Latest Advances in Sim4Life Segmentation AIs & Neural Activation Predictors

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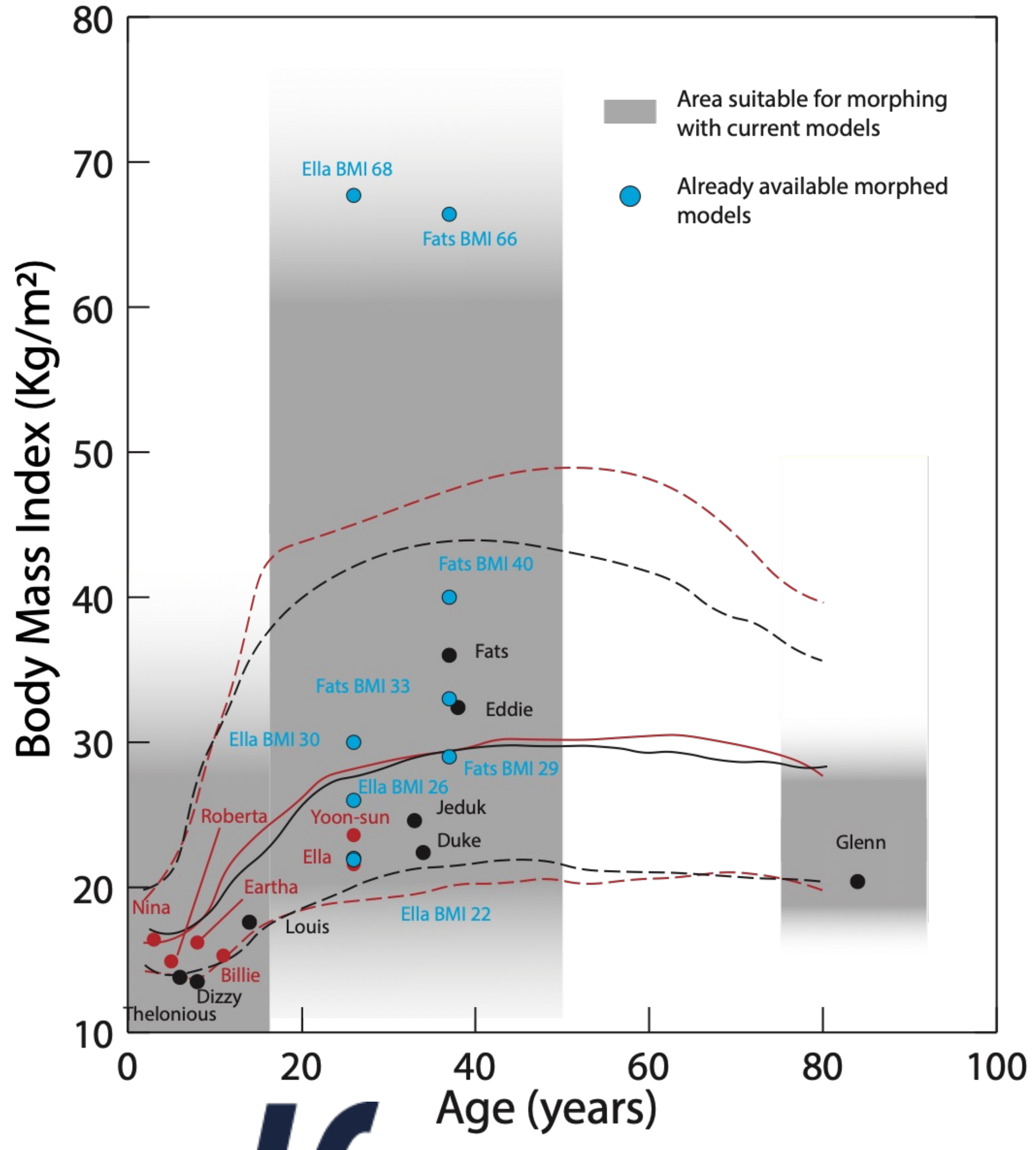
Personalized Anatomical Models

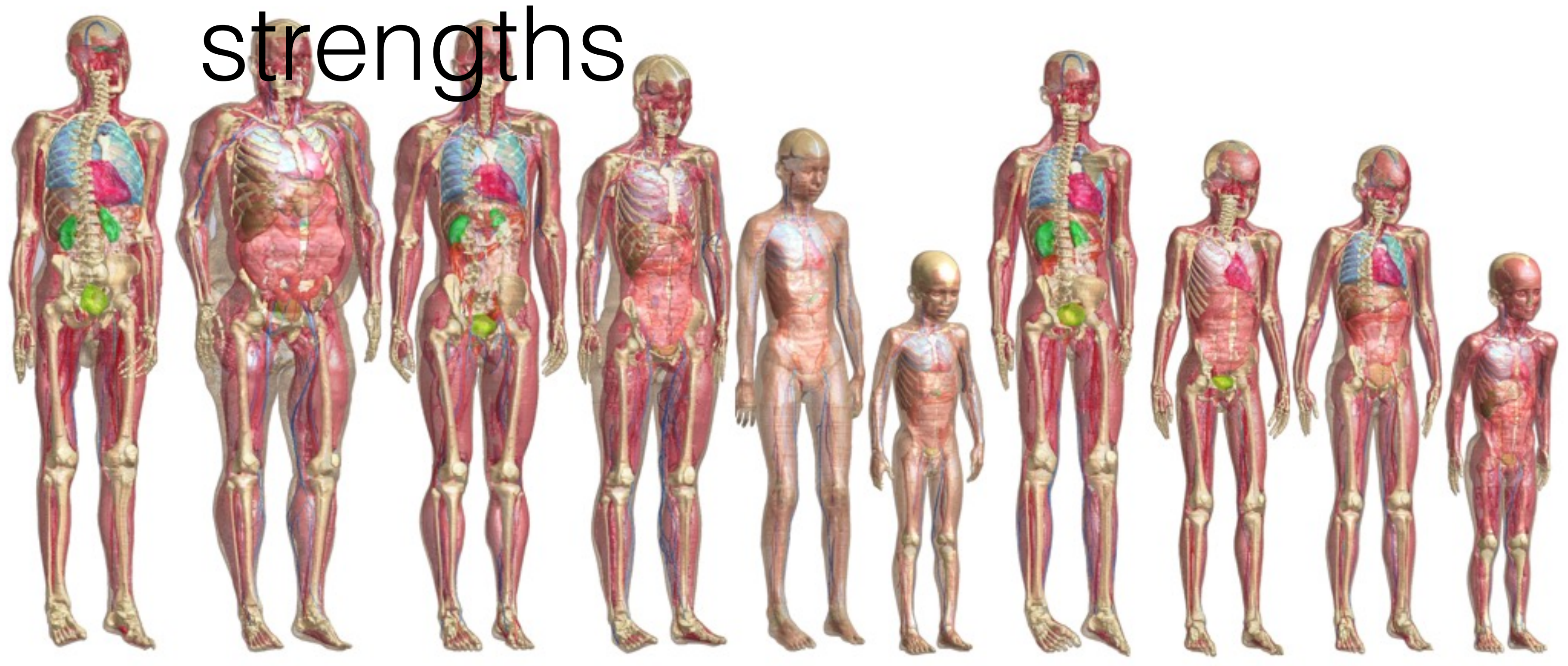
Virtual Population

- the availability of high quality ViP models and Sim4Life's ability of handling such complexity are unique and key strengths

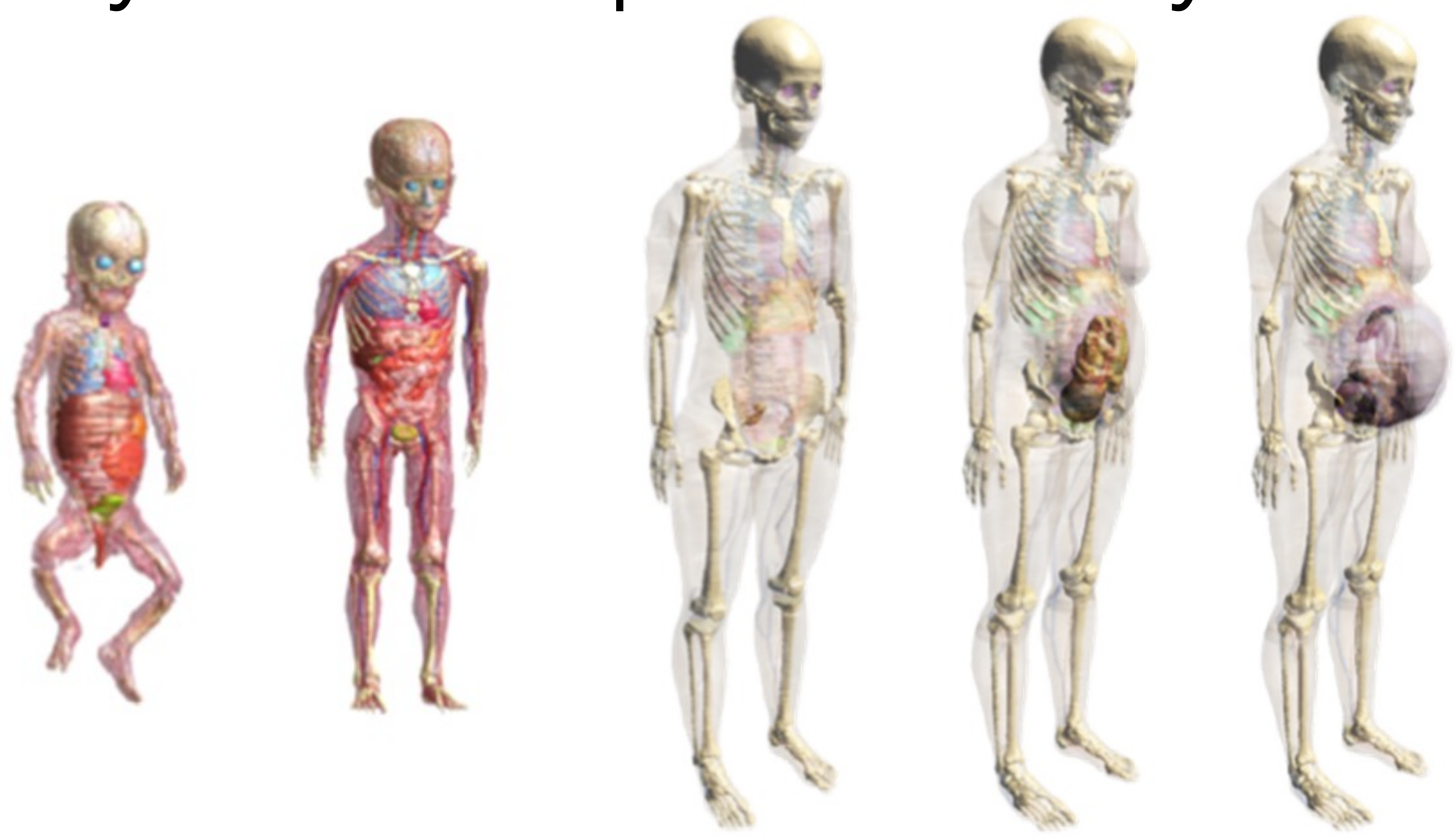
Morphed Models

BMI=29 BMI=36 (original) BMI=49



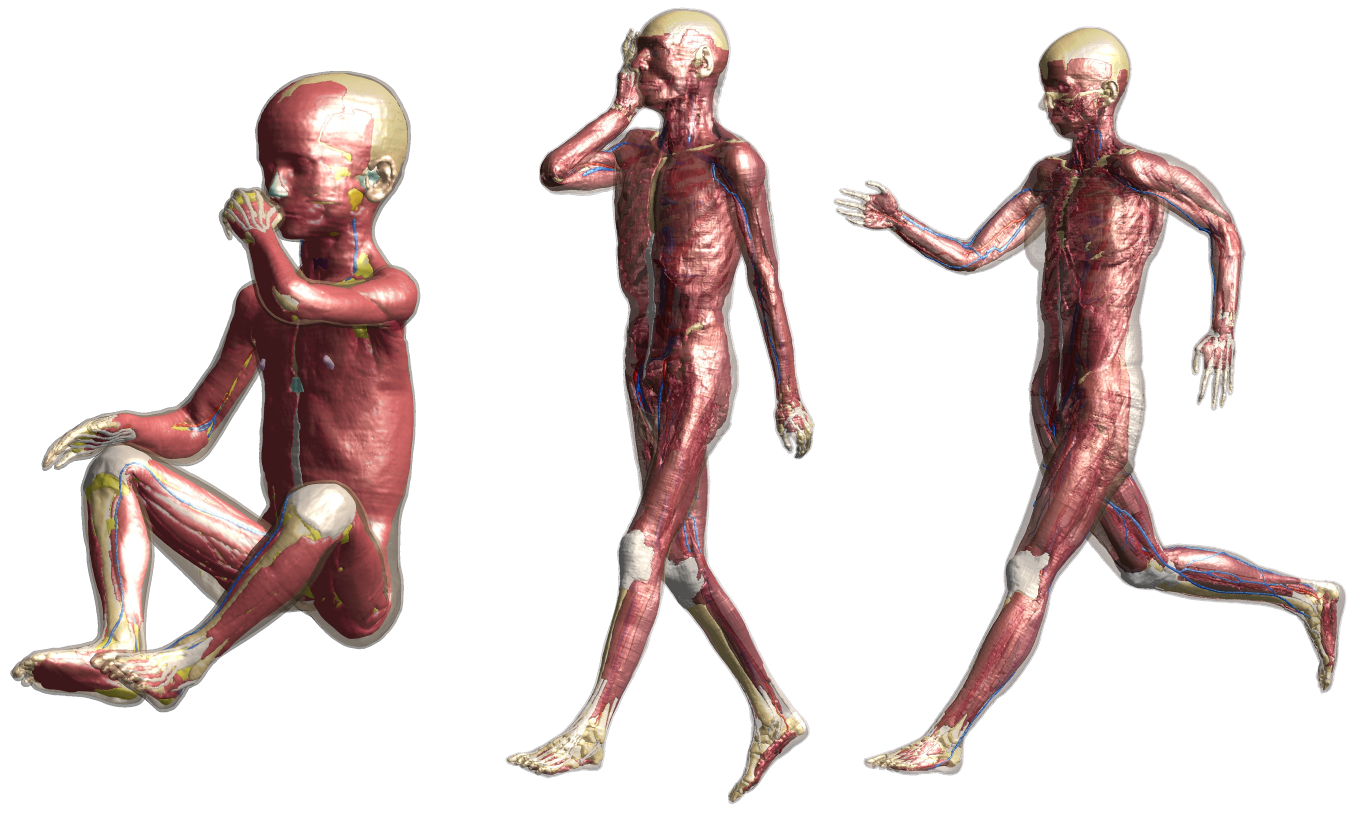


Virtual Population



Specific Population

Animal Models



Posed Models

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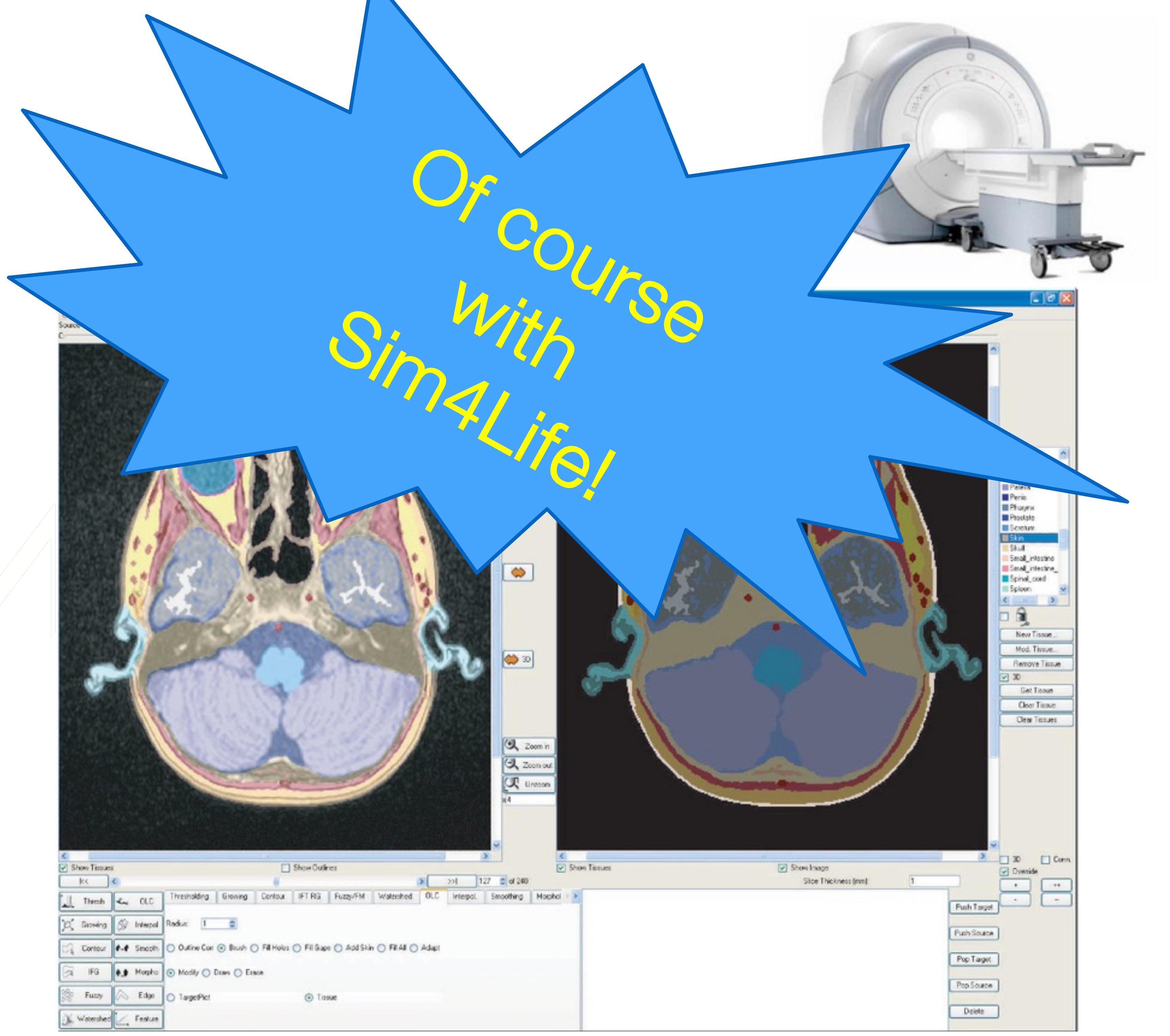
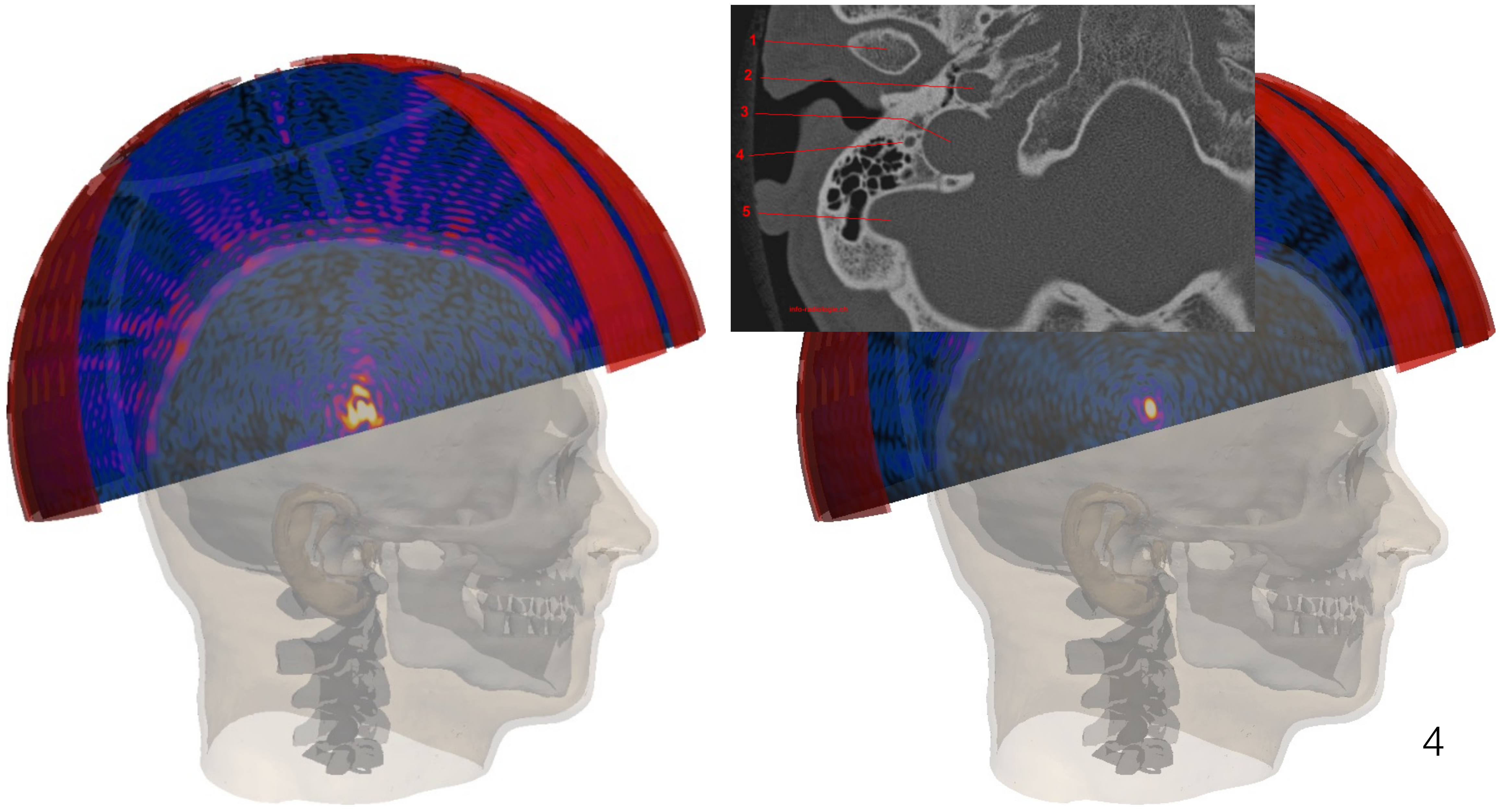
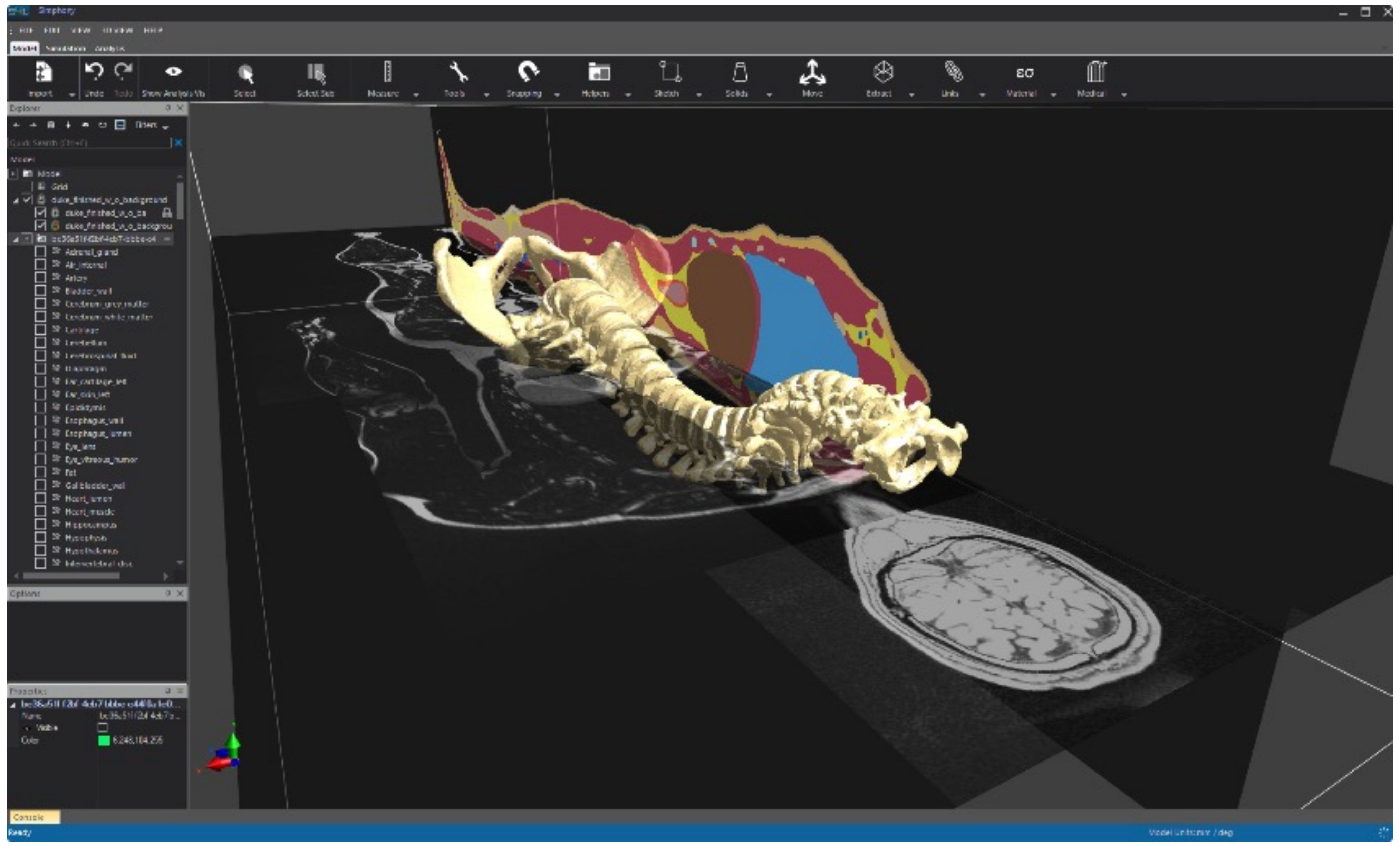
Image-Based Modeling

- another key strength is Sim4Life's ability of leveraging medical image data for image-based modeling
  - image-based property distributions (e.g., CT-based skull properties for FUS simulations)
  - image-based boundary conditions (e.g., MR-velocimetry-based computational fluid dynamics)
  - image-based anatomical model generation
- maximal realism, personalized modeling, precision medicine



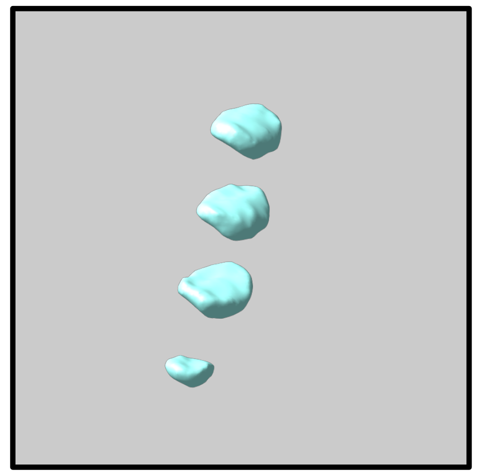
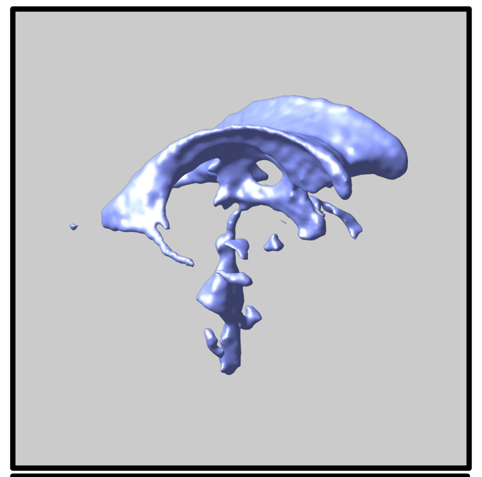
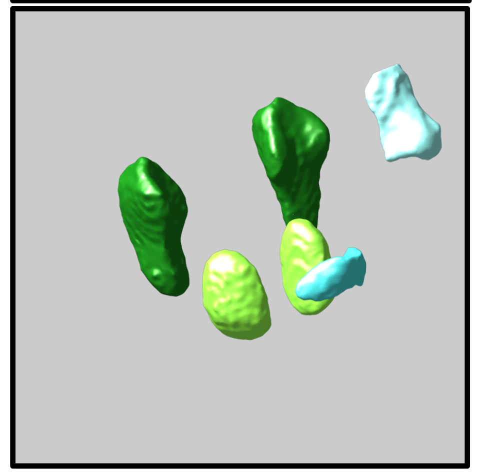


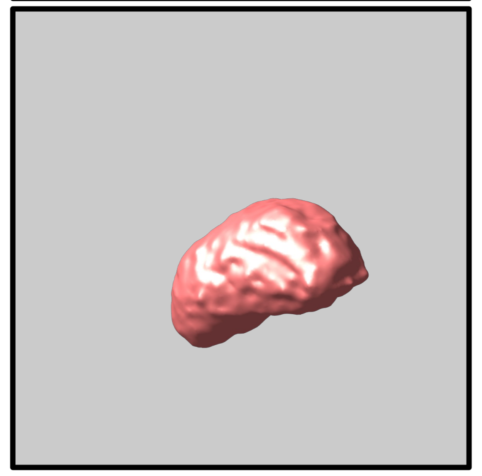
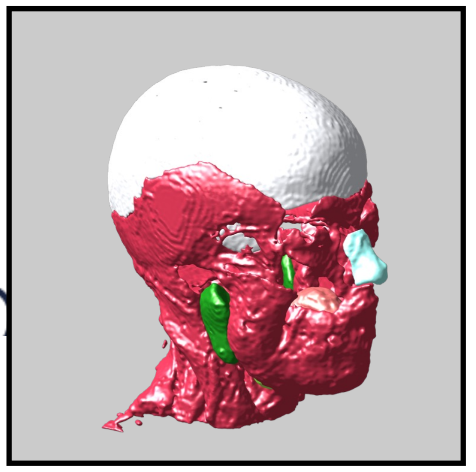


Evolution of Automatic Head Segmentation

Evolution of Automatic Head Segmentation

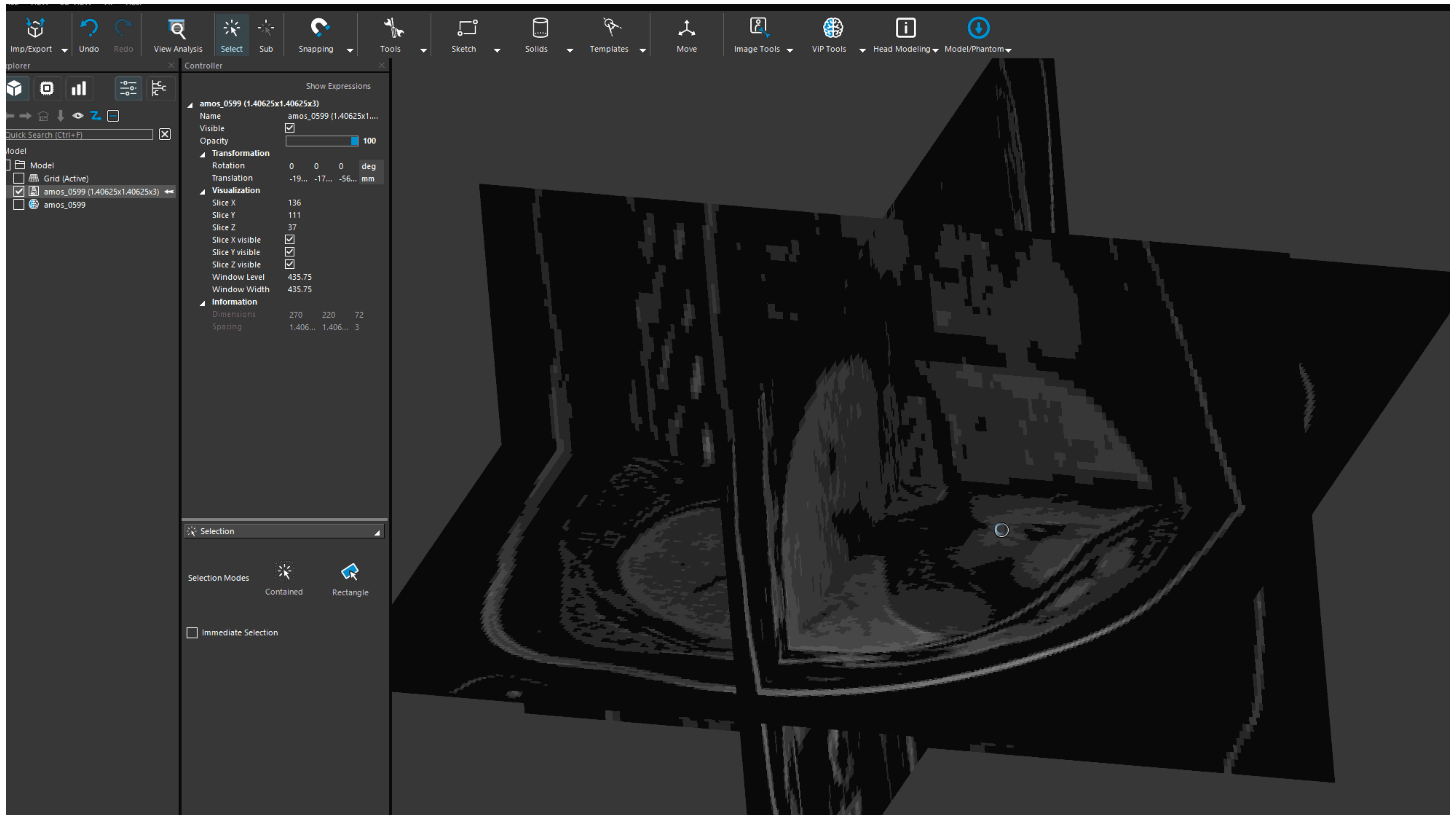
head16	head30	head40
16 tissues	**30 tissues**	**40 tissues**
requires T1 (+ T2)	requires T1	requires T1
trained on 20 subjects-DCRMR dataset	**trained on > 200 subjects-CC dataset**	trained on > 200 subjects-CC dataset
Philips 3T	**GE, Philips, Siemens, 1.5T+3T**	GE, Philips, Siemens, 1.5T+3T
	higher accuracy	**improved accuracy of hippocampus & thalamus**
	adds deep brain structures	**adds tendons/galea, muscle, and glands**
Sim4Life v7.2	Sim4Life v8.0	Sim4Life v8.0.1

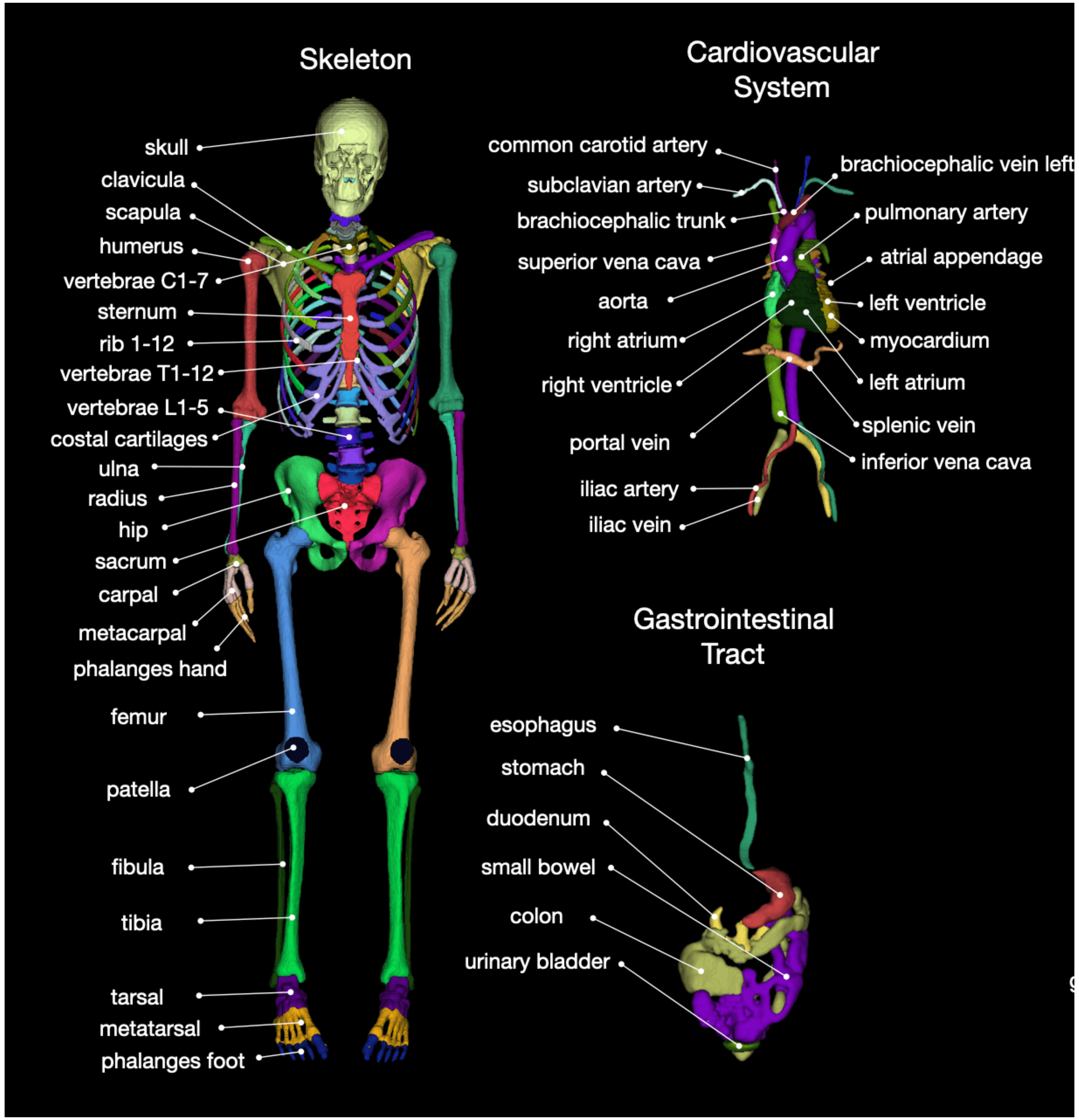




Whole Body Segmentation

- integration of TotalSegmentator (TS)
  - Uni-Spital Basel
  - segment > 100 structures in CT
- Total Vibe Segmentor
  - trained on MRI of torso (thoracic/abdominal/pelvic)
  - Vibe similar to T2/Dixon
  - predictions quite promising





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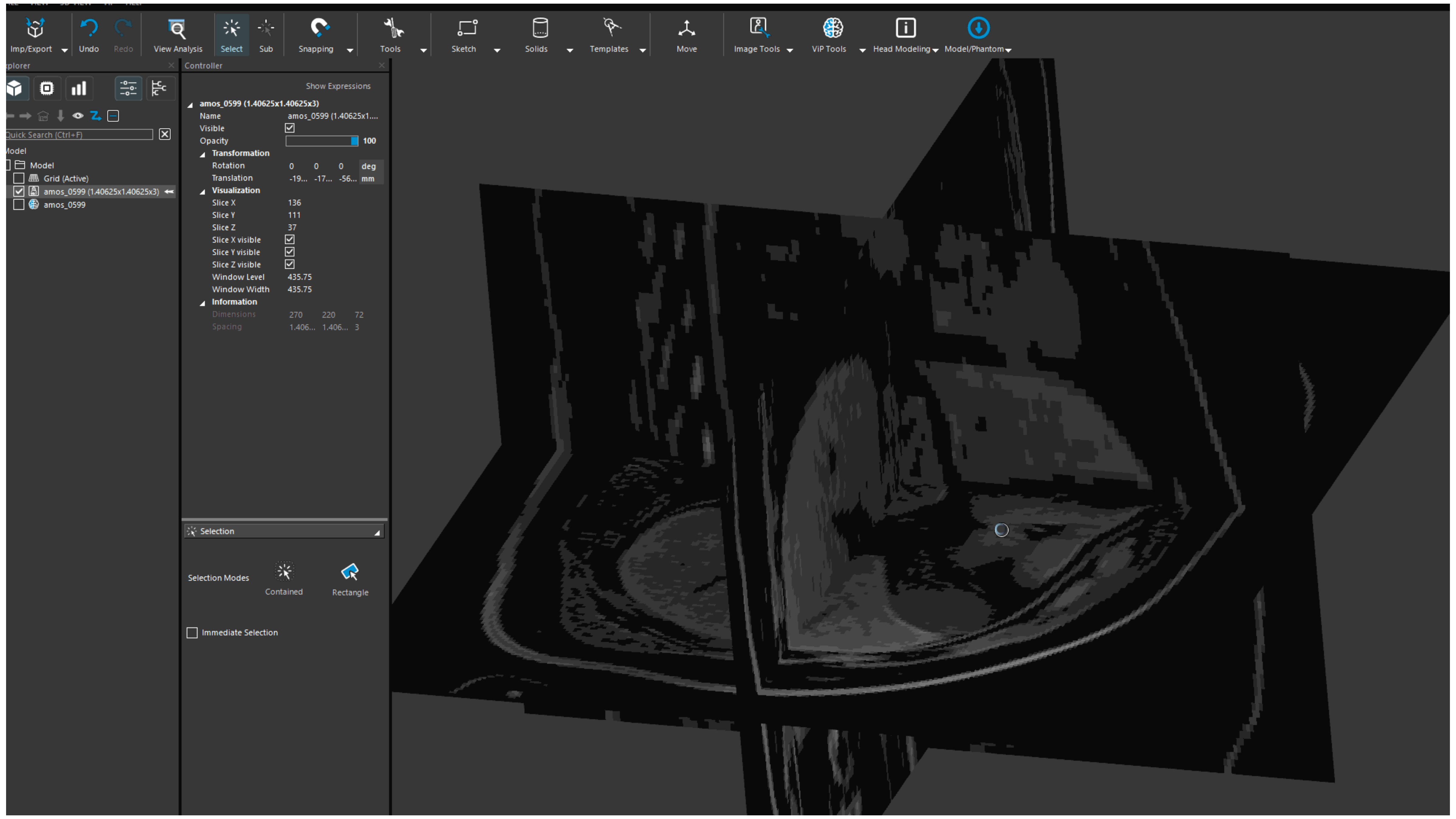

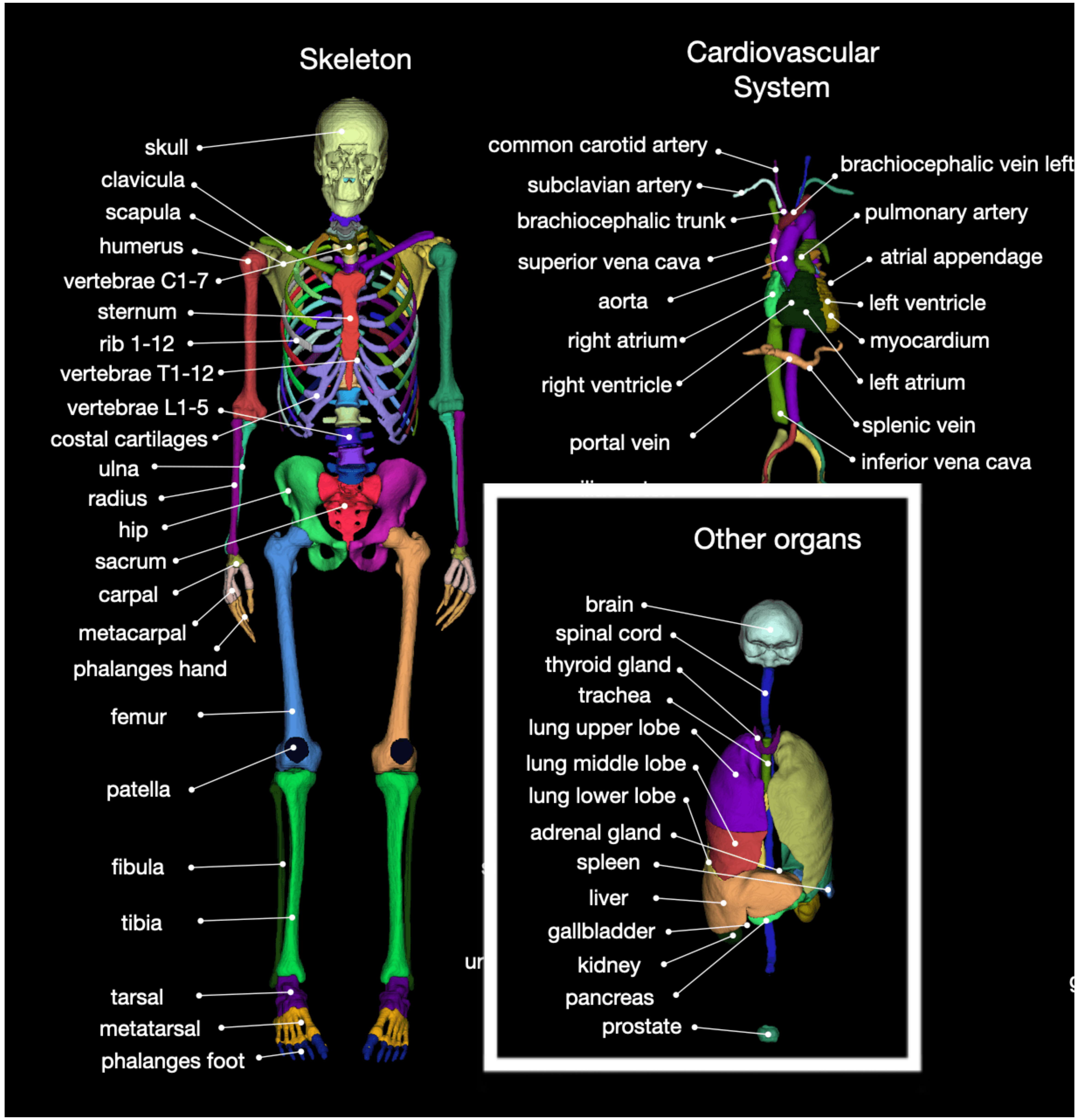

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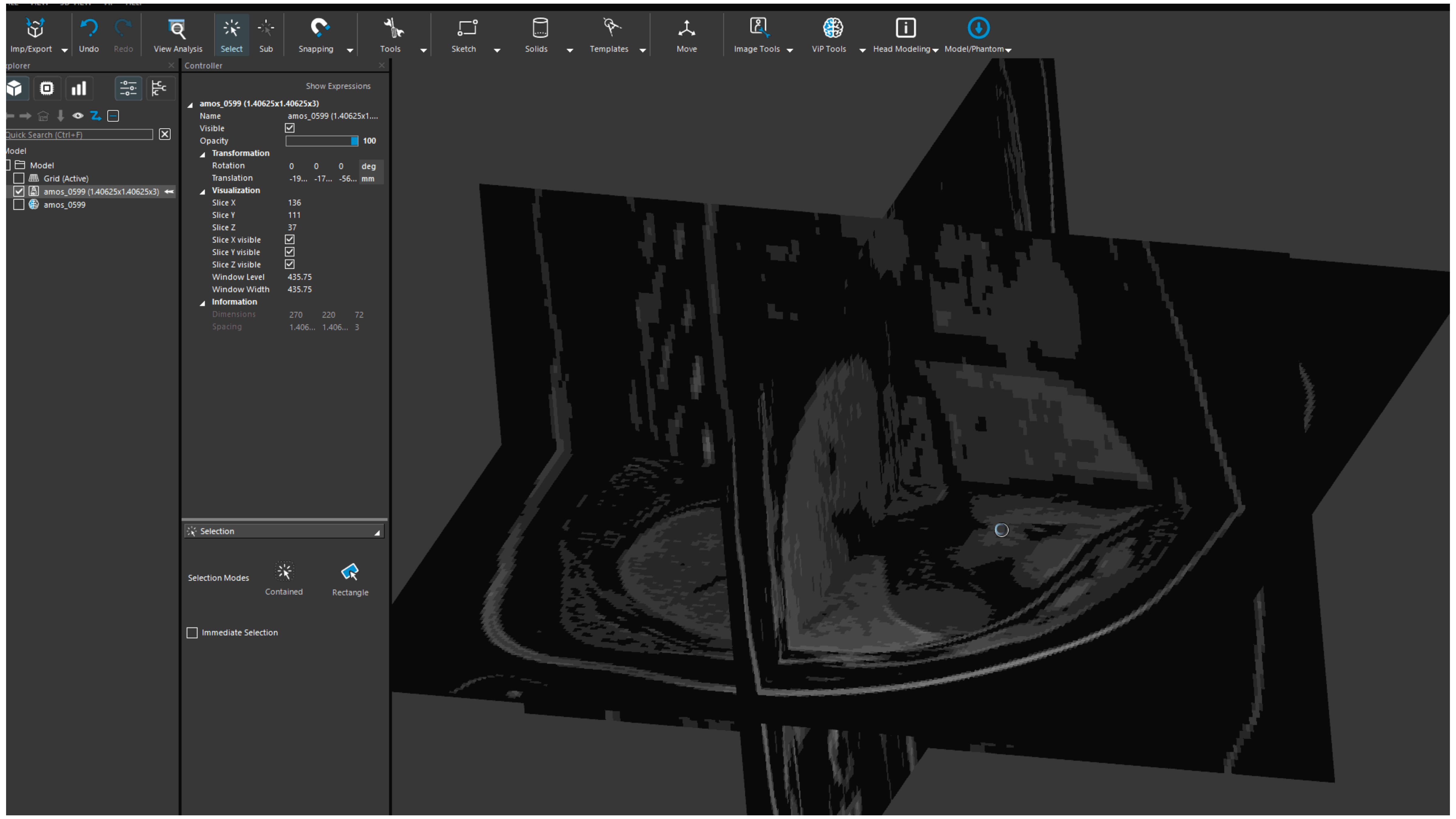

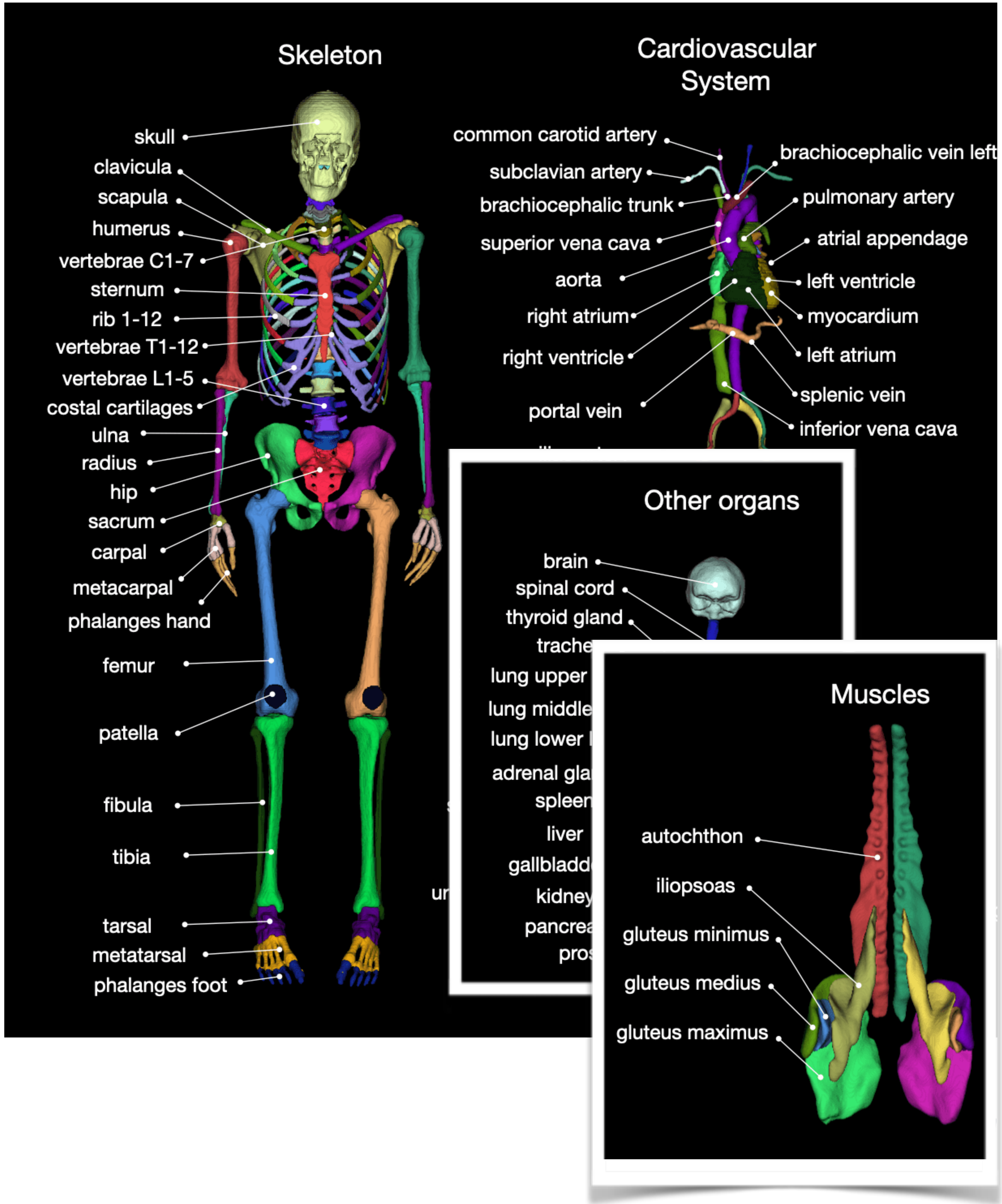

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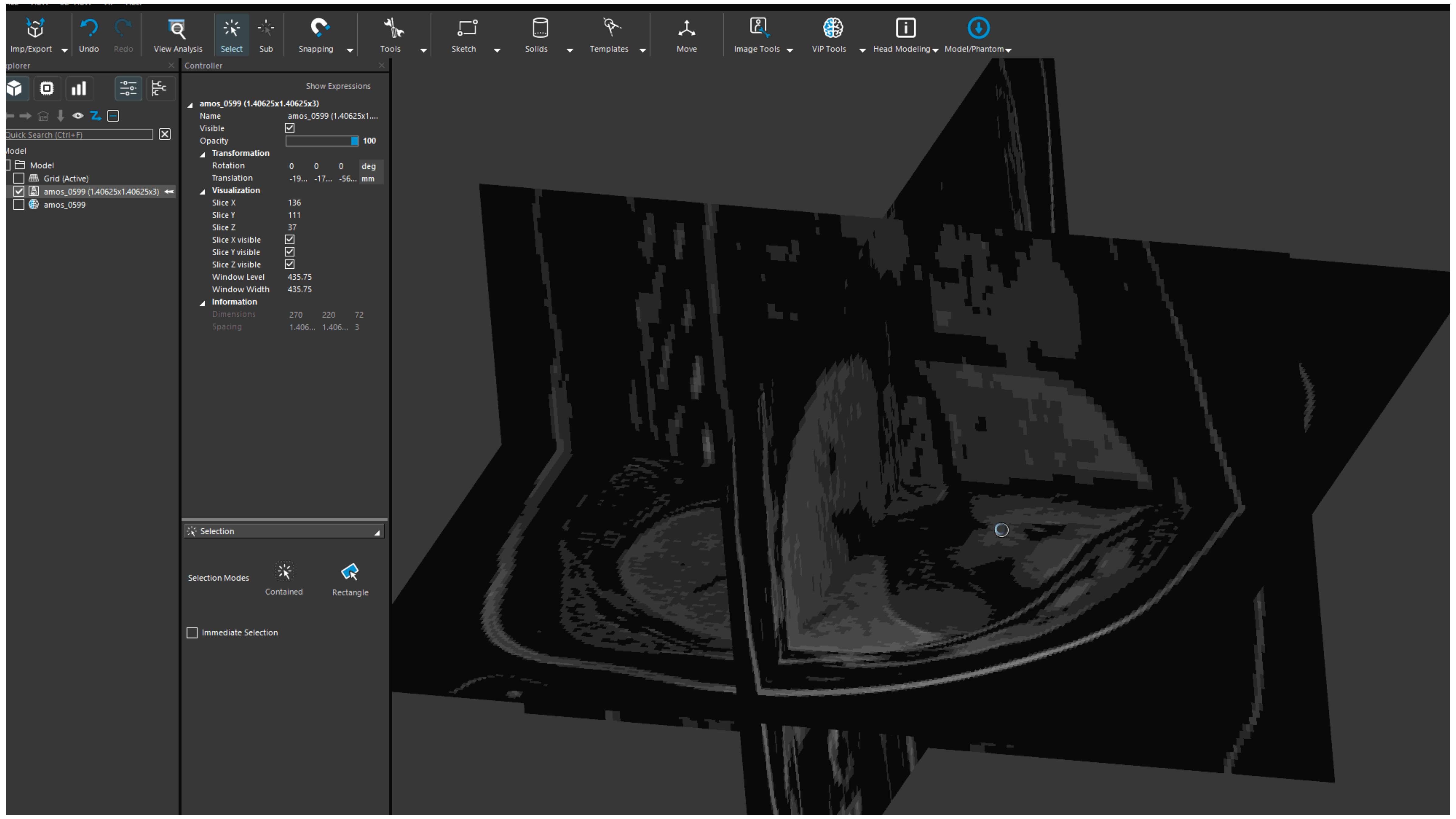
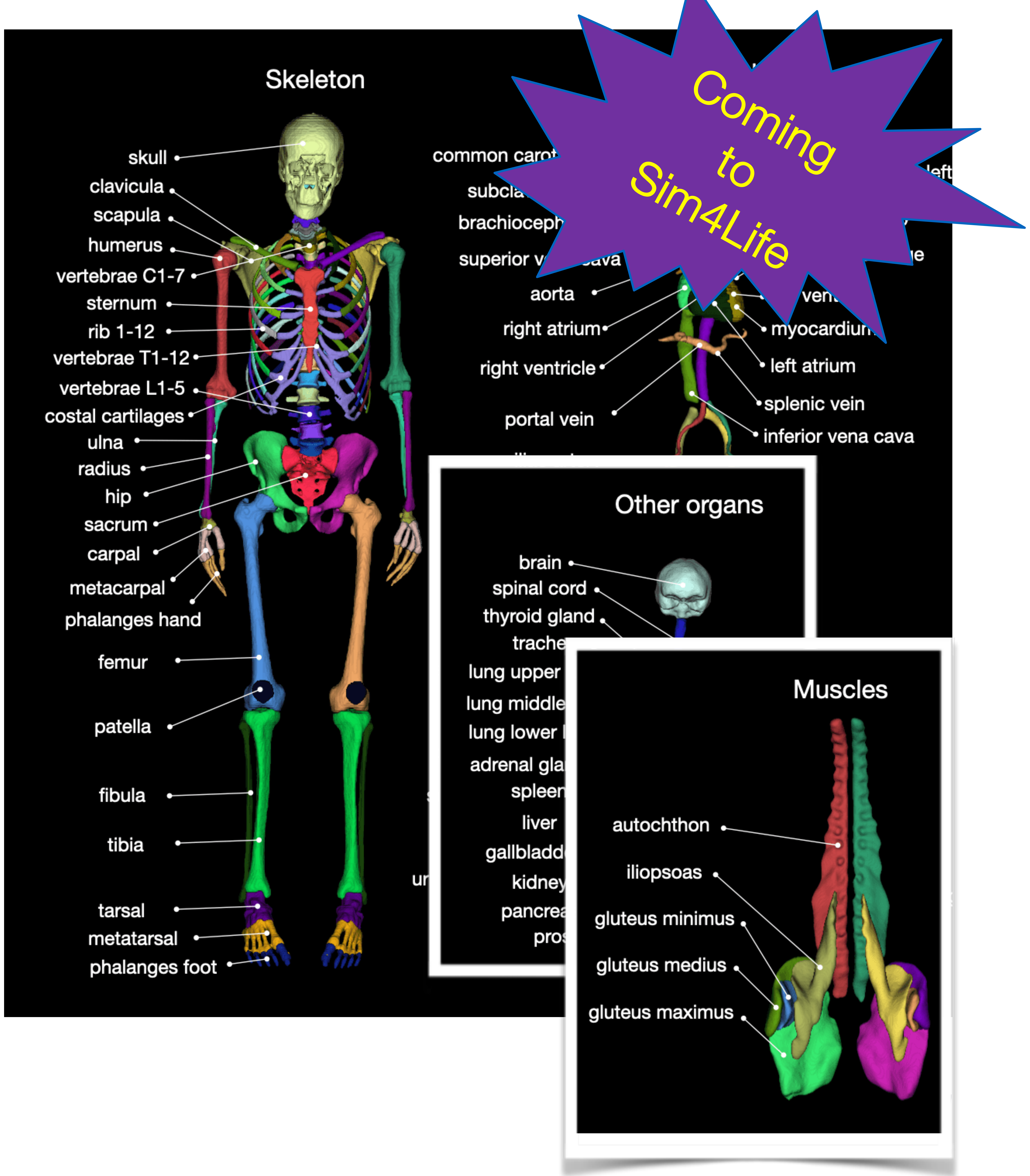
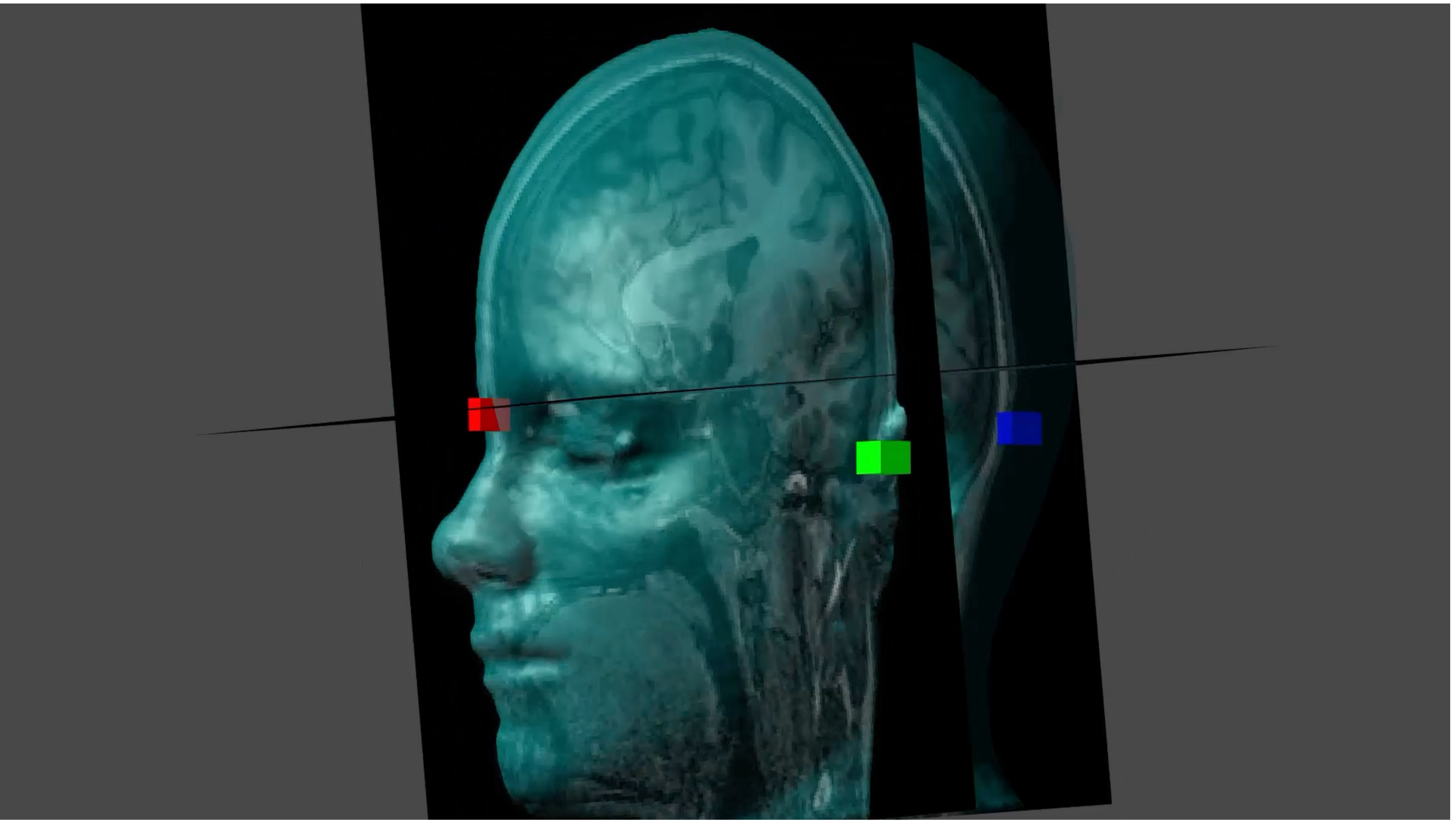
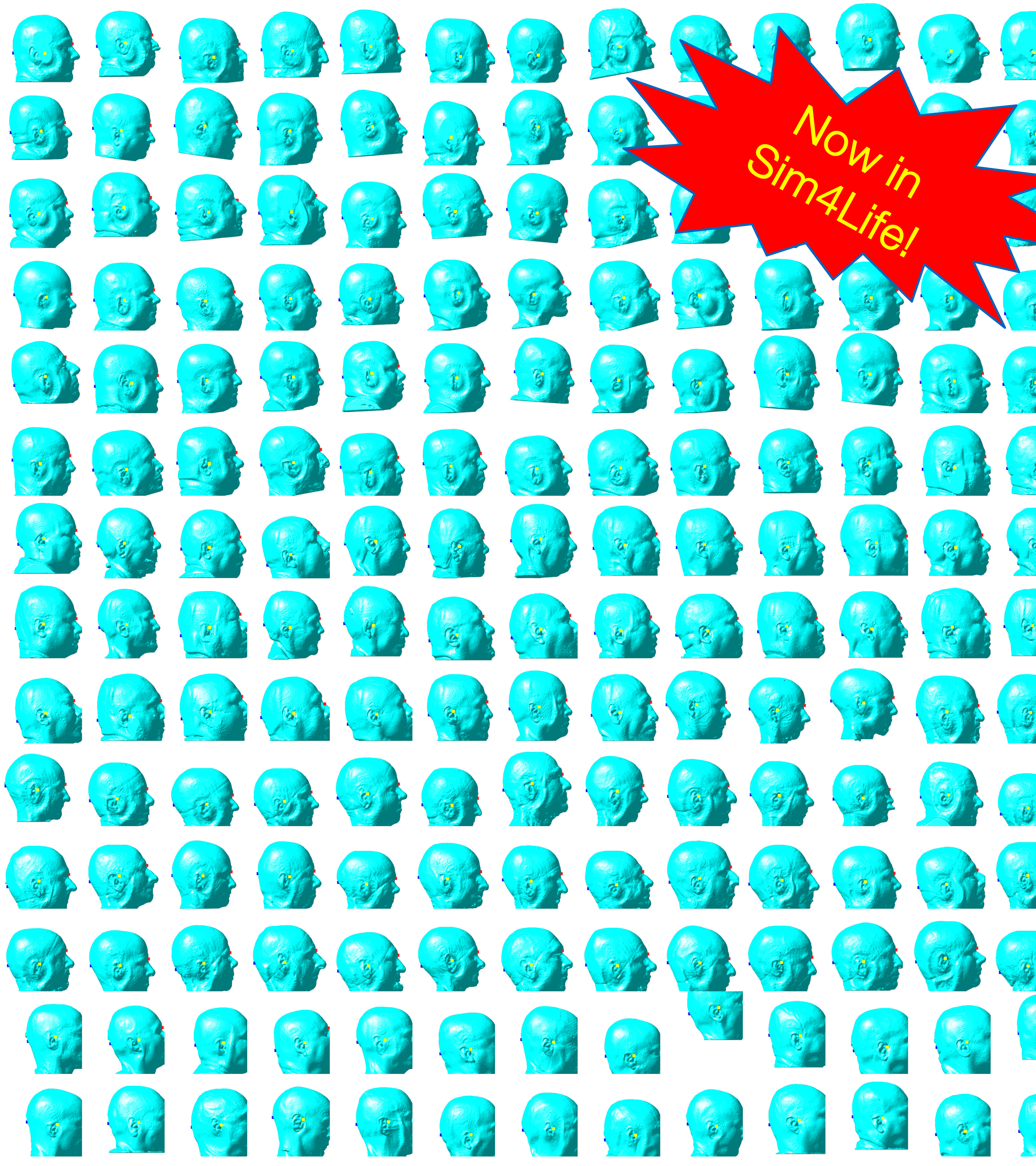




Placing Anatomical Landmarks

- EEG 10-10 system tool (since S4L v7.2)
  - requires users to locate 4 fiducials
  - was not automatic
- AI trained



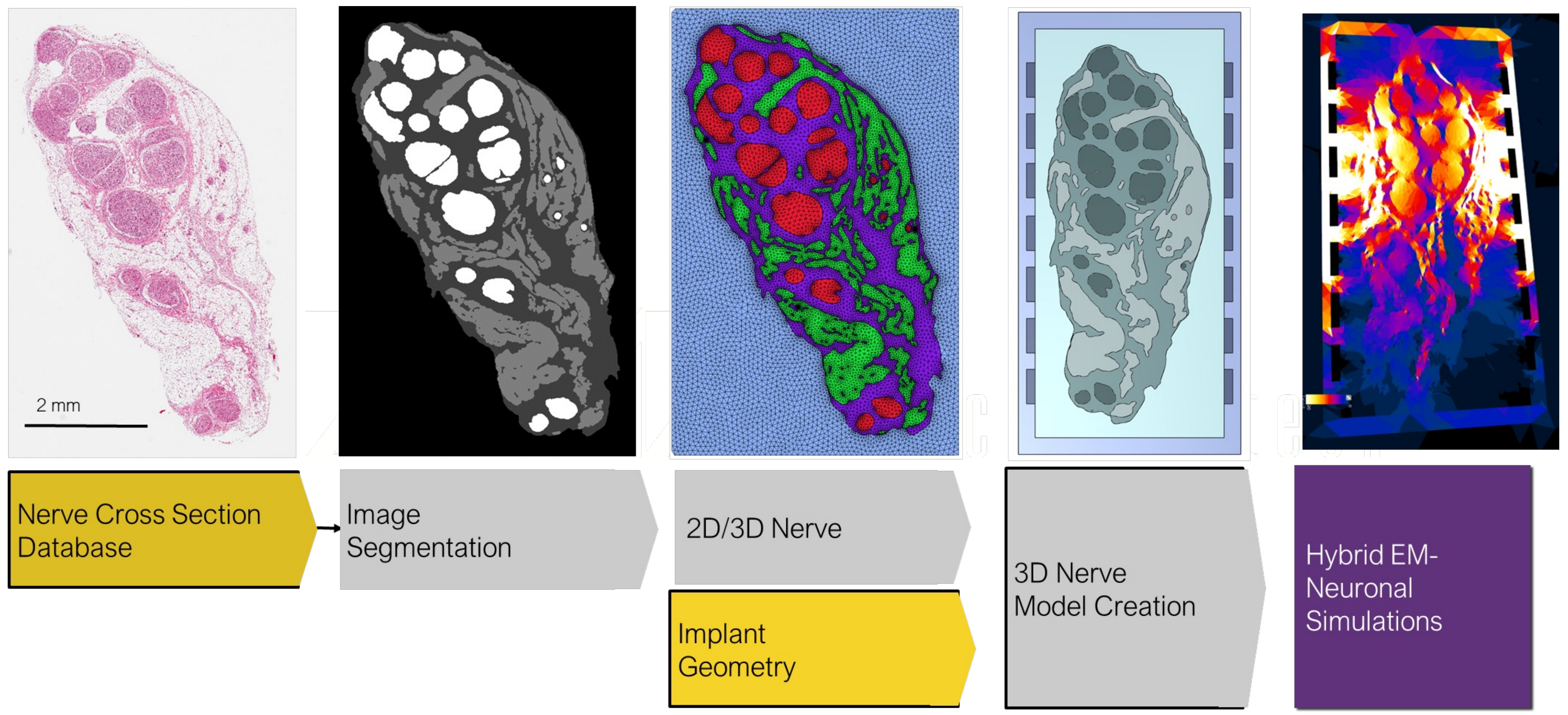


Fast Prediction of Neural Activation

Neural Interface Modeling in Sim4Life

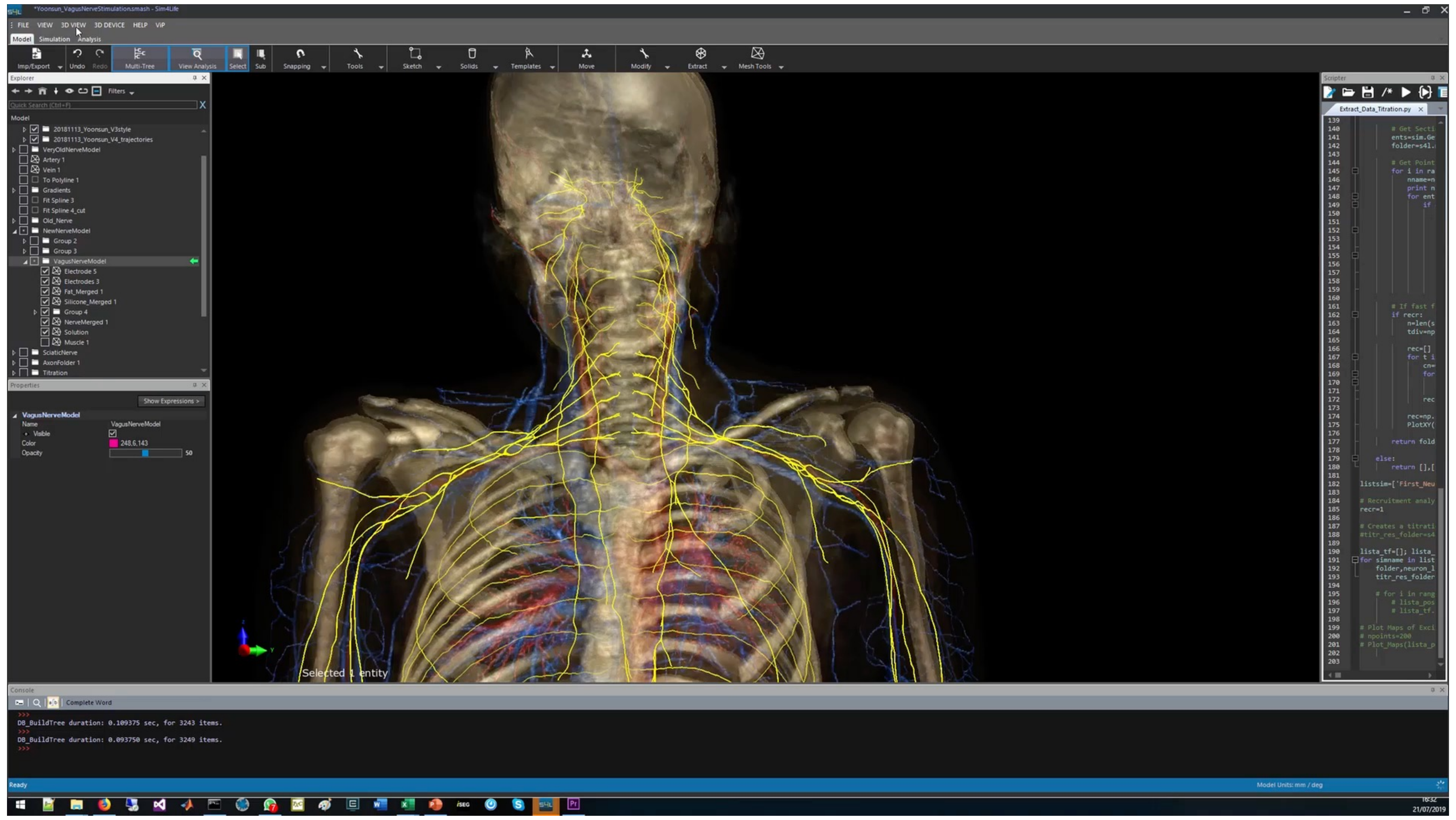
neuroprosthetics and electroceuticals

- electrical stimulation of neural fibers (activation) for therapeutic purposes
- computational simulations: efficient and flexible
- already applied to personalize SCI therapies (Rowald et al., 2022) and drive bioelectronics research at PNS level (Gupta et al., 2020)



coupled EM-NEURON simulations

- electromagnetic (EM) simulations predict the electric field distribution in the patient's model
  - therapeutic effects
  - safety investigation
  - electrode design & stimulation optimization
- electrophysiological (NEURON) simulations predict the effect of the EM exposure on neural fibers
  - accurate modelling (based on Yale's NEURON)



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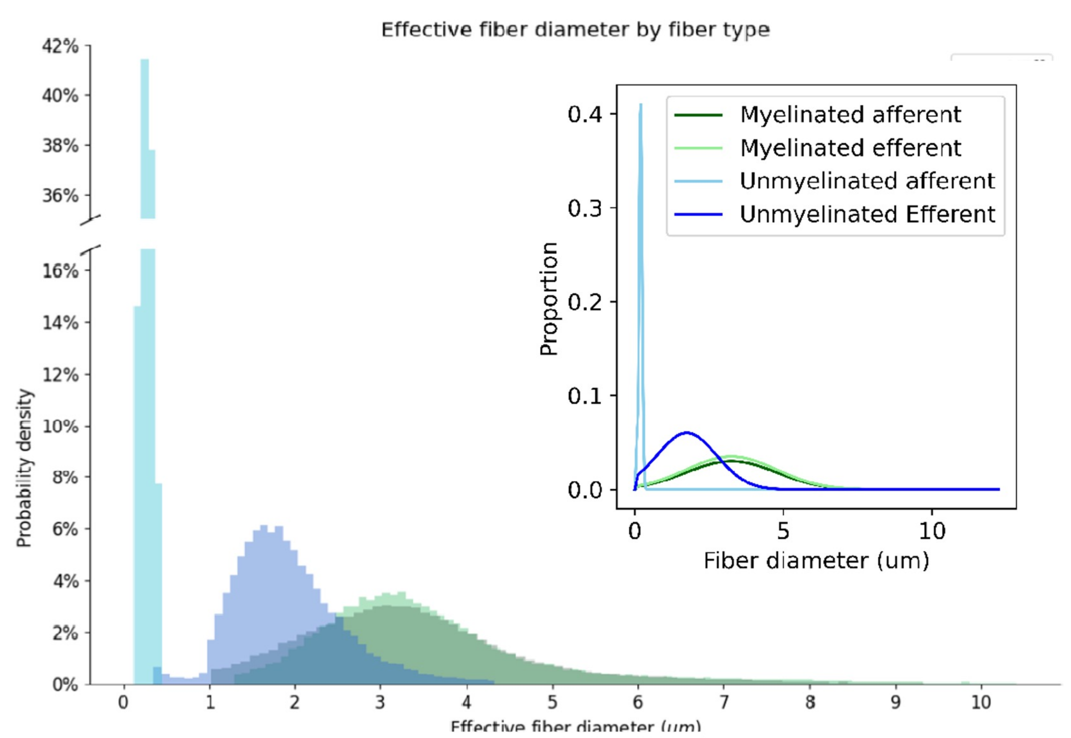

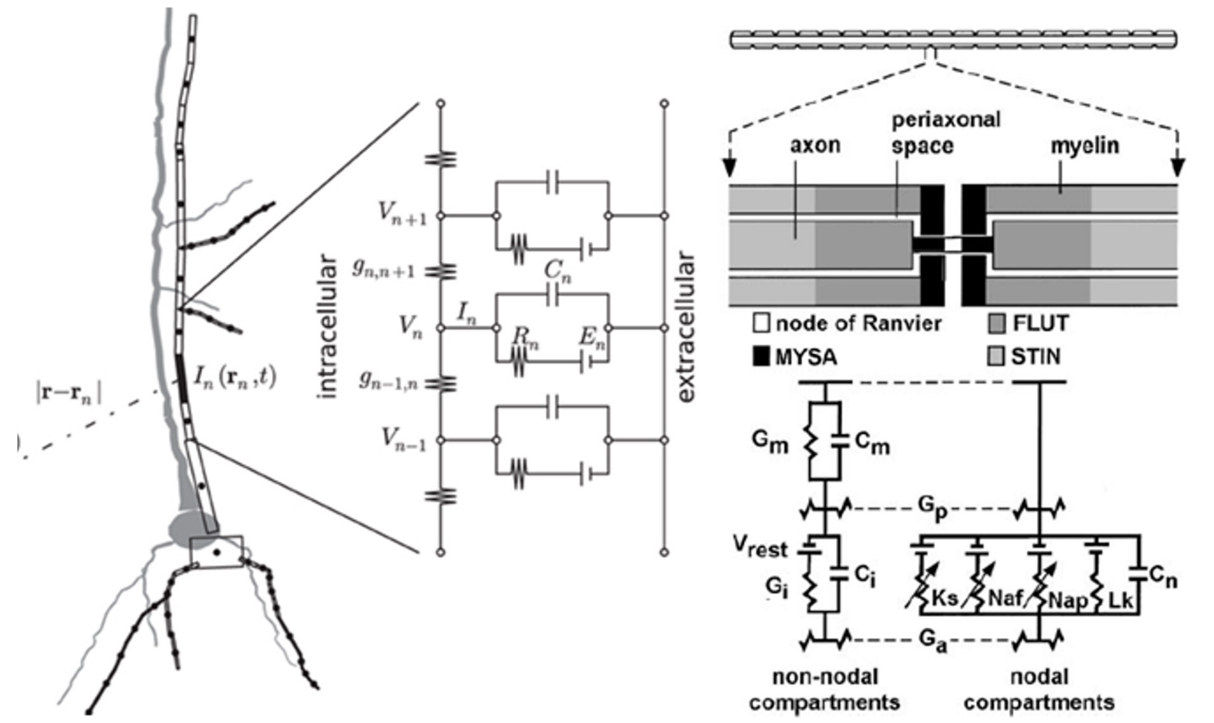

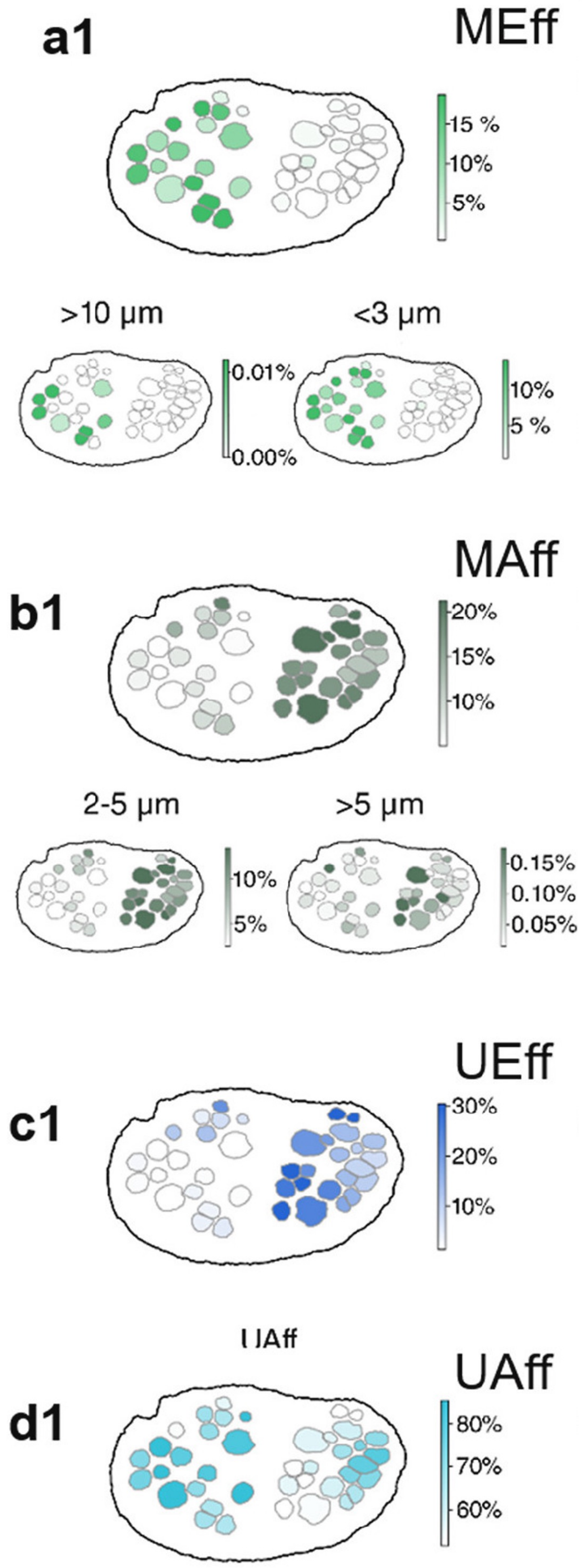

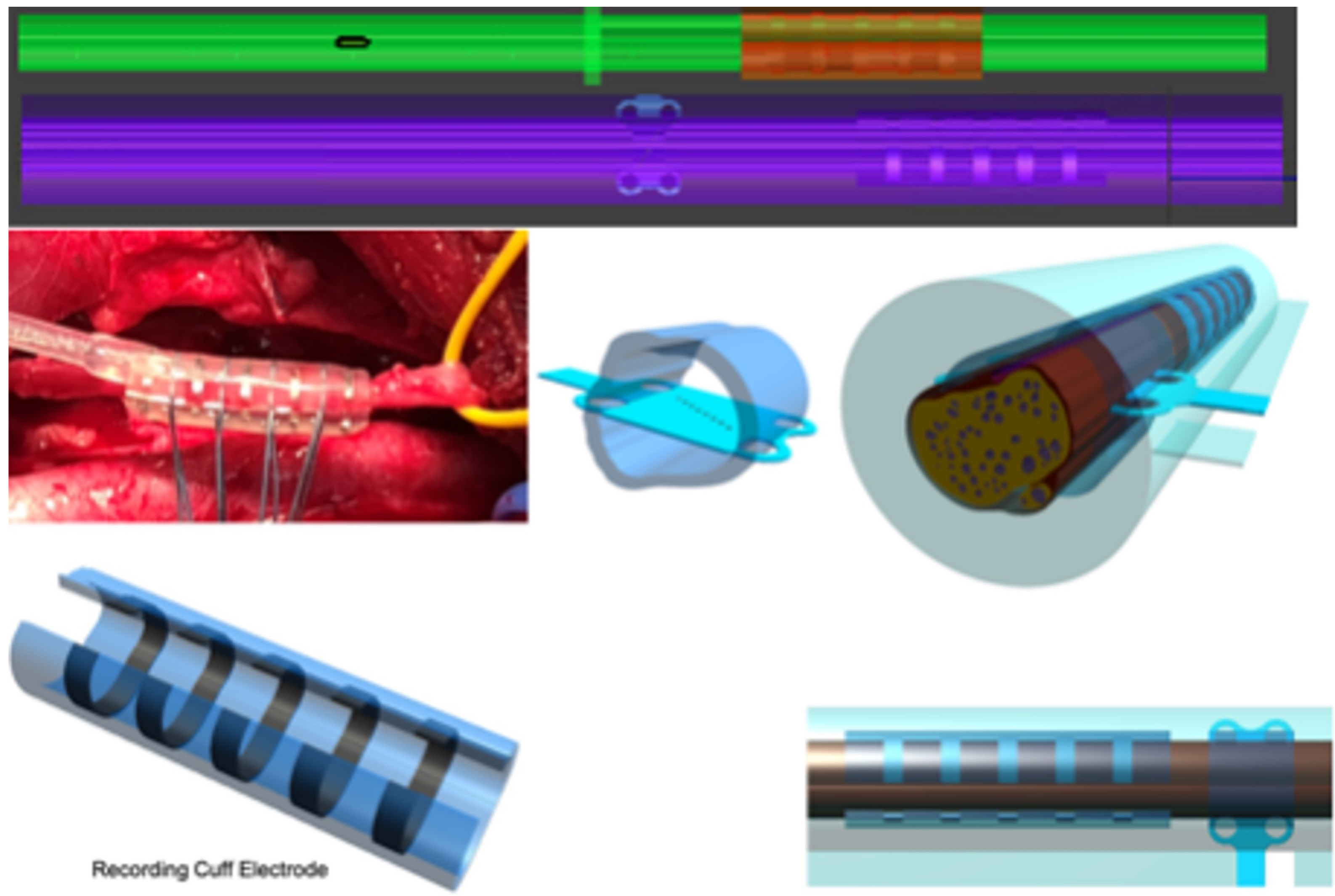

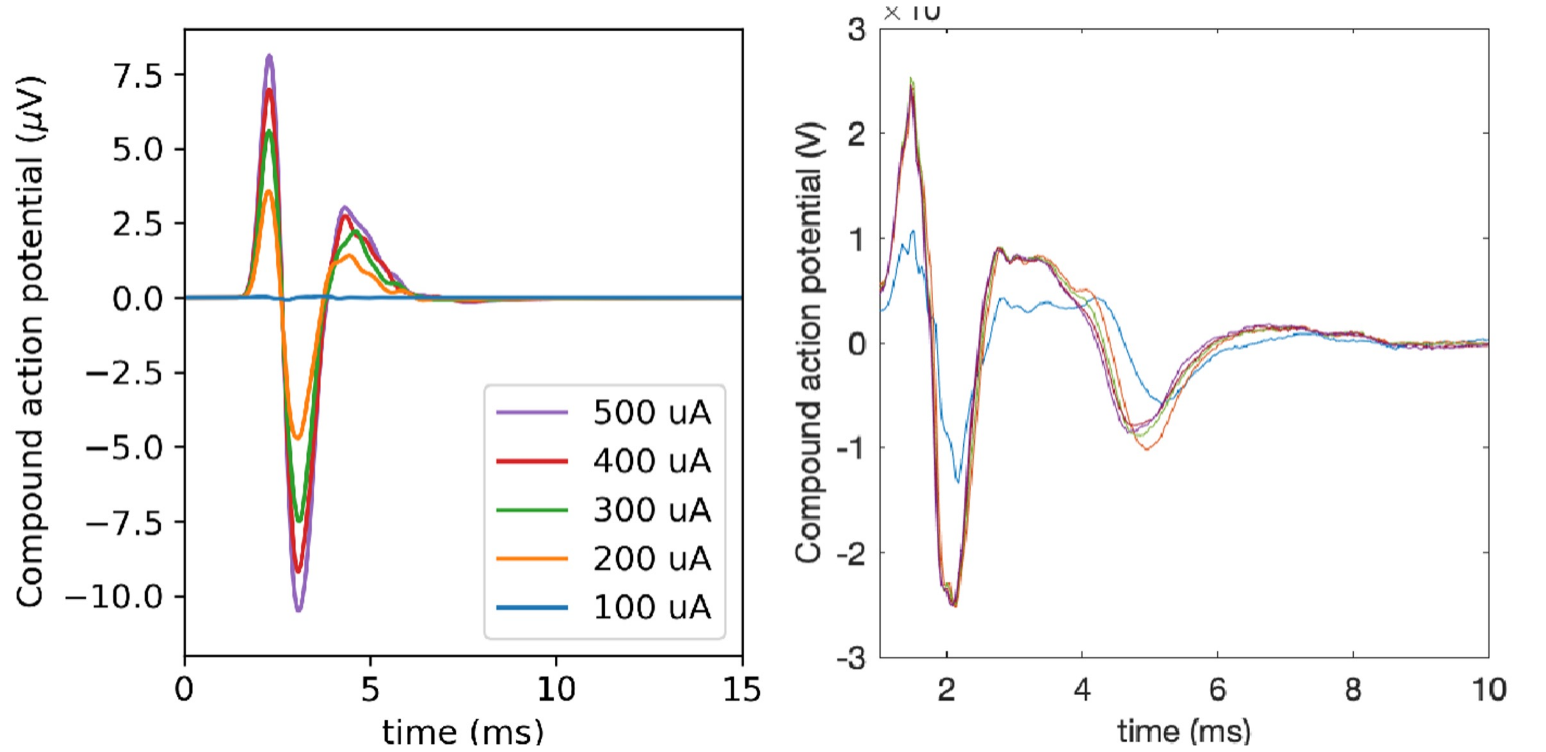

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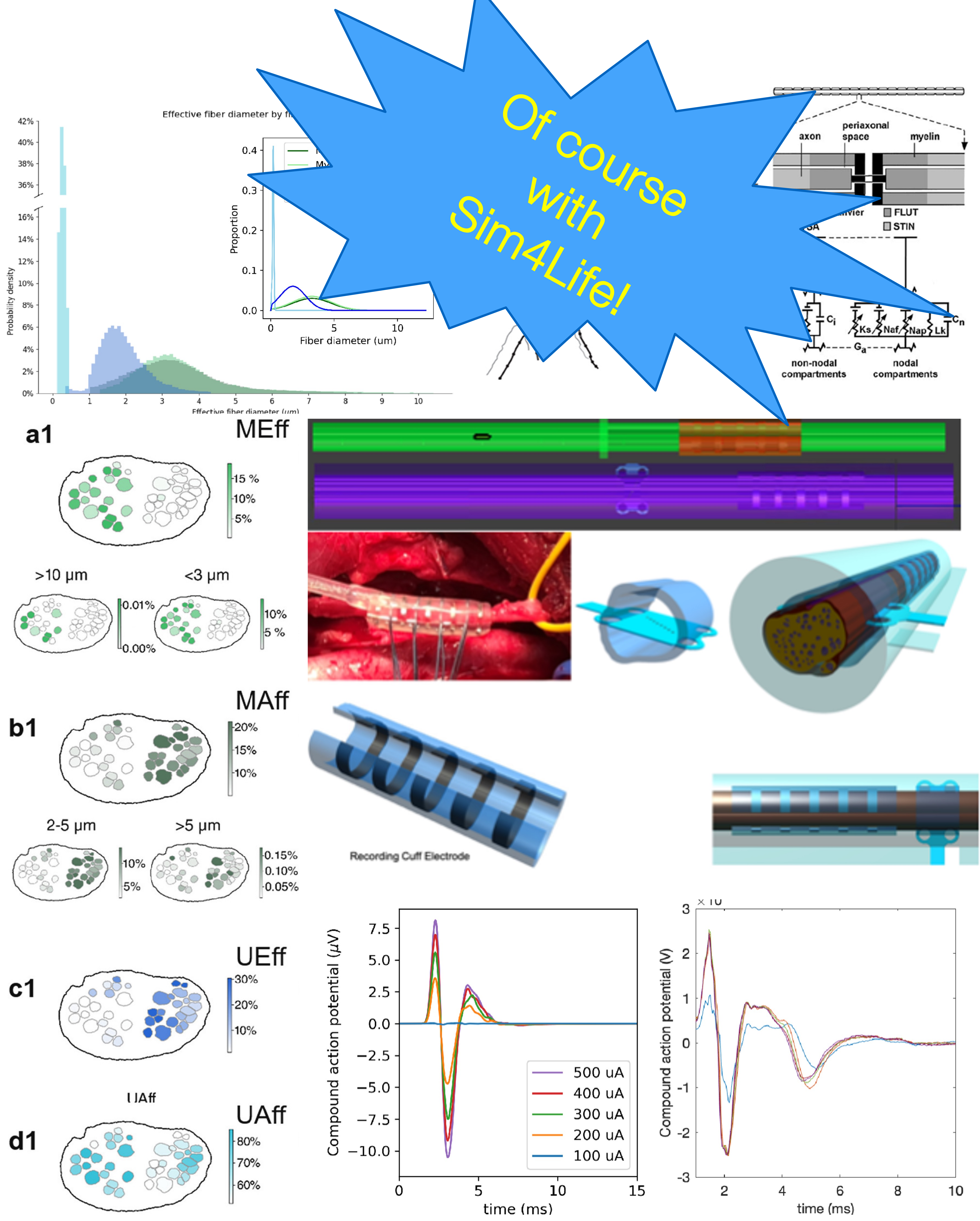

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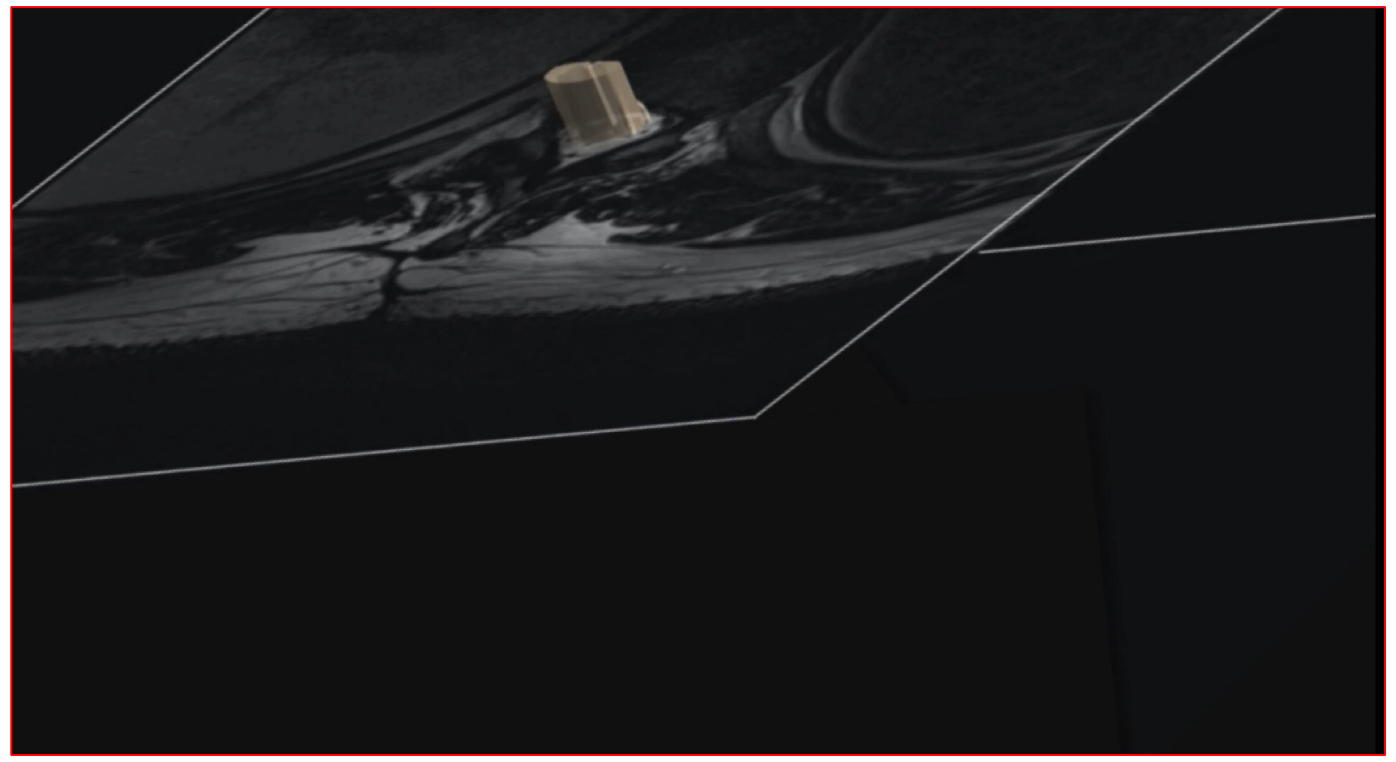

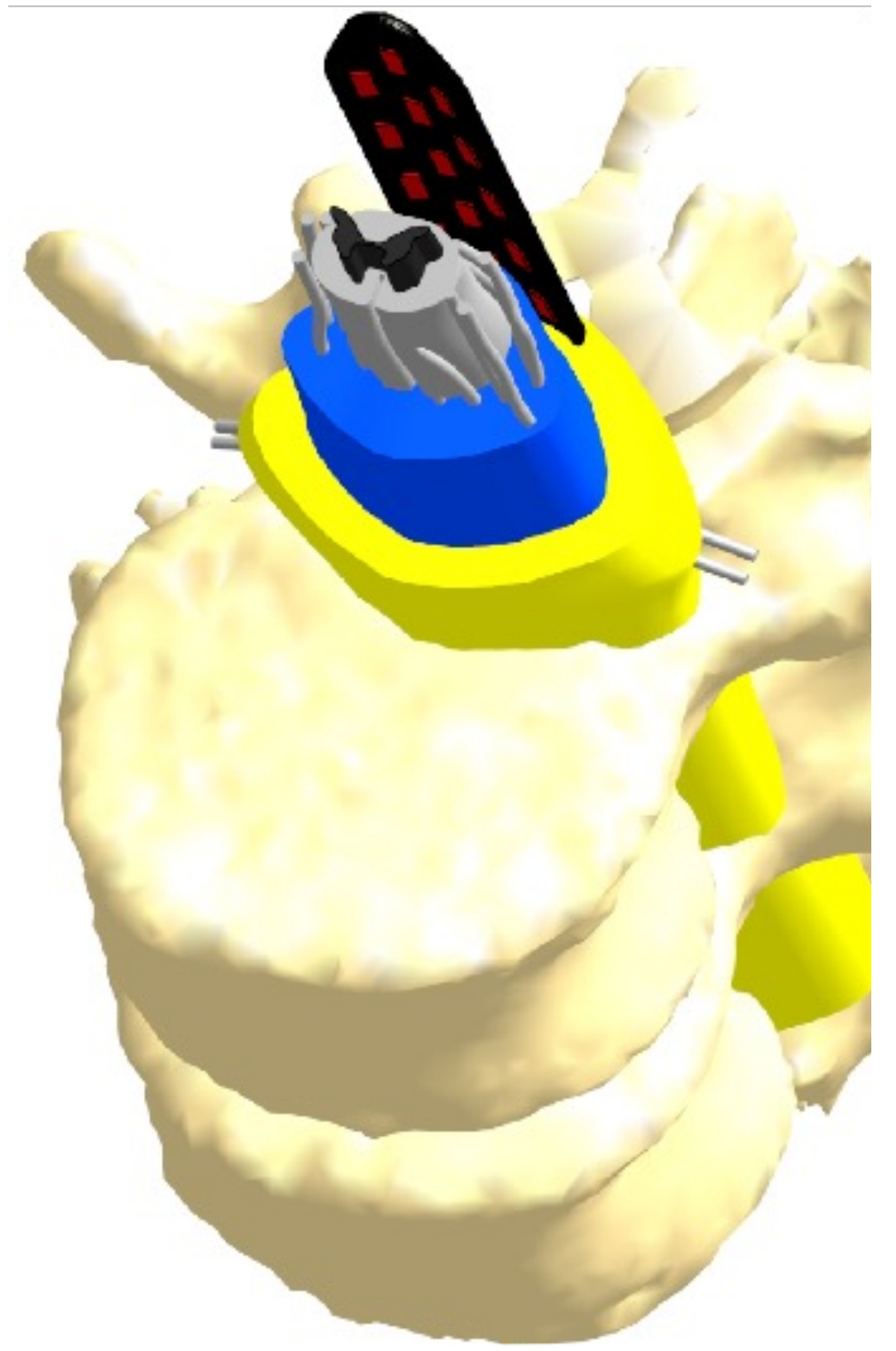

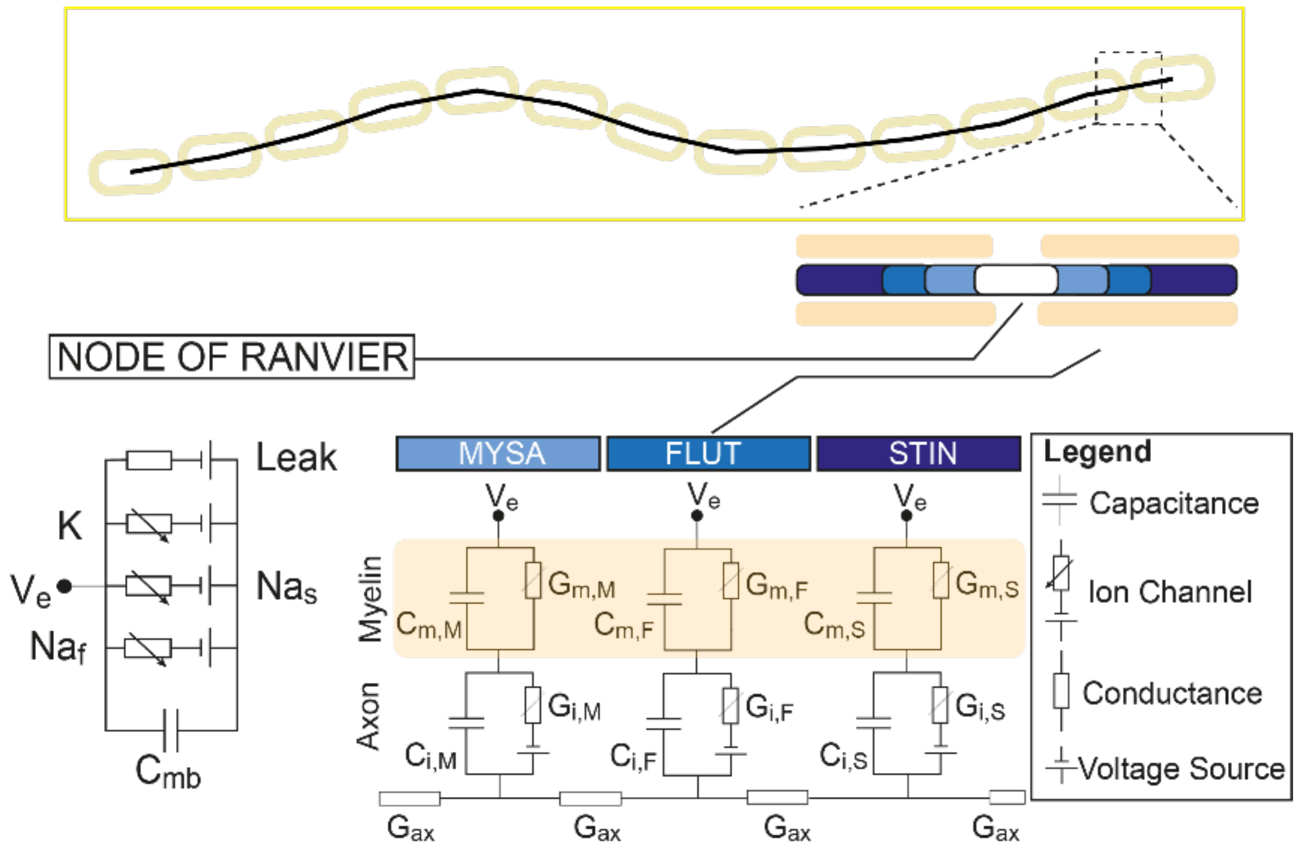

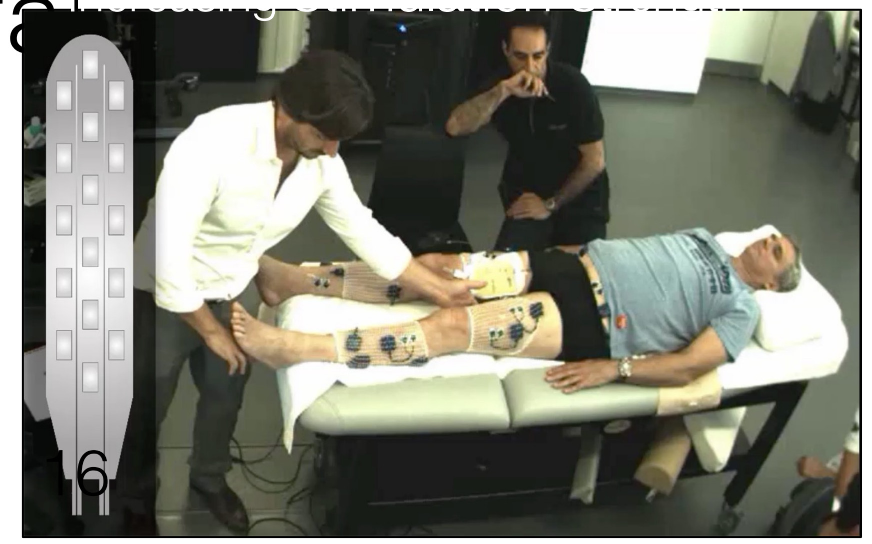

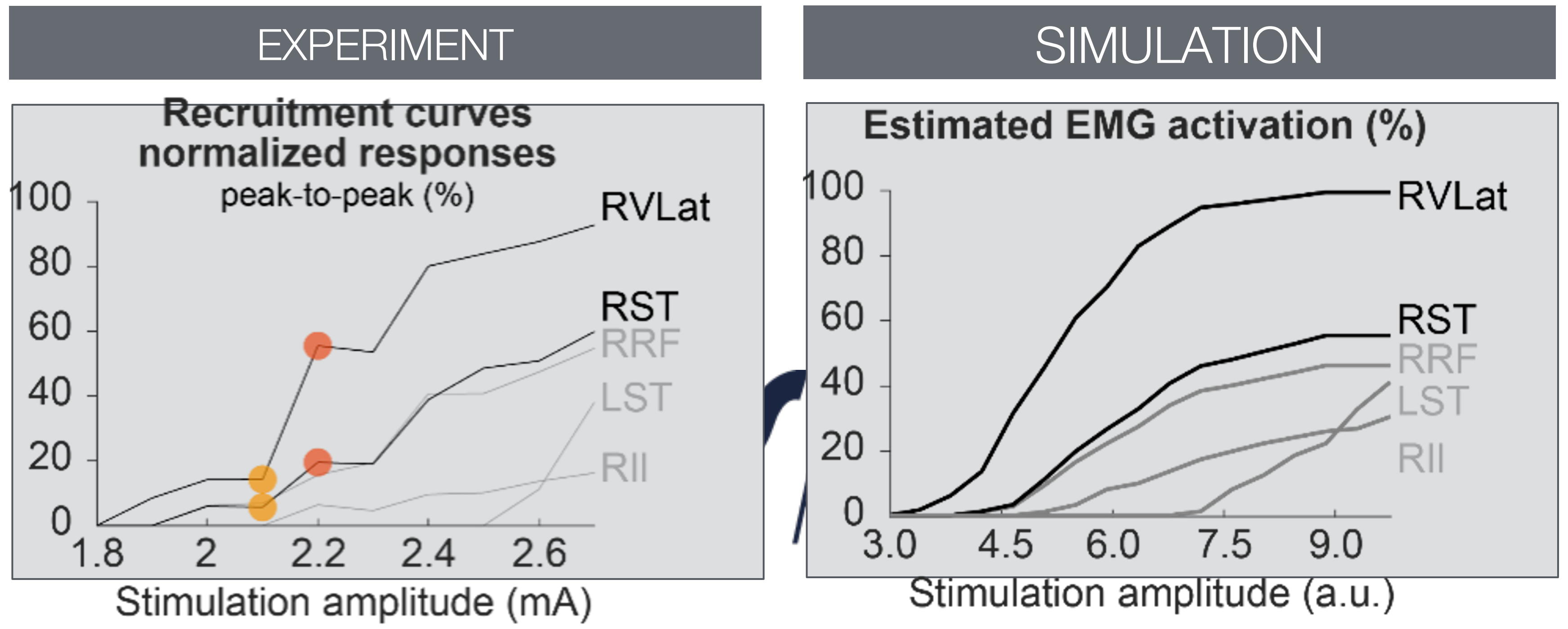

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- electr ON) simulations predic e EM exposure on neura fibers
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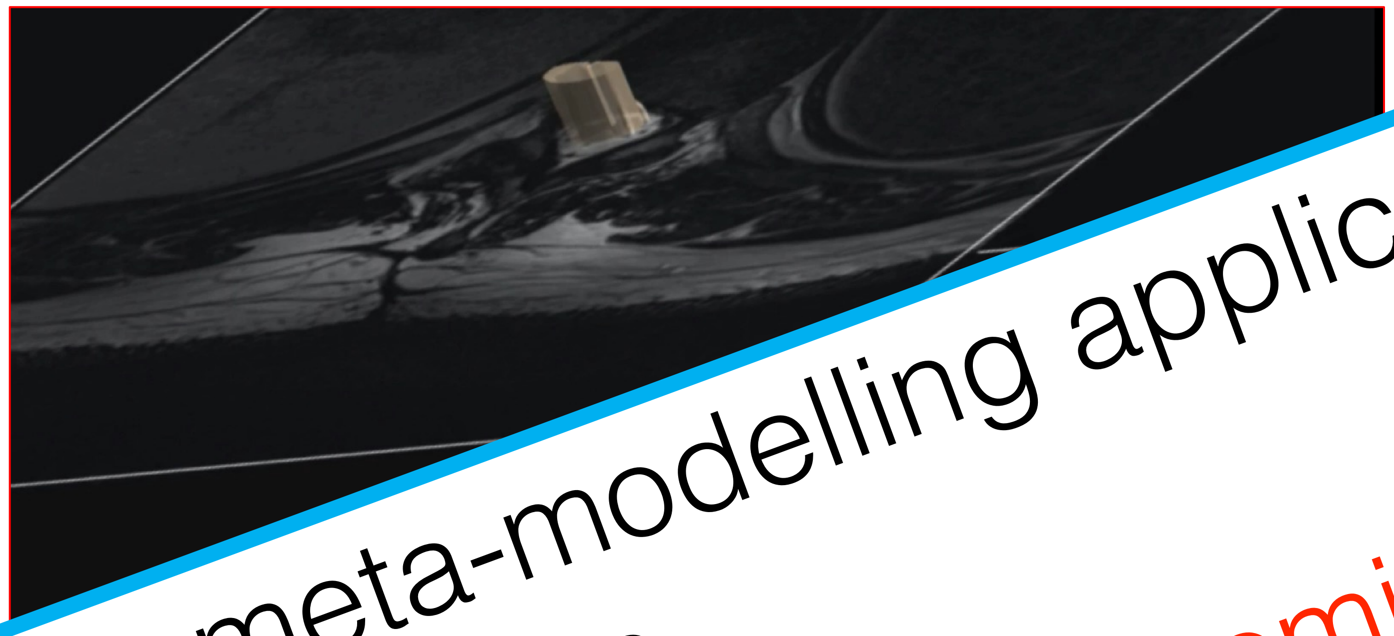
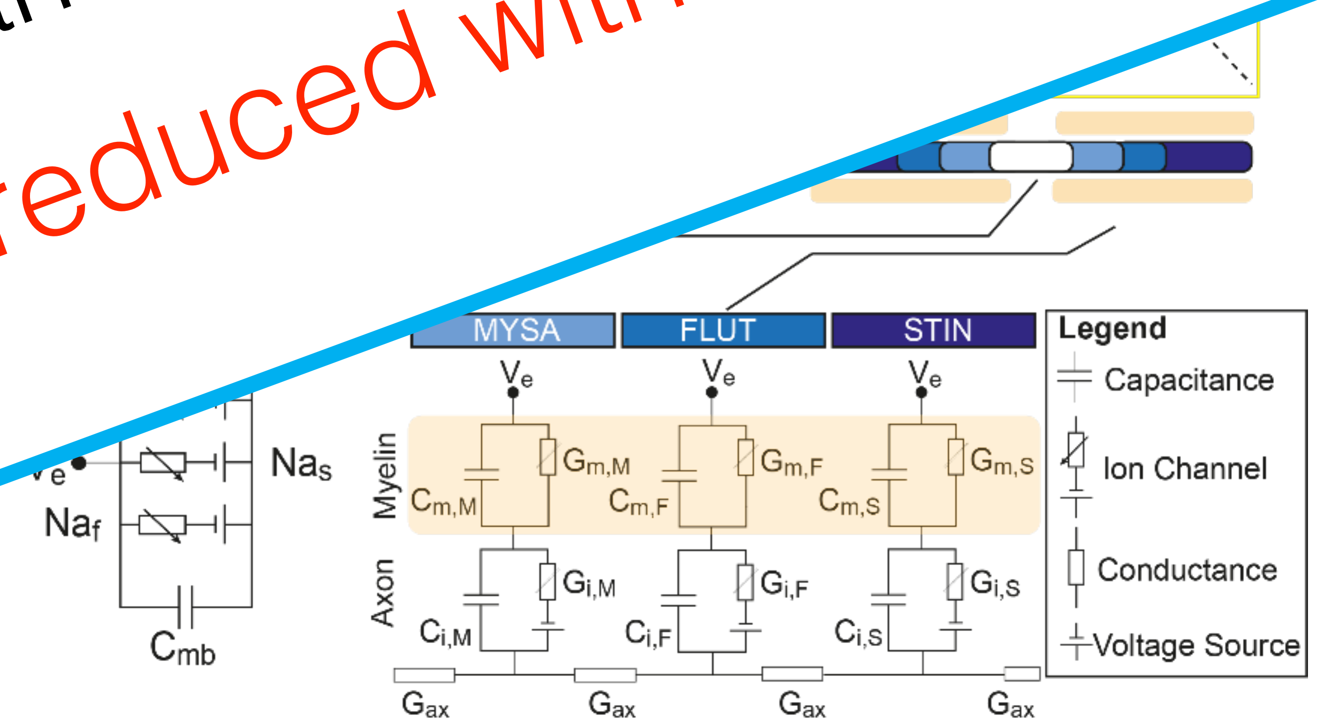
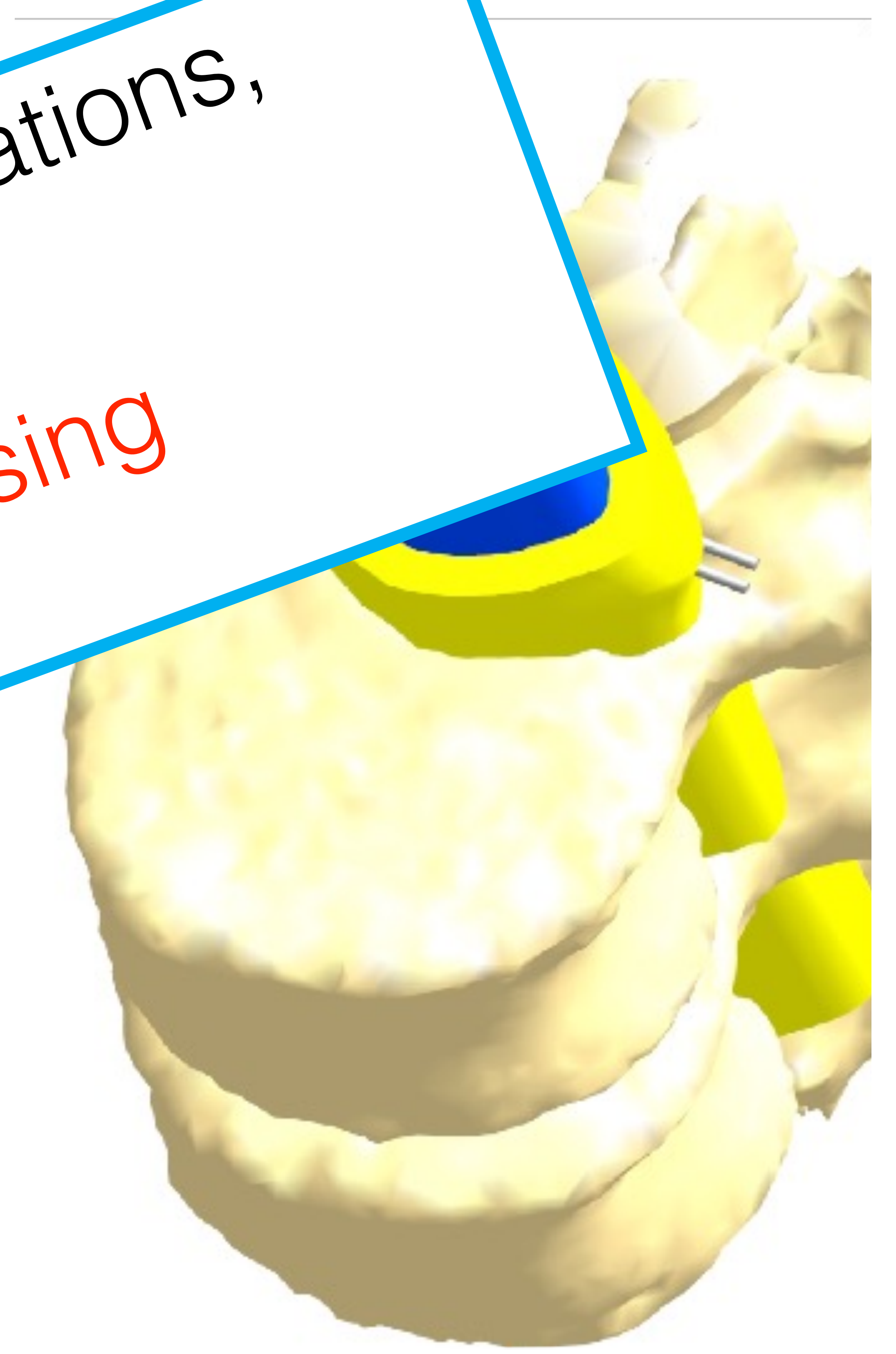
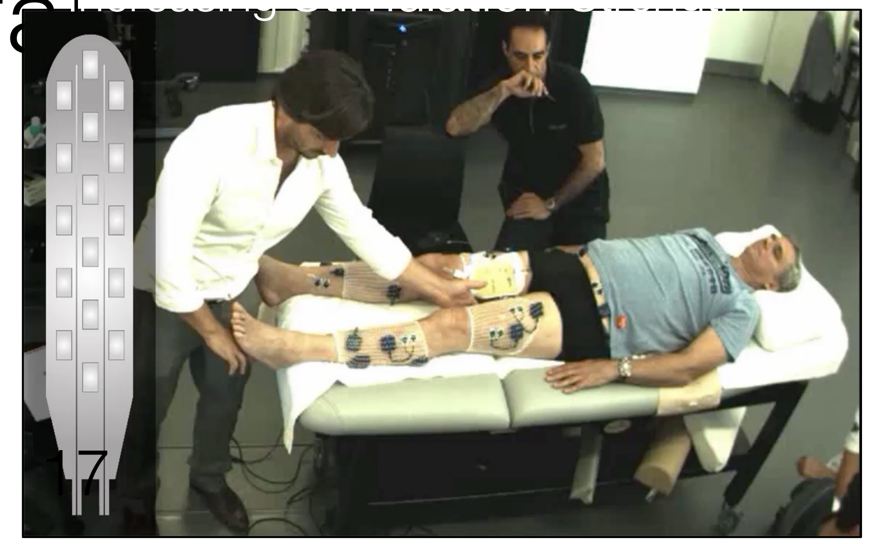
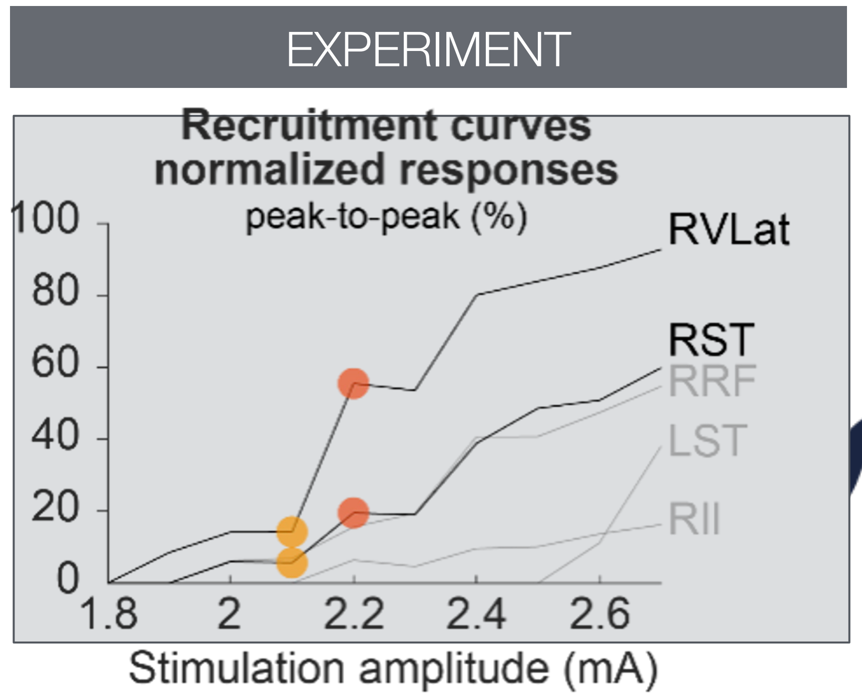
- but: computationally too expensive for meta-modelling applications, such as optimization in large parameter space
- how can computational cost be reduced without compromising accuracy?

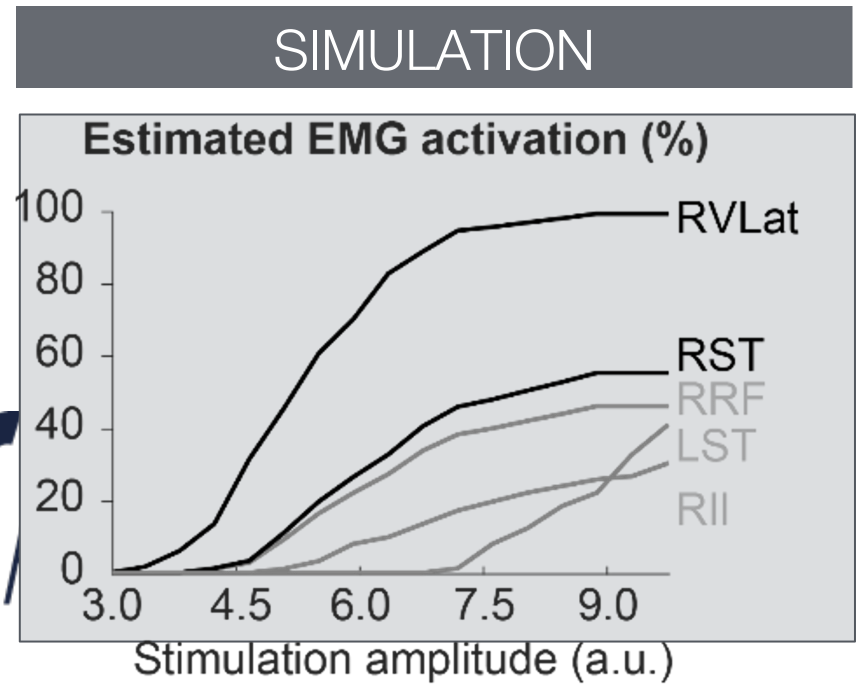










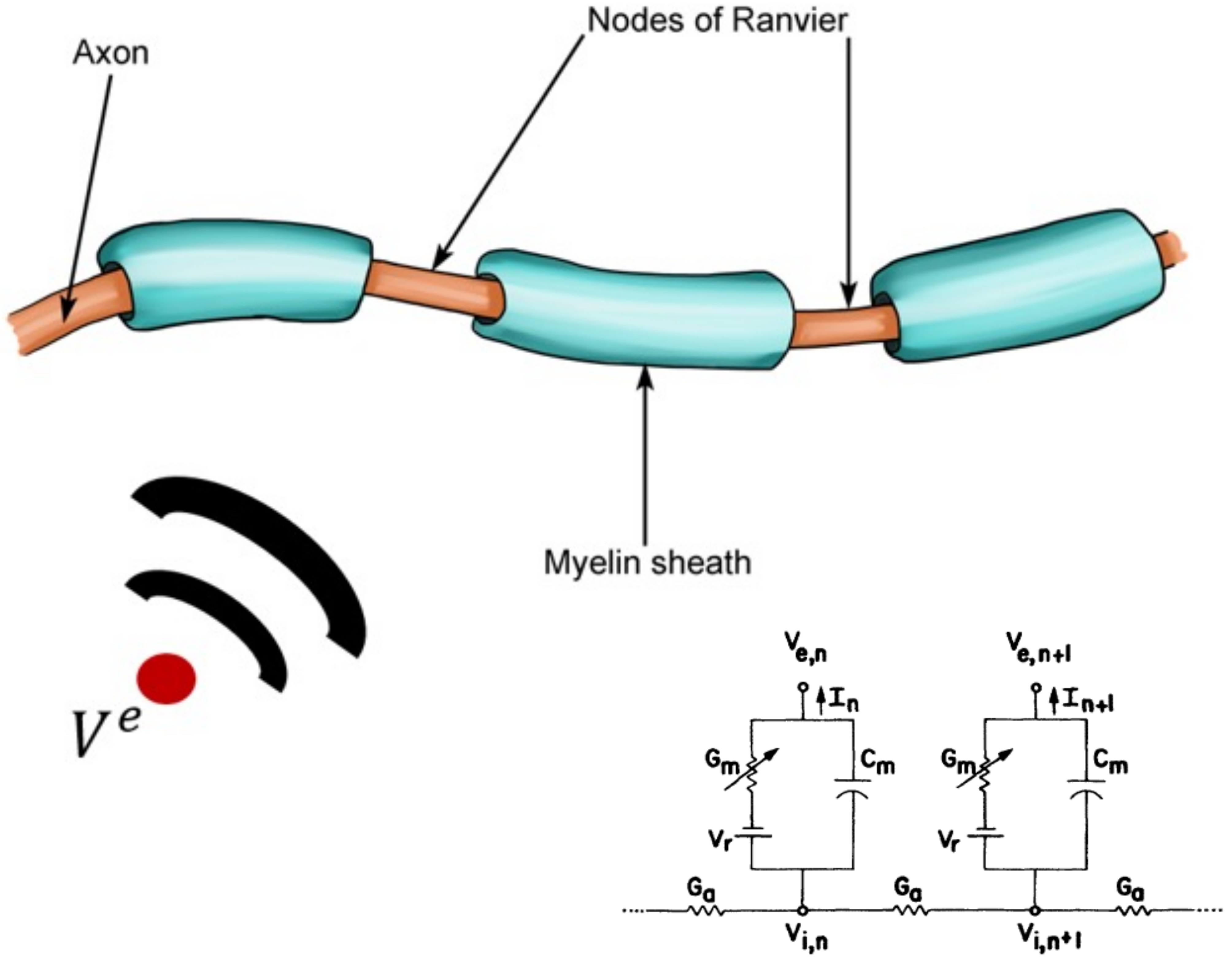


Classic Activating Function

- lateral currents (externally induced)

- simple, fast to compute
- linear on extracellular potential (superposition principle applicable)

- but
  - no leakage,
  - no axial diffusion
  - not suitable for complex fiber models (multi-cable, periaxonal spaces, paranodal elements...)



Rate of change | Ion | Lateral displacement (propagation) | Lateral displacement (due to external potential)

$$C\frac{dV_n}{dt} = I_{ion} + \frac{V_{n+1}-V_n}{R_a} - \frac{V_n-V_{n-1}}{R_a} + \frac{V^e_{n+1}-V^e_n}{R_a} - \frac{V^e_n-V^e_{n-1}}{R_a}$$

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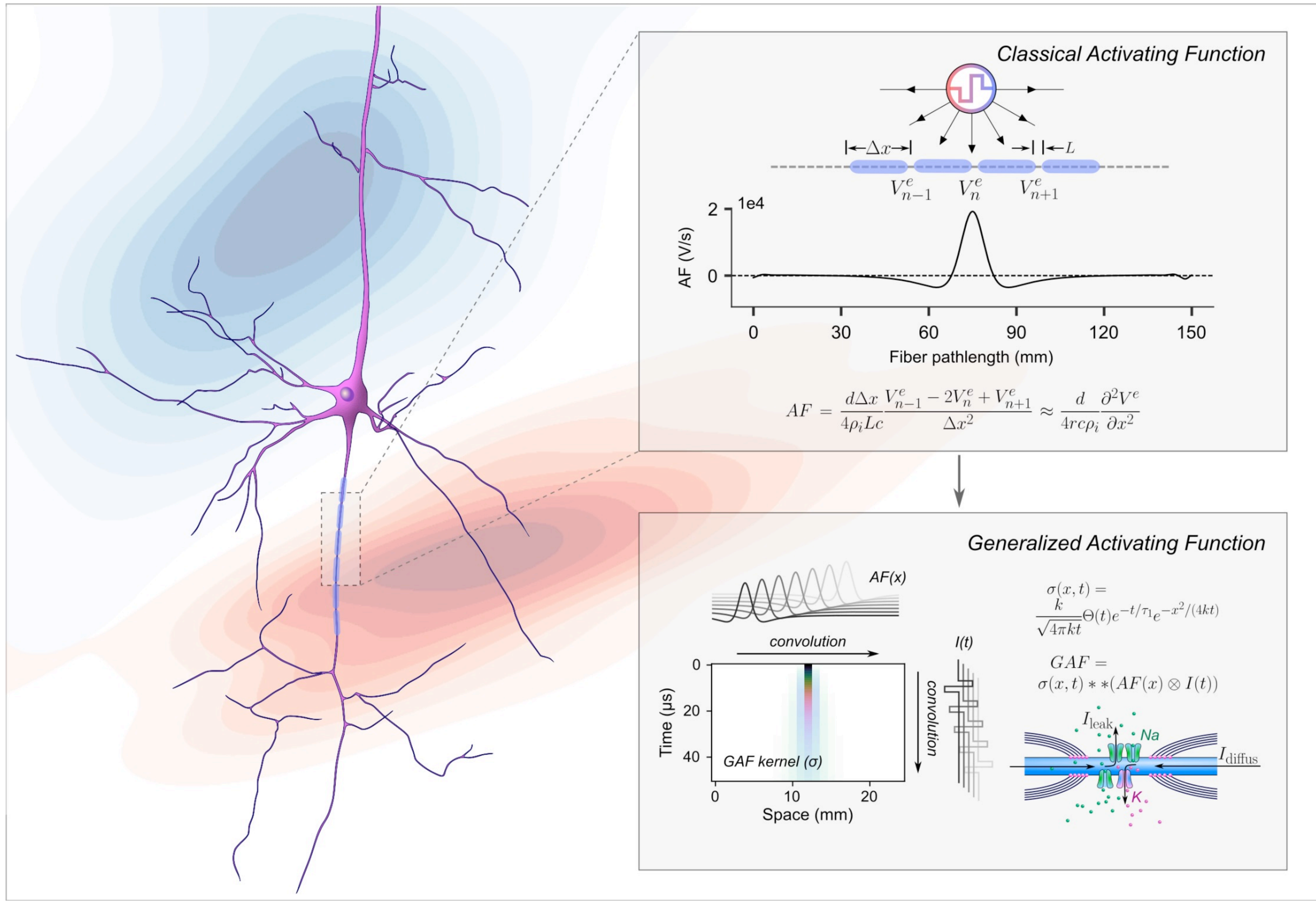
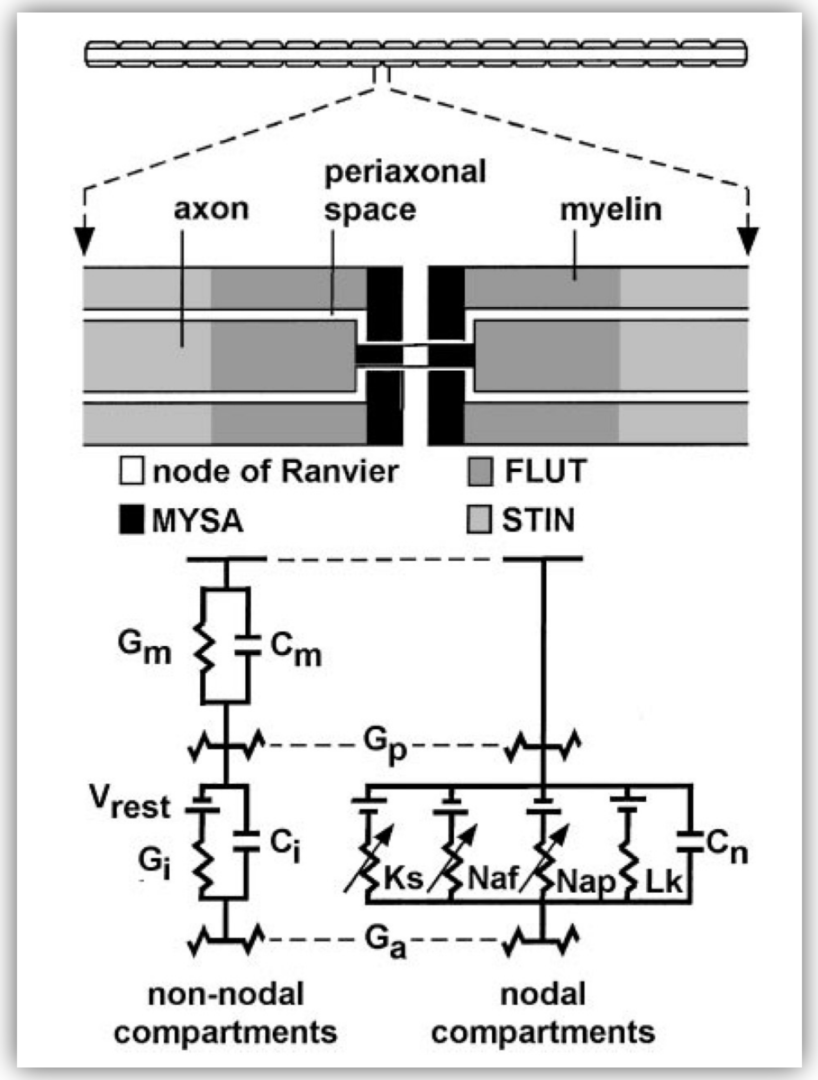
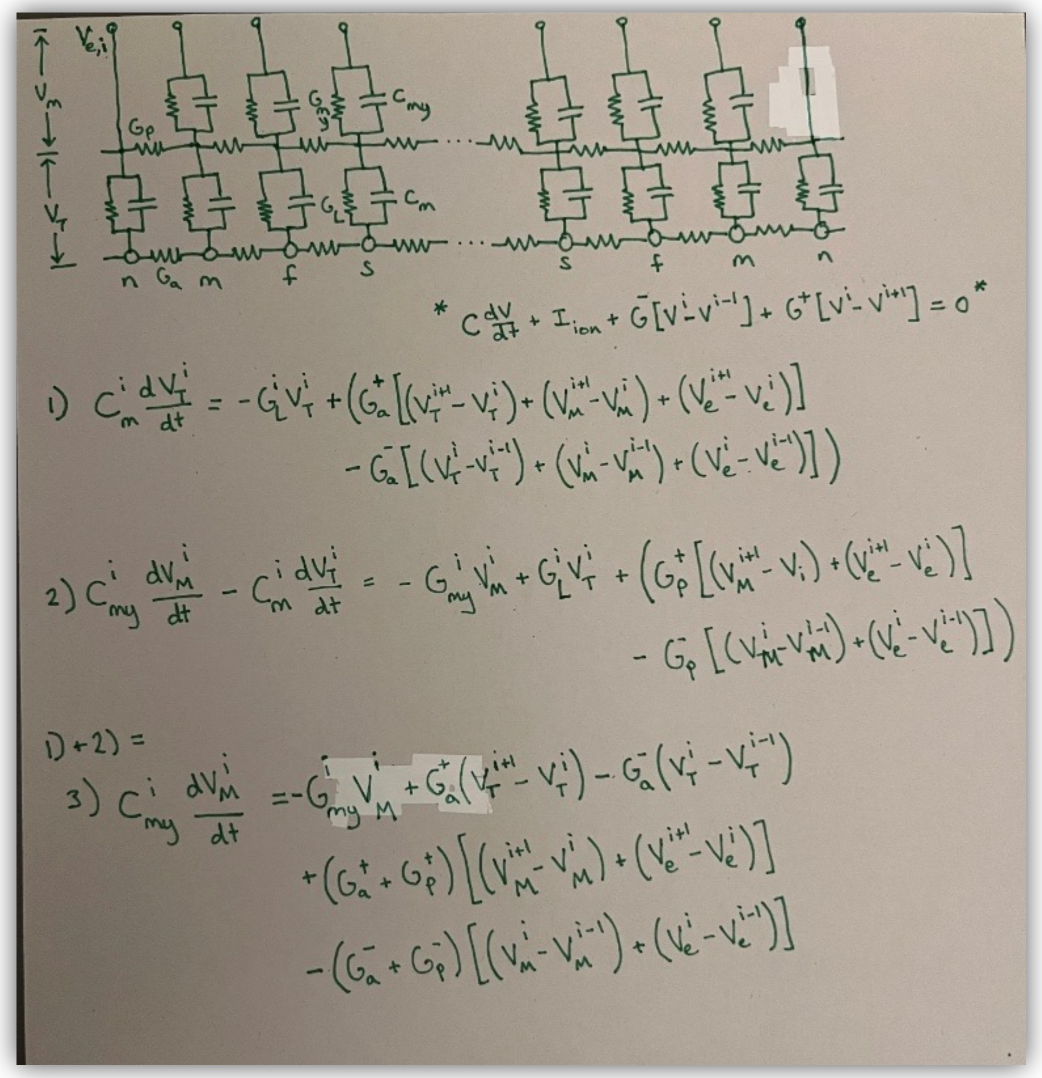
(Generalized) Activating Function

generalized activating function

- lateral currents (externally induced)
- lateral currents (propagation)
- ionic currents (leakage only)
- simple, fast to compute (10^2 faster than NEURON)
- linear on extracellular potential (superposition principle applicable -> 10^5 faster than NEURON)
- suitable for optimization in large parameter spaces
- generalizable to more realistic fiber models, such as MRG (double-layered, heterogeneous)
- capable of predicting spinal root recruitment







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