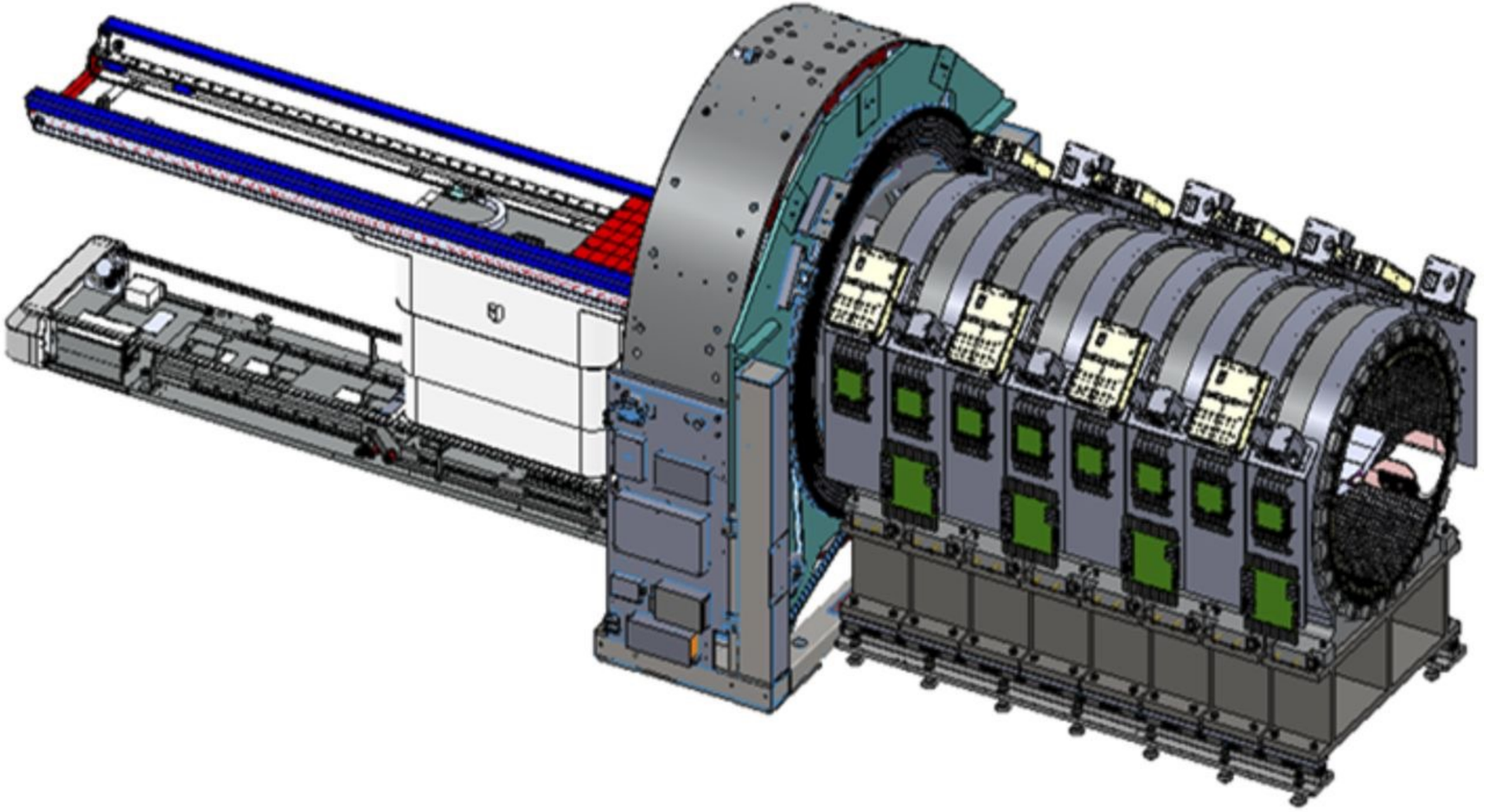


C) Total-body-PET: linear lines of response

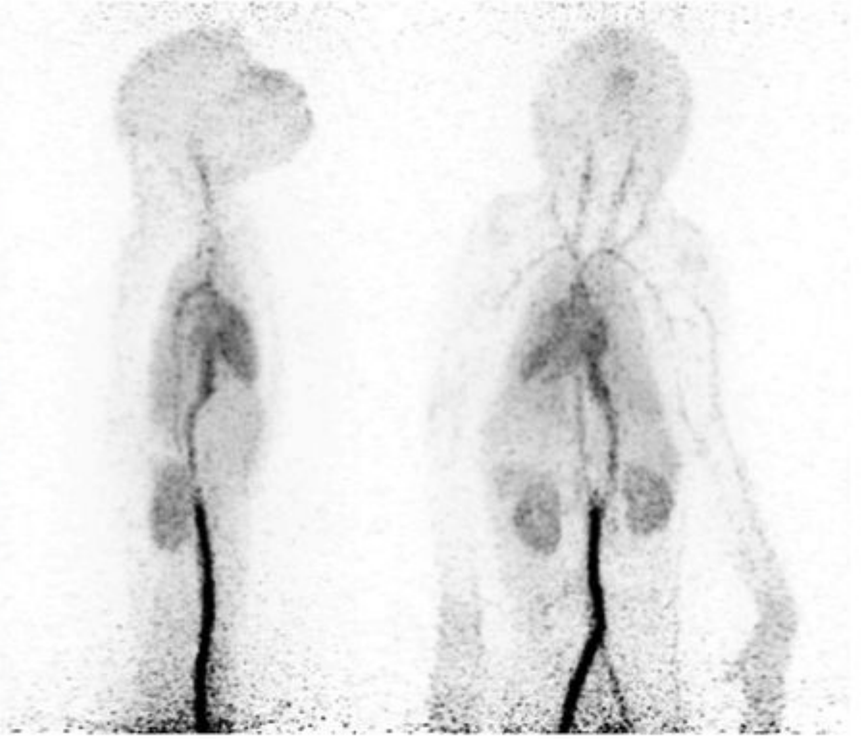


D) Total-body-PET: angular lines of response

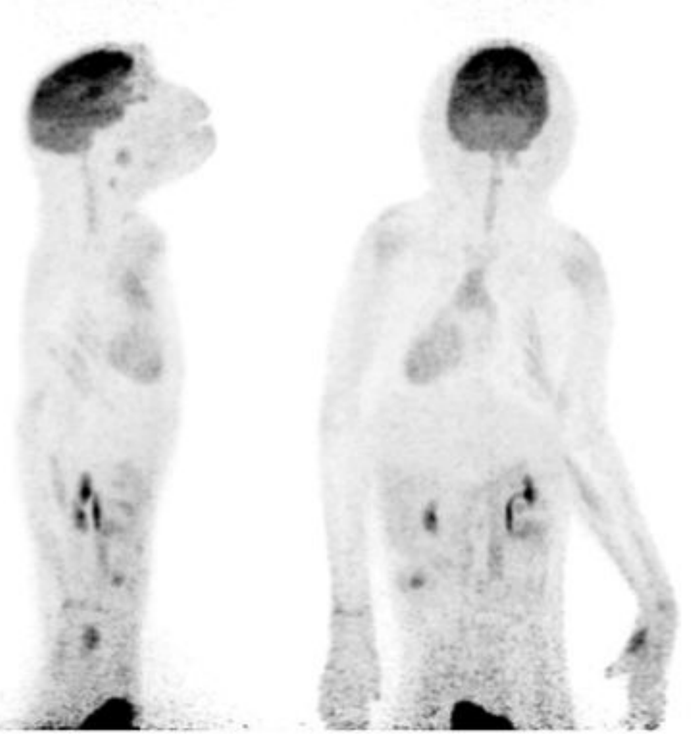




Cherry et al (2018)



0- to 30-s scan



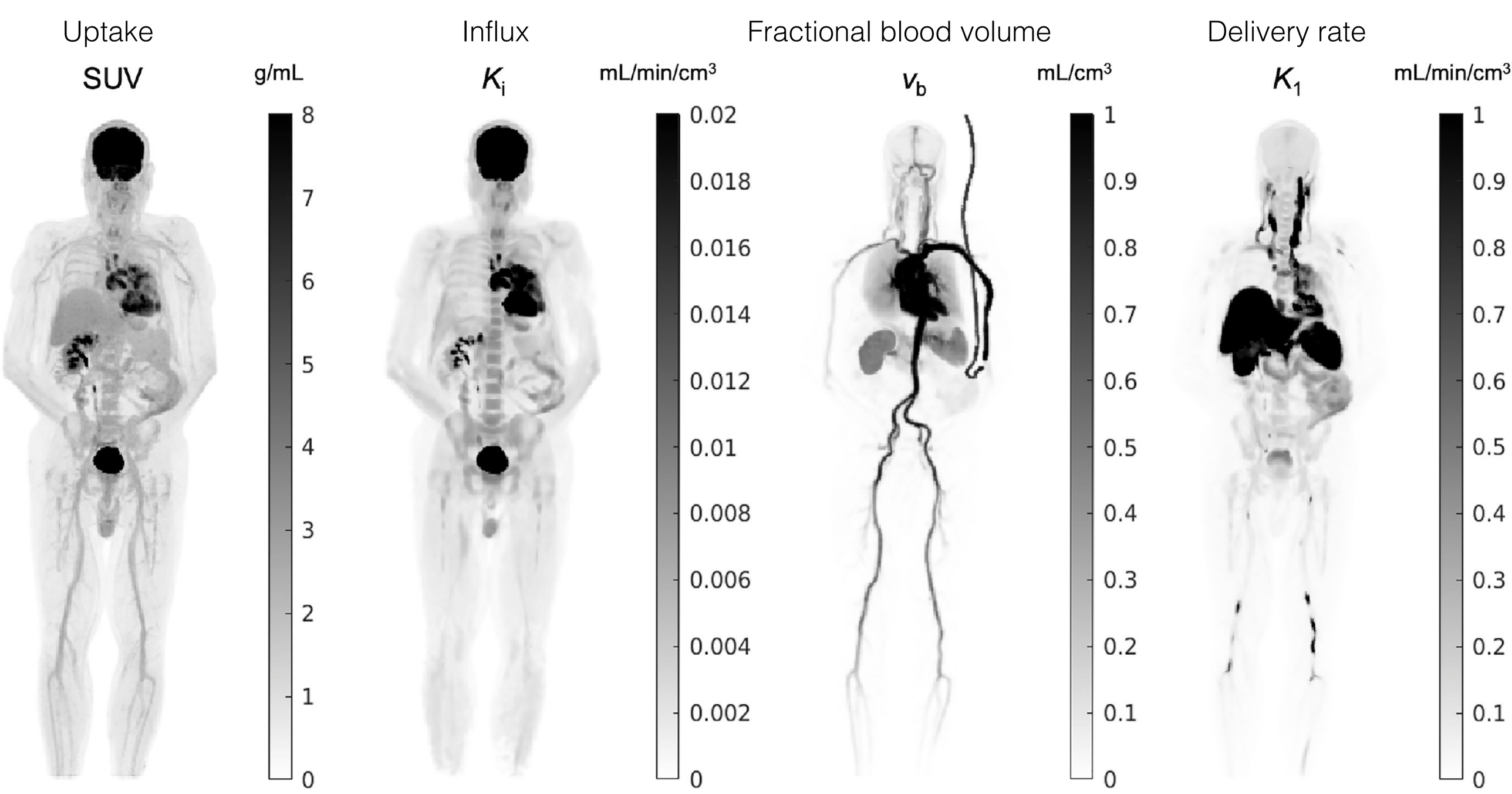
55- to 60-min scan

Cherry et al (2018)

EXPLORER
UNITED IMAGING
EXPLORER

UC Davis / EXPLORER Team

0 min 0 sec


Uptake
SUV
g/mL
8
7
6
5
4
3
2
1
0
Influx
K_i
mL/min/cm³
0.02
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
Fractional blood volume
v_b
mL/cm³
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Delivery rate
K_1
mL/min/cm³
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0

Ng et al (2022)

SIEMENS
Healthineers
BIOGRAPH Vision
SIEMENS
Healthineers

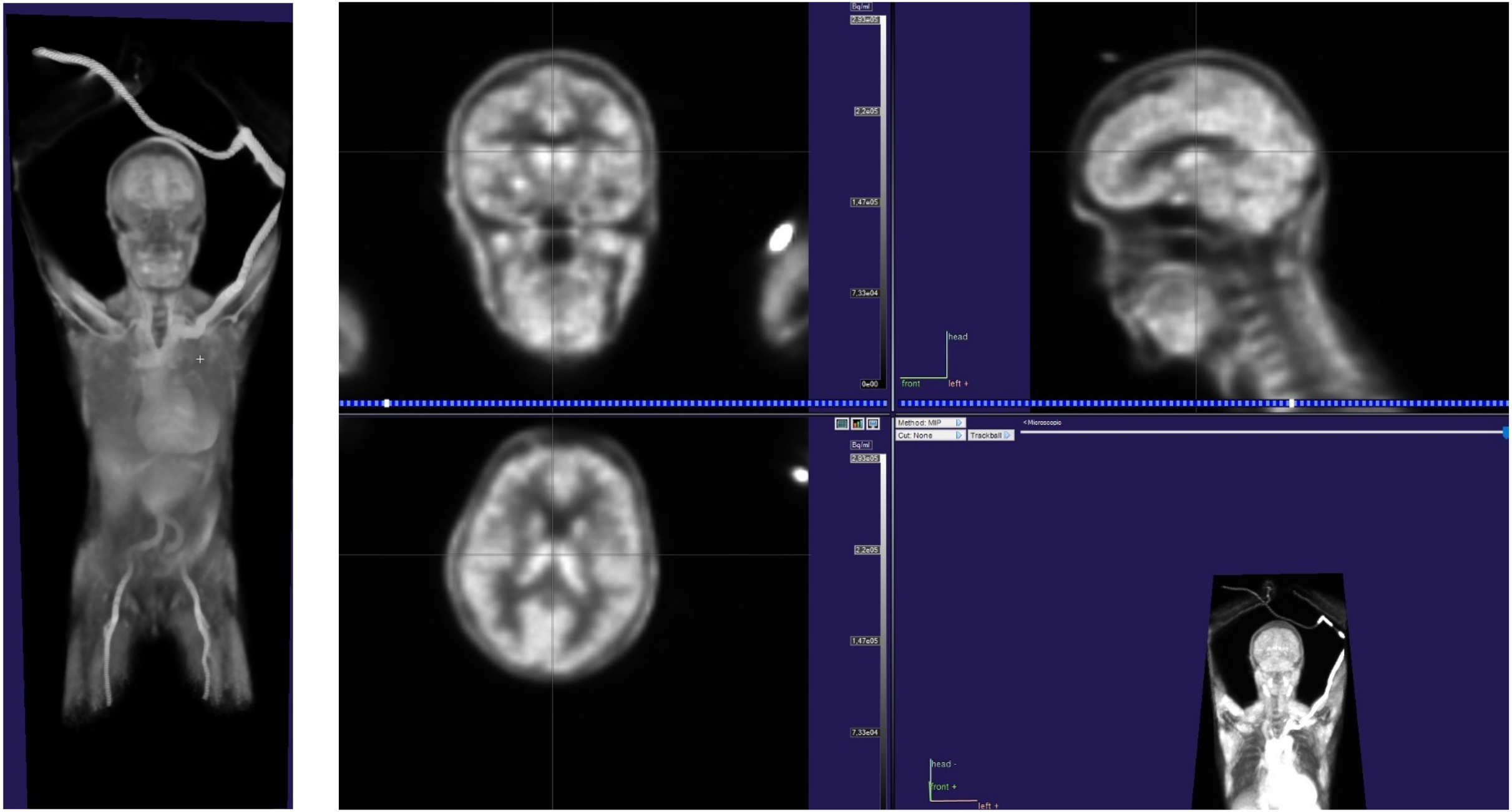
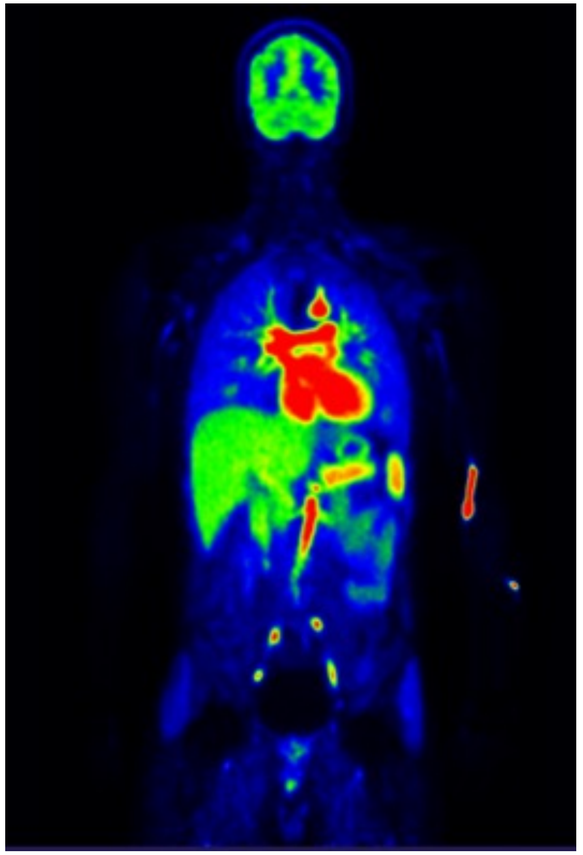


Image courtesy of Juhani Knuuti

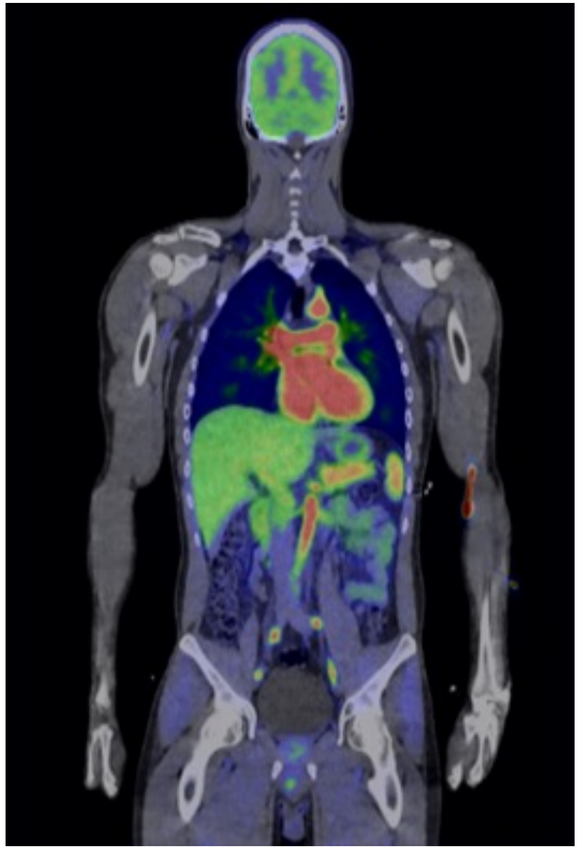
Imaging whole-body biological circuits

CT

PET



PET-CT



Improving the SNR

- **Siemens Quadra** scanner can pick up ~24 times more gamma counts than conventional PET-CT
- **SNR** of a reconstructed PET scan is $\sqrt{N}$ where N is the number of events
- **Event detection** depends on sensitivity (S), injected activity (A) and imaging time (T) scaled by constant (k), thus $SNR = k \times \sqrt{S \times A \times T}$

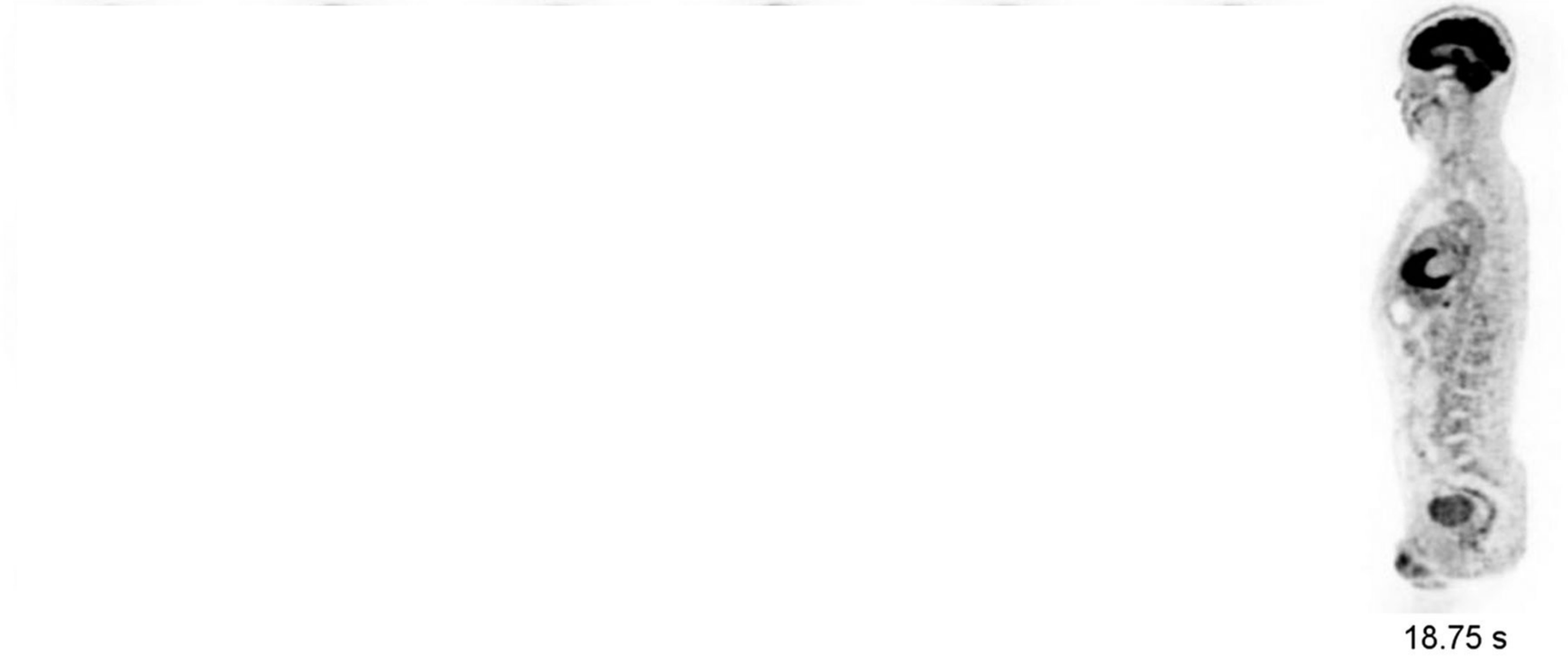
What to do with the increased sensitivity

- **Increase SNR by a factor of $\sqrt{24}$ = 4.9** while keeping the protocol otherwise fixed
- **Reduce imaging times with a factor of 24,**
  - Routine 24-minute [18F]FDG scan could be accomplished in just one minute.
  - Significantly increases patient throughput and comfort, which decreases subject motion, further improving image quality.
- **Image-based input** can be routinely used (e.g. carotid artery) as it will be most likely in the imaging —> reduced workload

What to do with the increased sensitivity

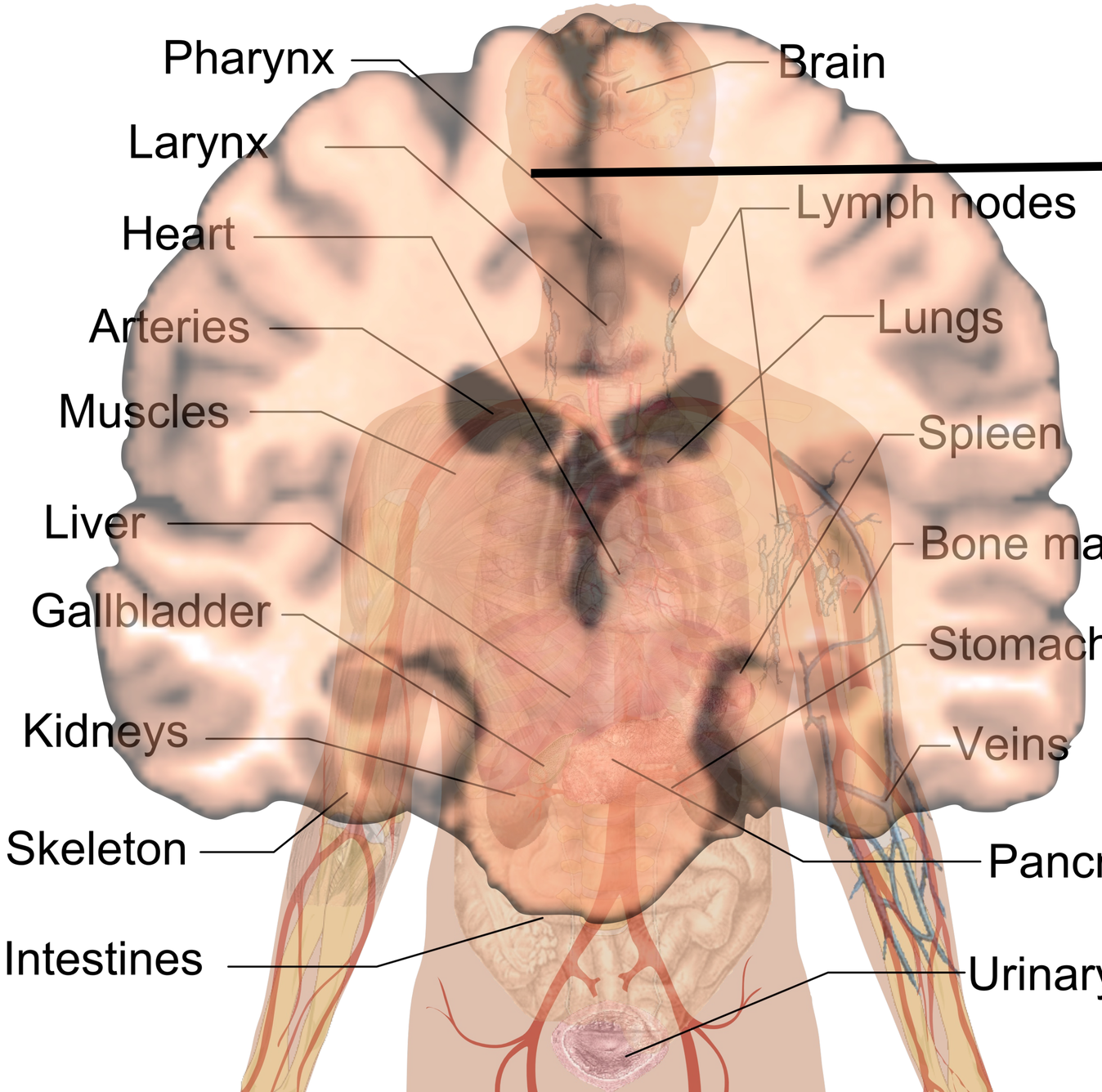
- **Reduce the injected activity by a factor of 24.**
  - Typical whole-body [18F]FDG scan requiring ~480 MBq injected activity —> now injection 20 MBq —> effective doses < 0.3 mSv.
  - **Up to 40 consecutive scans** with the same effective dose that is currently received from a single scan,
  - **Permits multi-injection activation studies** with short-lived radiotracers (15O2), longitudinal studies with more datapoints, or multi-ligand studies
- **Routine whole-body imaging** allows diagnosis of conditions outside main target region

256 MBq injected activity (18F-FDG)



Badawi et al (2019)

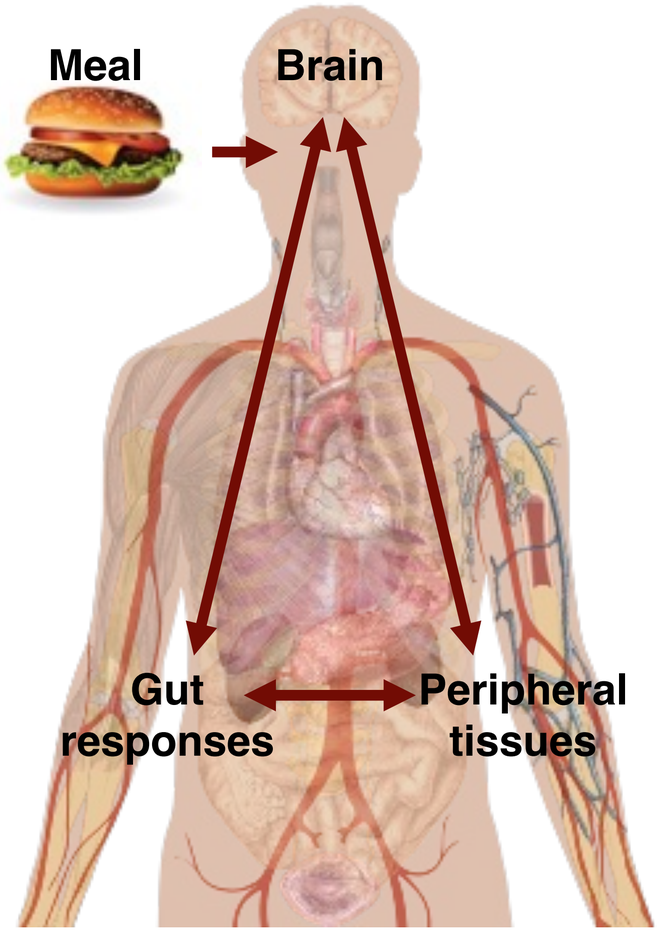
Internal organs

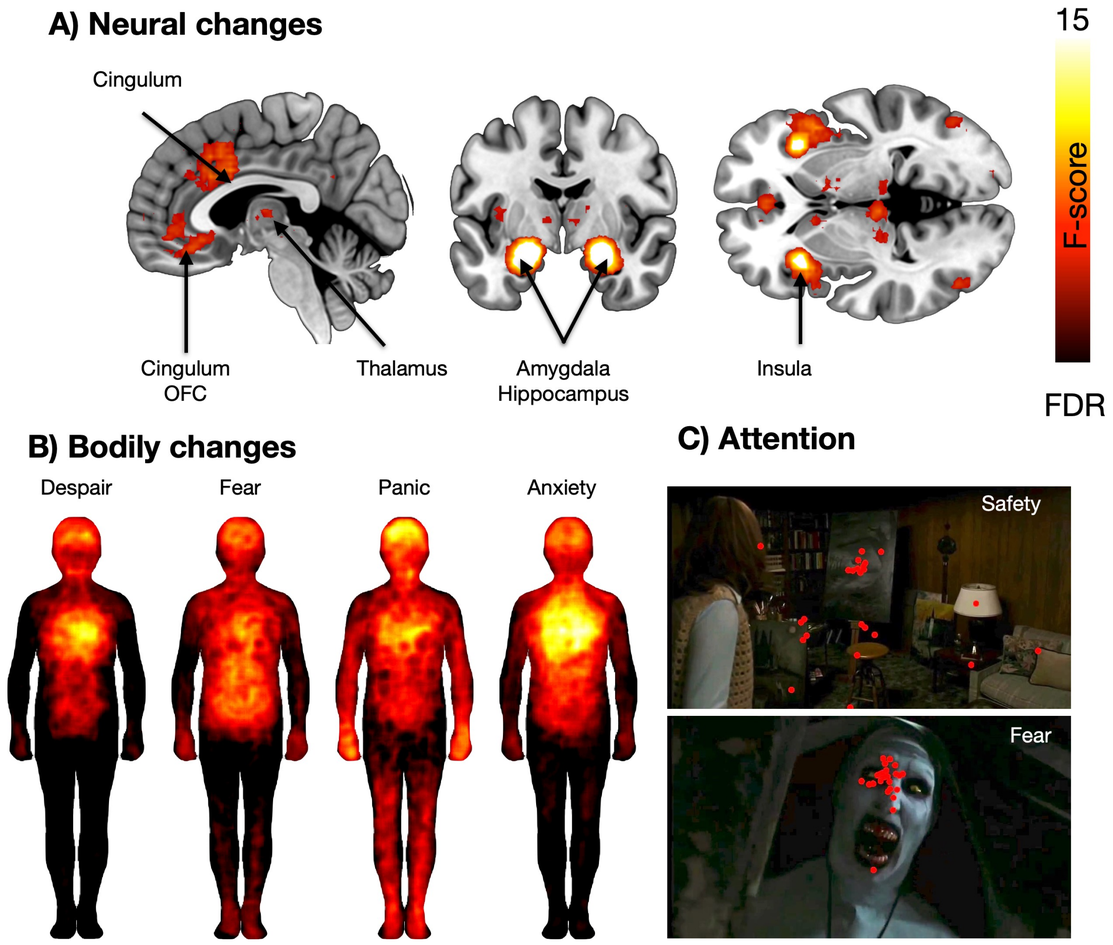


↑Brain = cool!

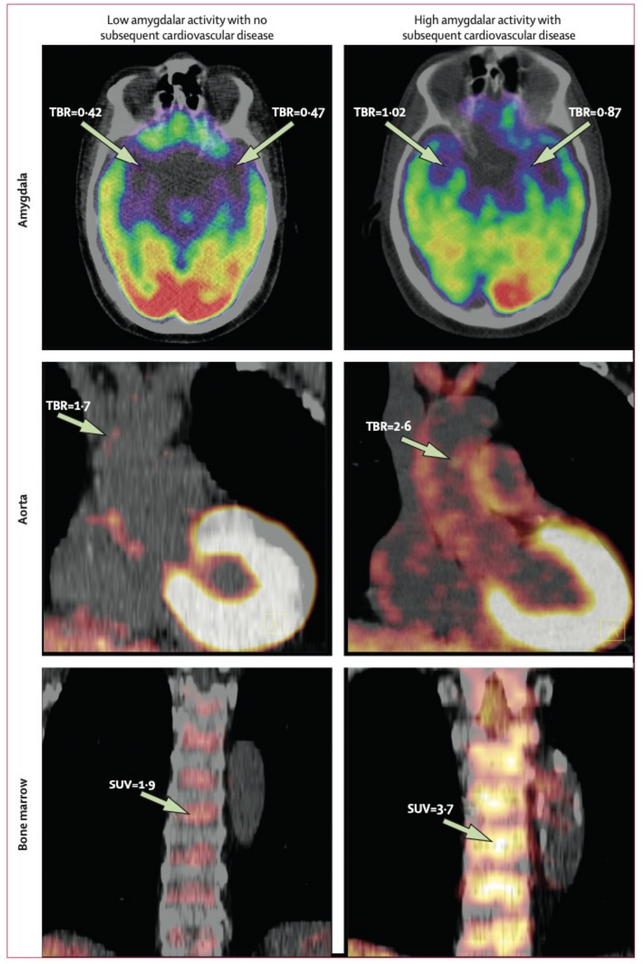
↓Gut = boring!

Why care about the non-brain?



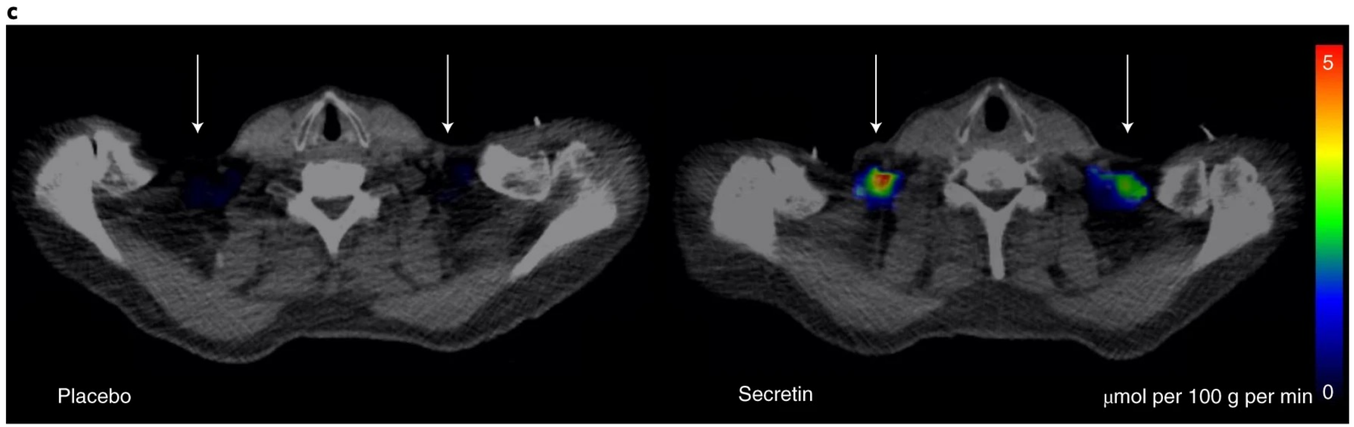


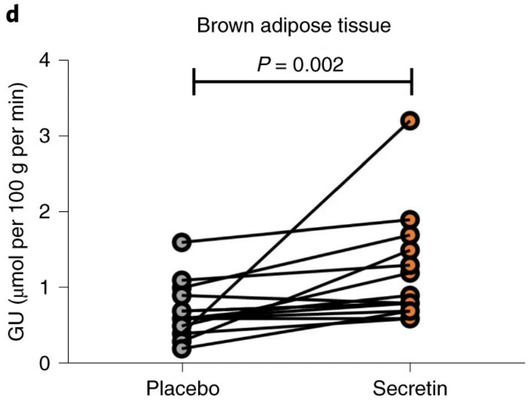
Nummenmaa et al (2018)

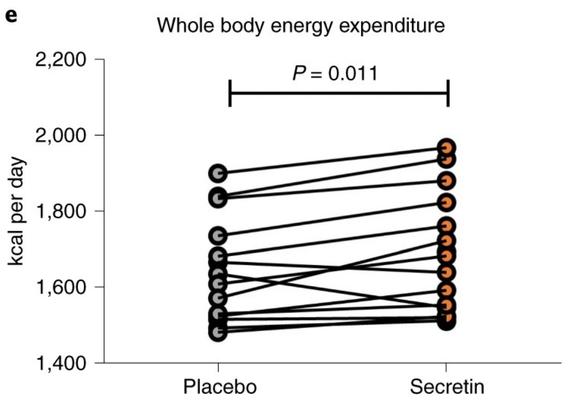


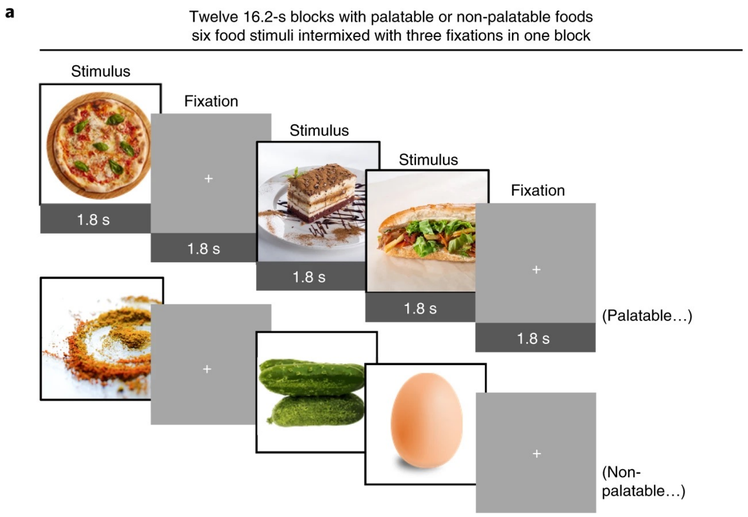
Tawakol et al (2017)

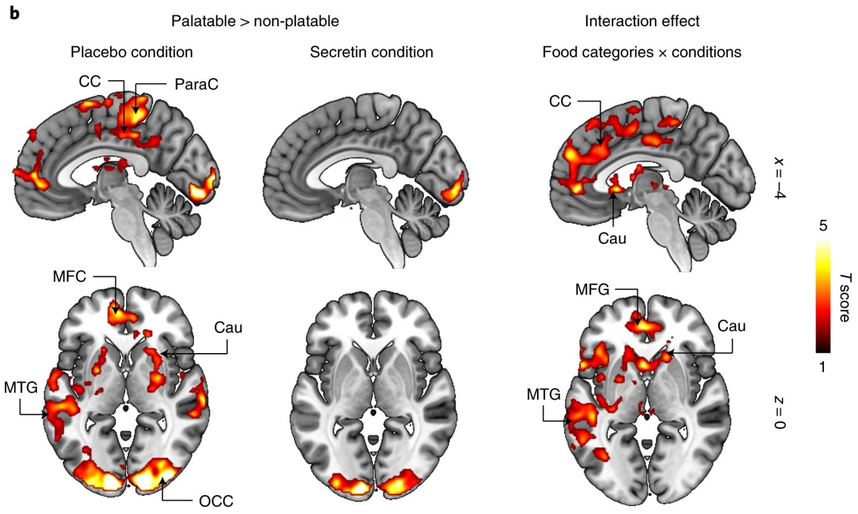
Why care about the non-brain?







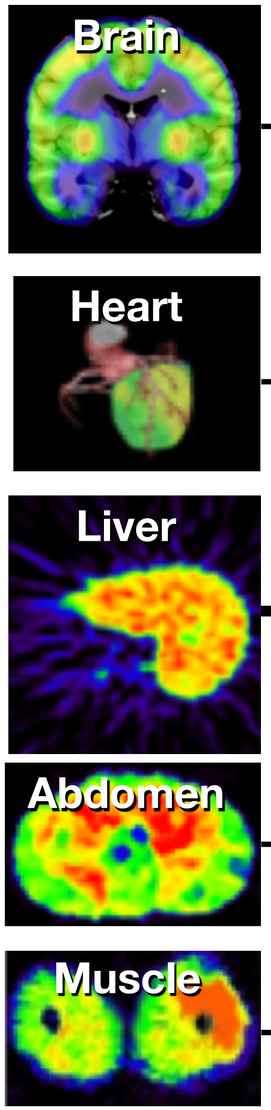




Laurila et al (Nat Metabolism 2022)

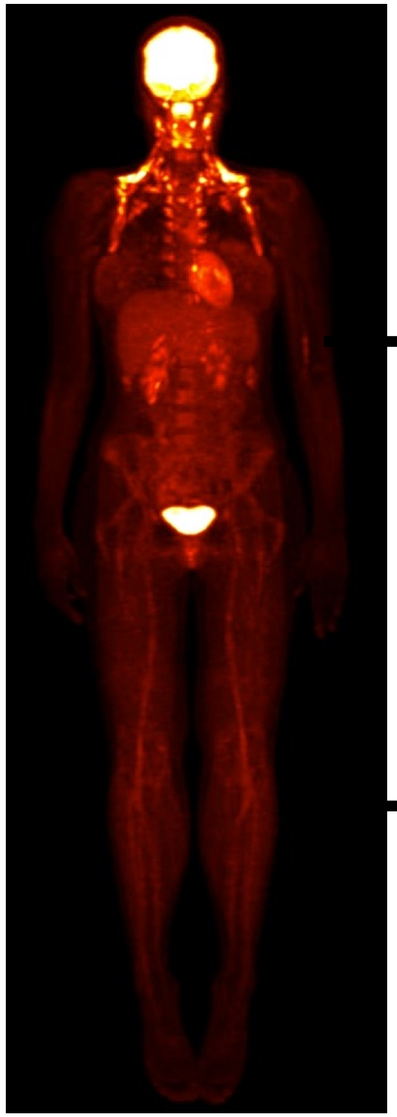
Modern PET

Tissue-specific imaging (3 h)



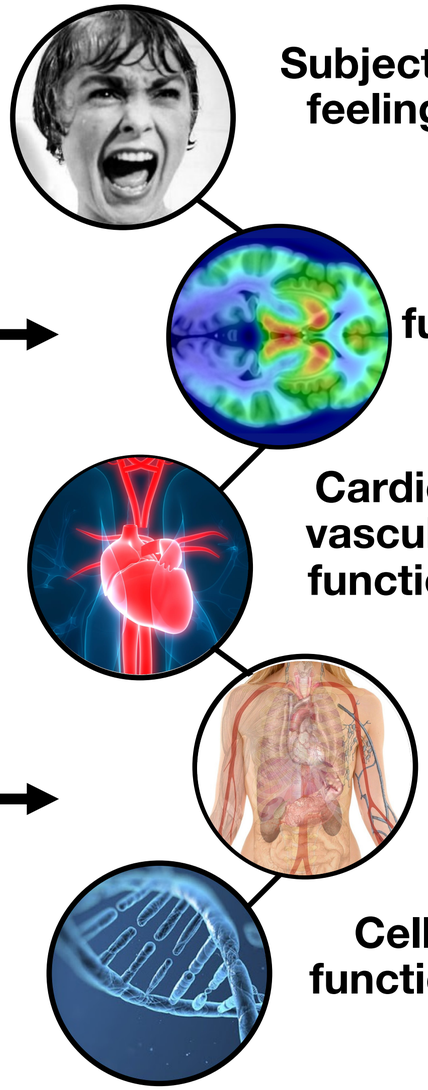
New state-of-the art

Ultrafast total-body imaging



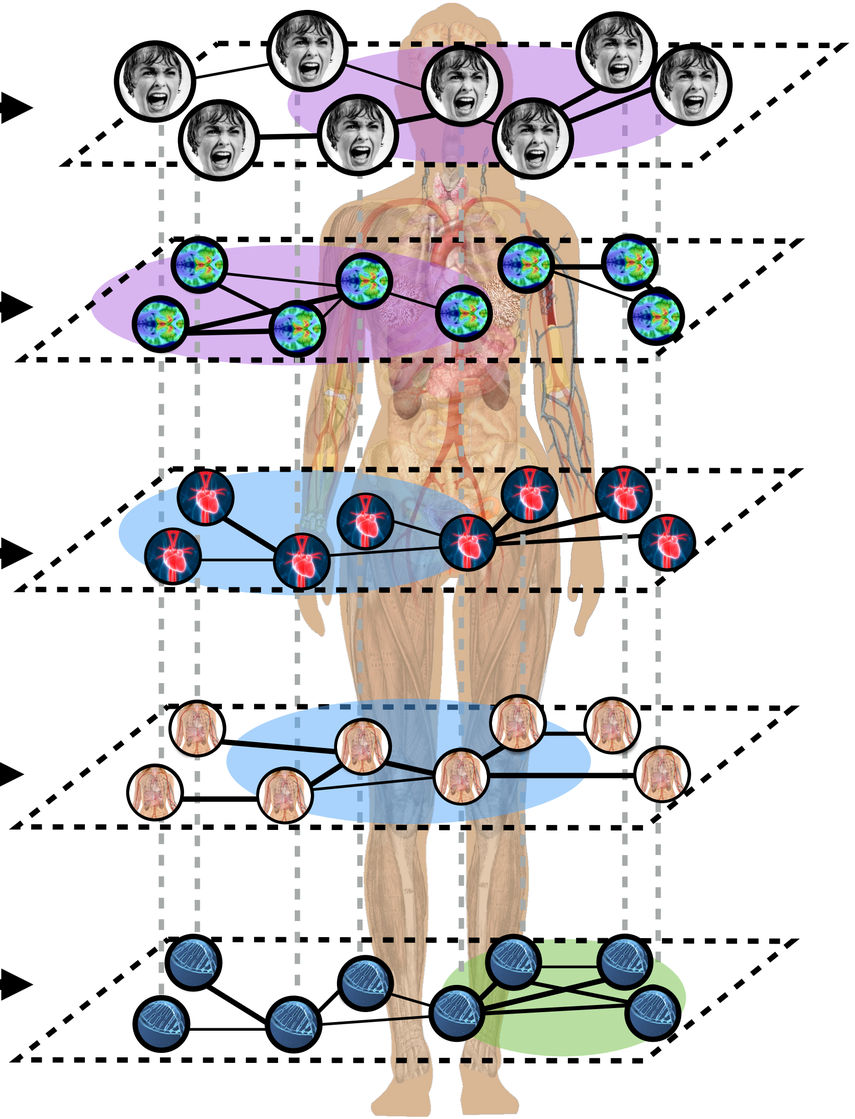
Simultaneous studies of multiple systems

Multilevel measurements



High-resolution multisystem biological imaging

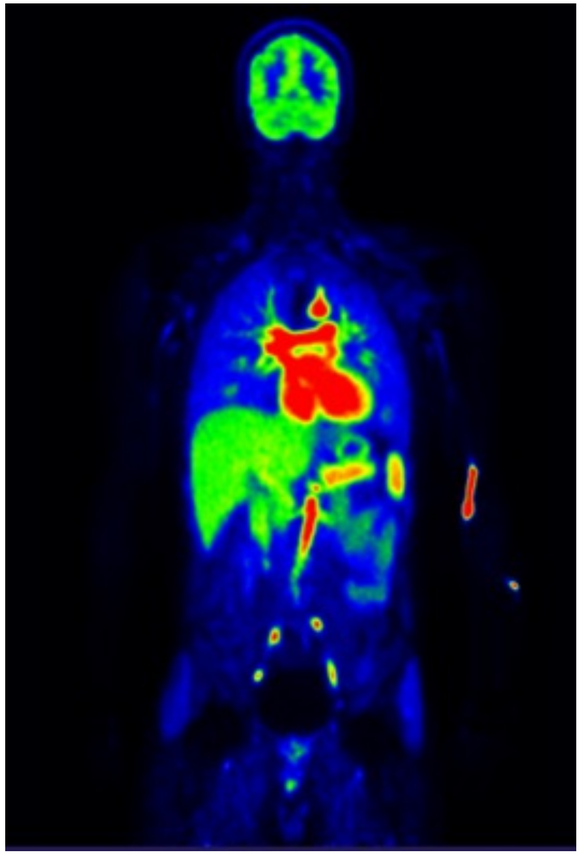
Network and system level studies



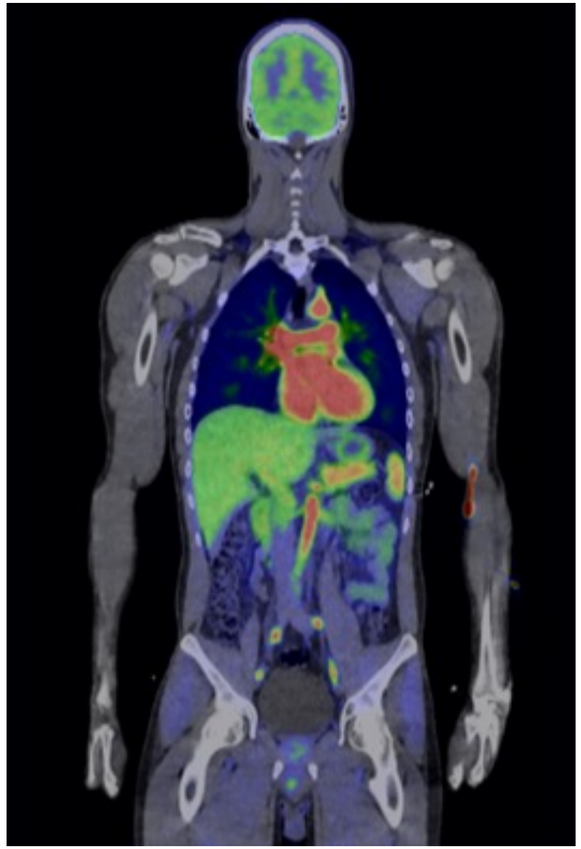
Not just a walk in the park

CT

PET



PET-CT



Prospects of true multi-compartment modelling

Dynamic PET image

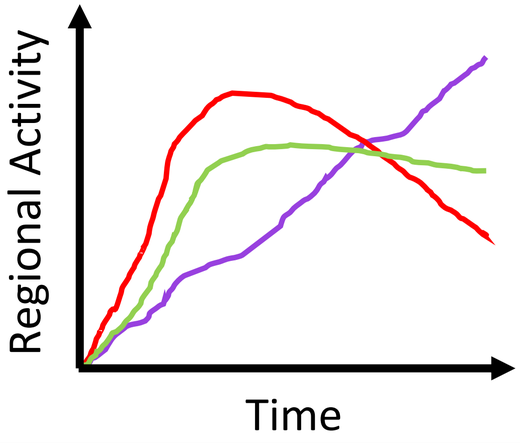
Segmentation and ROI definition

Manual & ICA

ROIs for data extraction

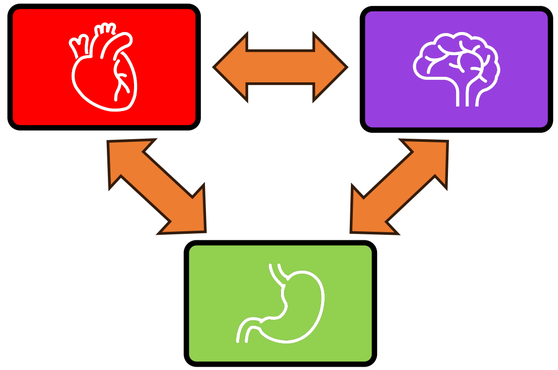
ICA optimisation

Regional time activity courses



Compartmental data

Multi-compartment modelling



Optimising the equations