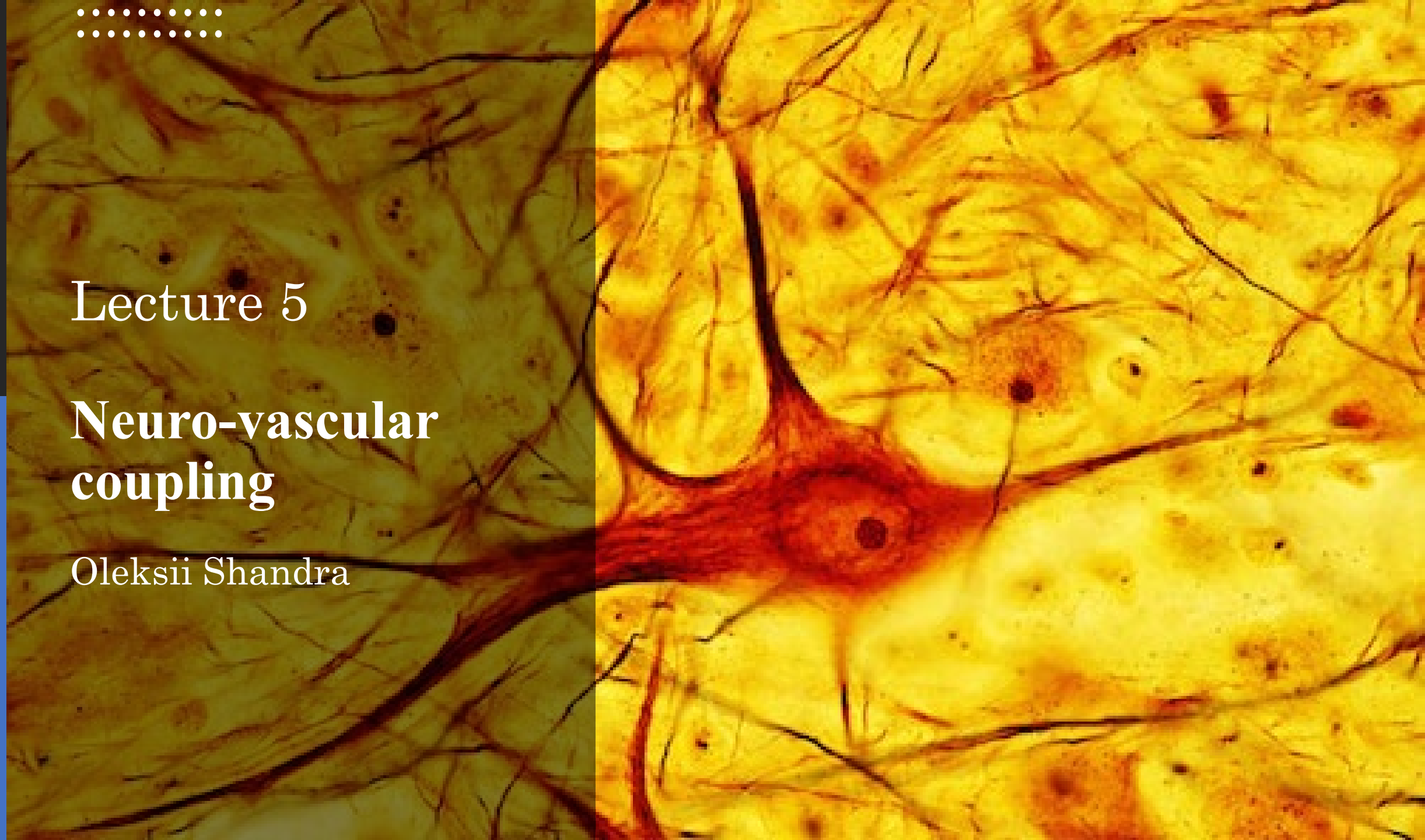
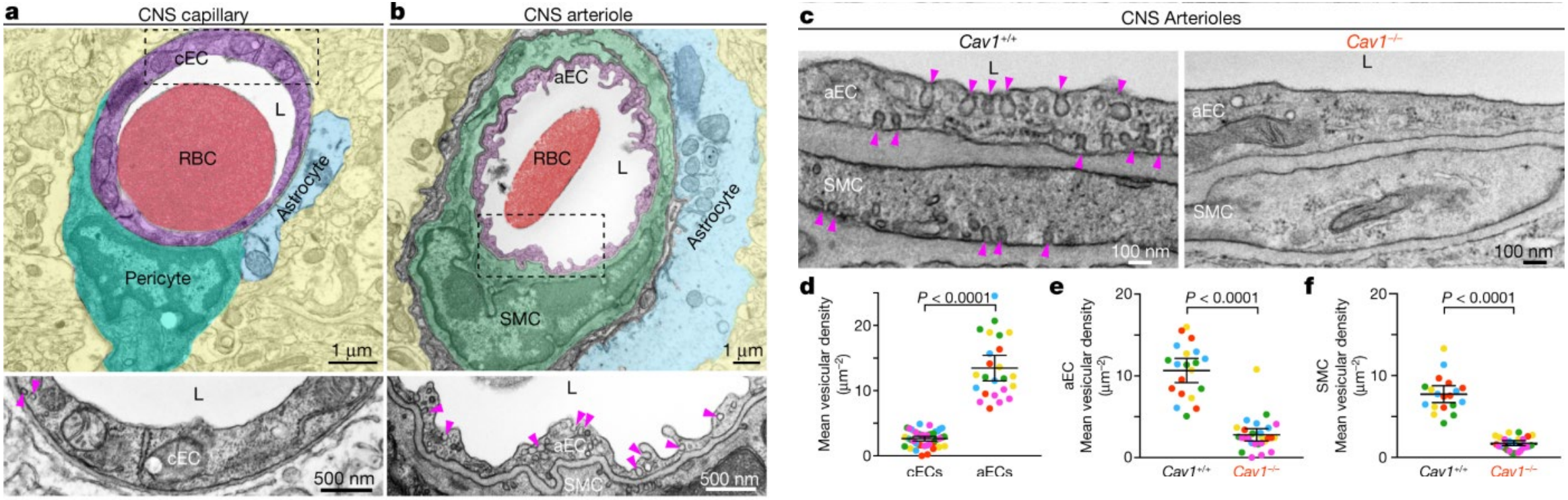


Lecture 5

Neuro-vascular coupling

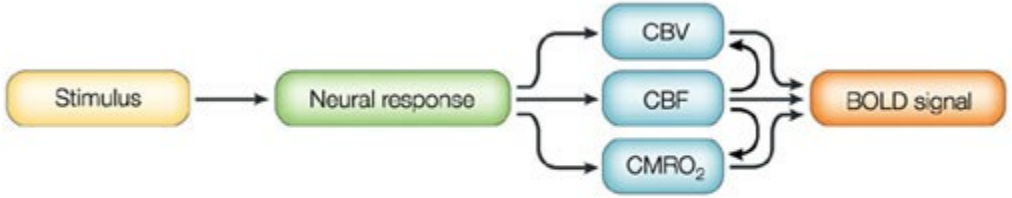
Oleksii Shandra

Neuro-vascular coupling

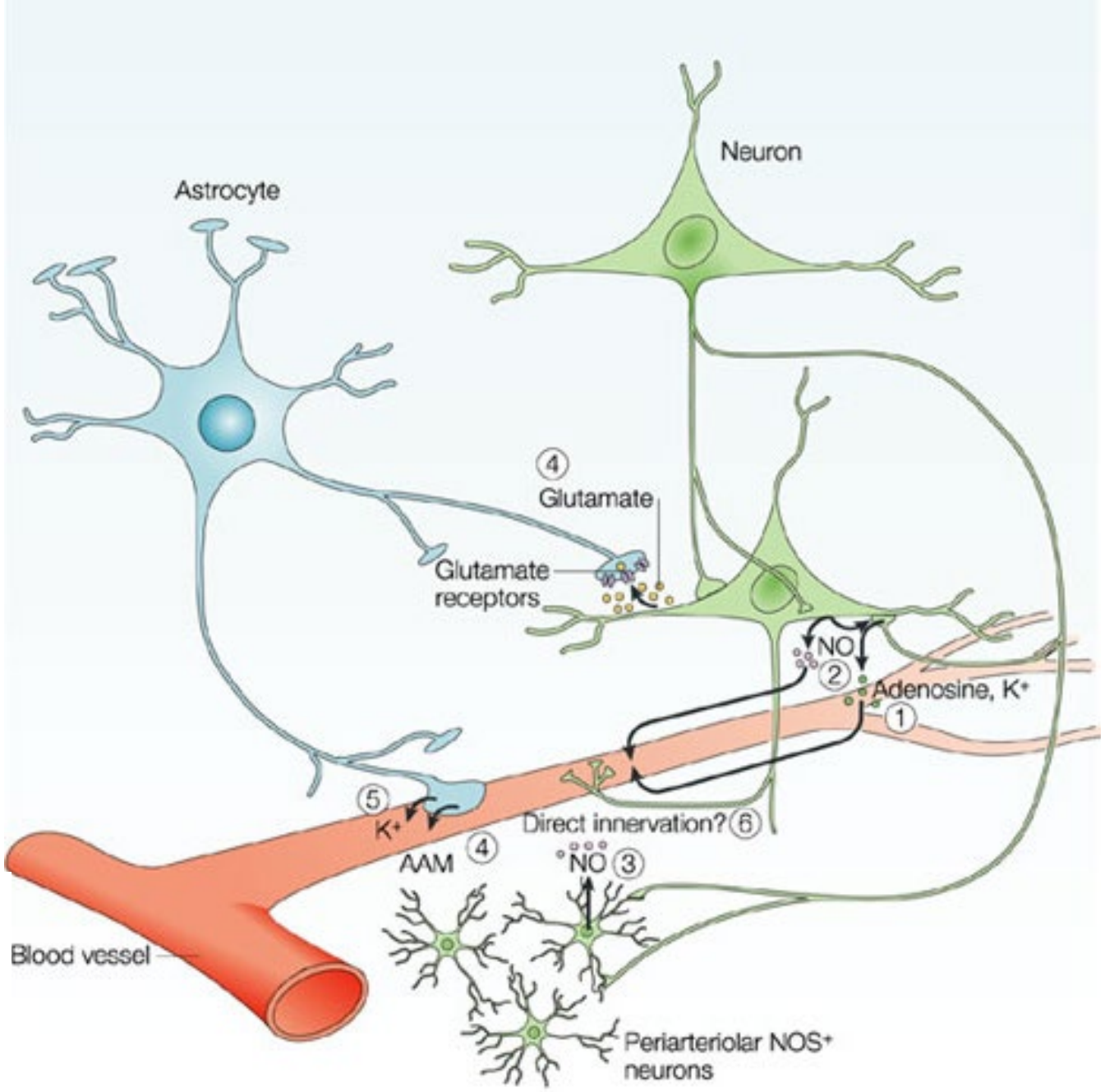


Bernardo L. Sabatini & Chenghua Gu, 2020 Nature

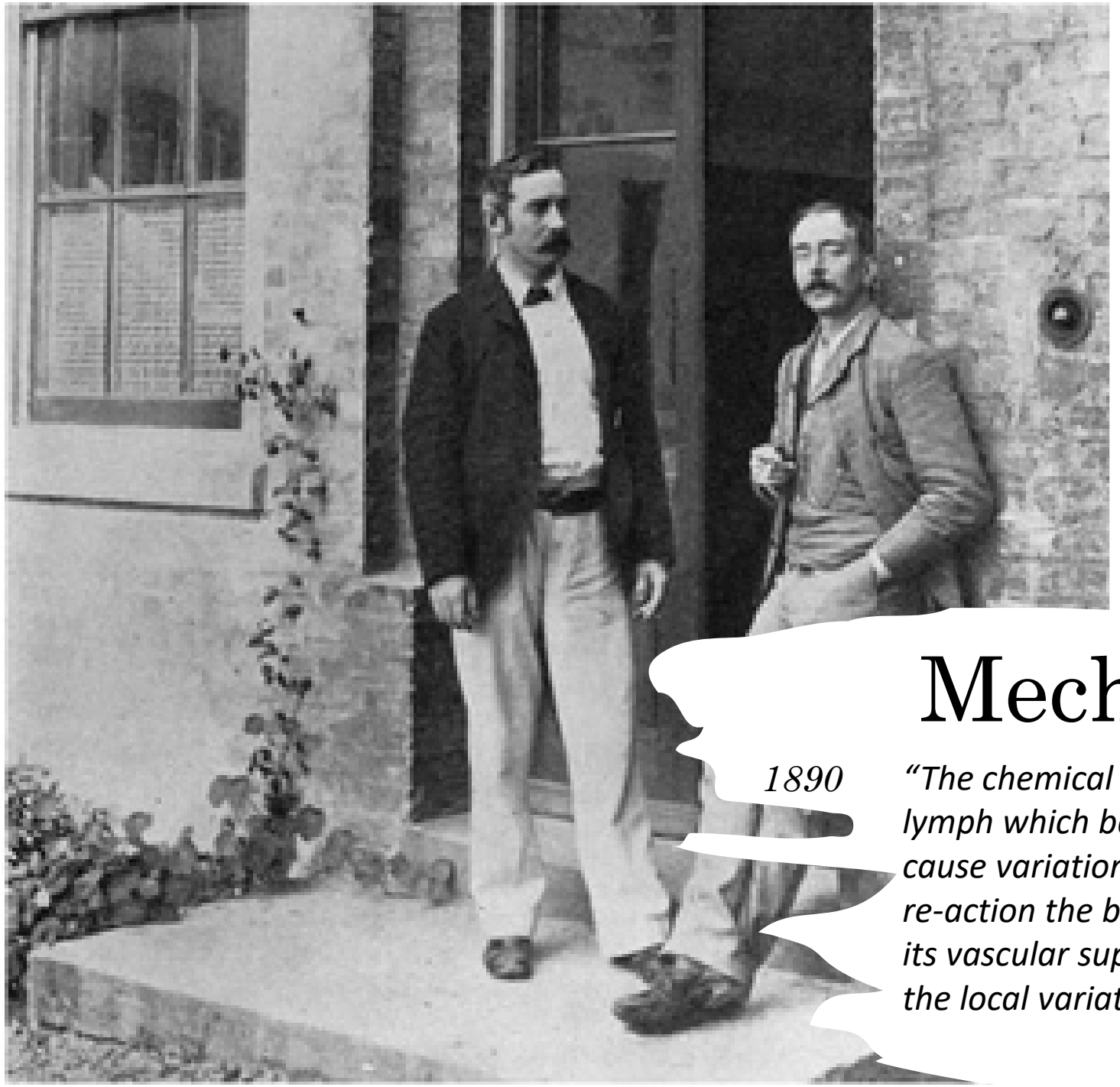
Mechanisms of NVC

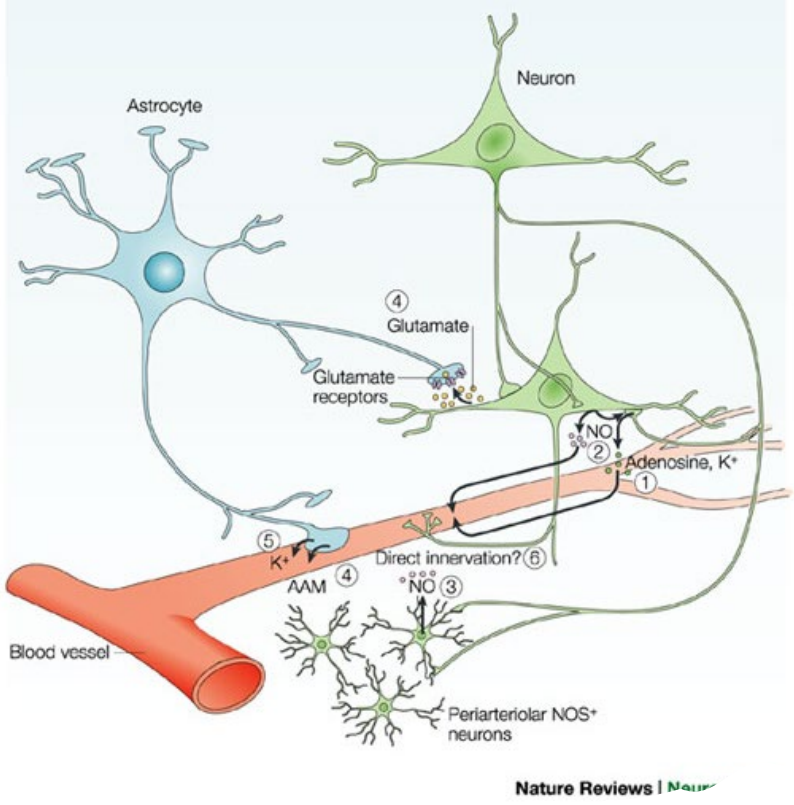


Nature Reviews | Neuroscience



Nature Reviews | Neuroscience



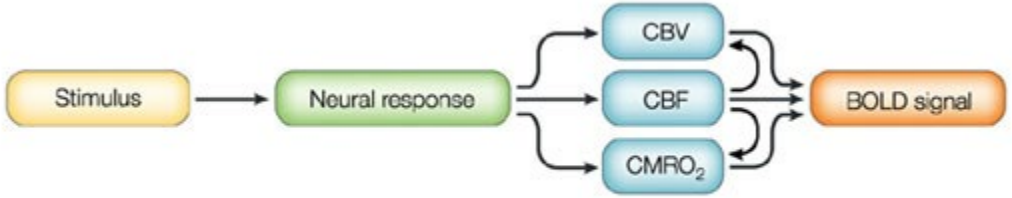


Mechanisms of NVC

1890

"The chemical products of cerebral metabolism contained in the lymph which bathes the walls of the arterioles of the brain can cause variations of the caliber of the cerebral vessel: that in this re-action the brain possesses an intrinsic mechanism by which its vascular supply can be varied locally in correspondence with the local variations of functional activity".

Mechanisms of NVC



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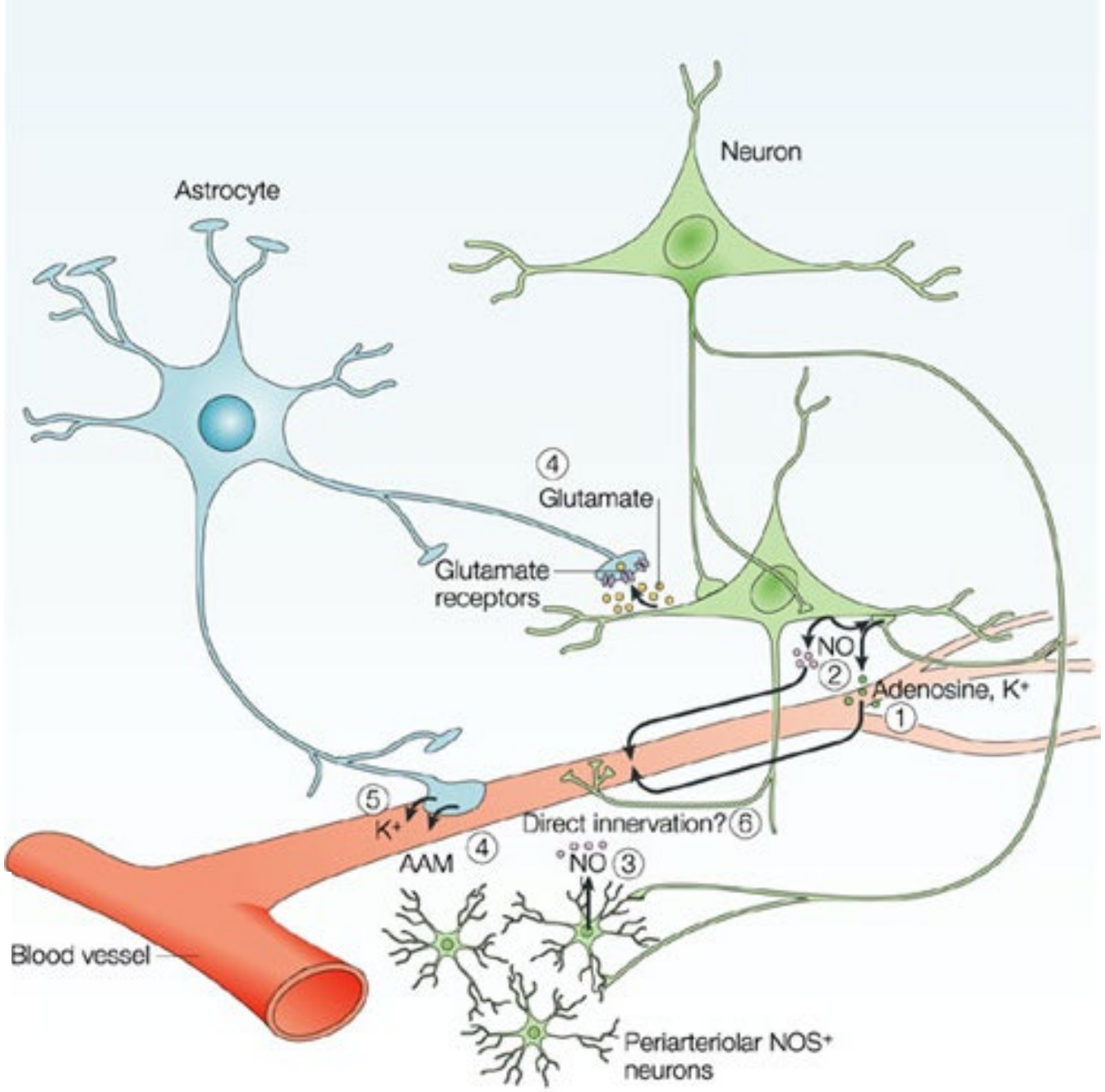

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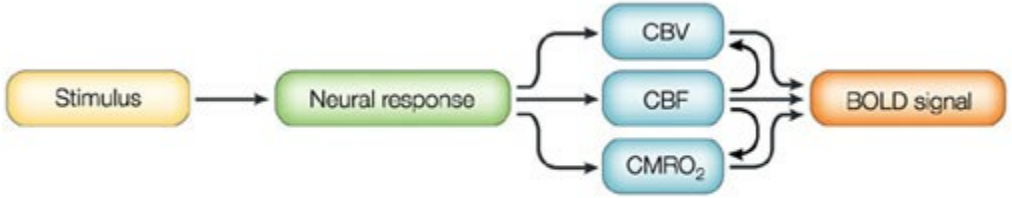
Mechanisms of NVC



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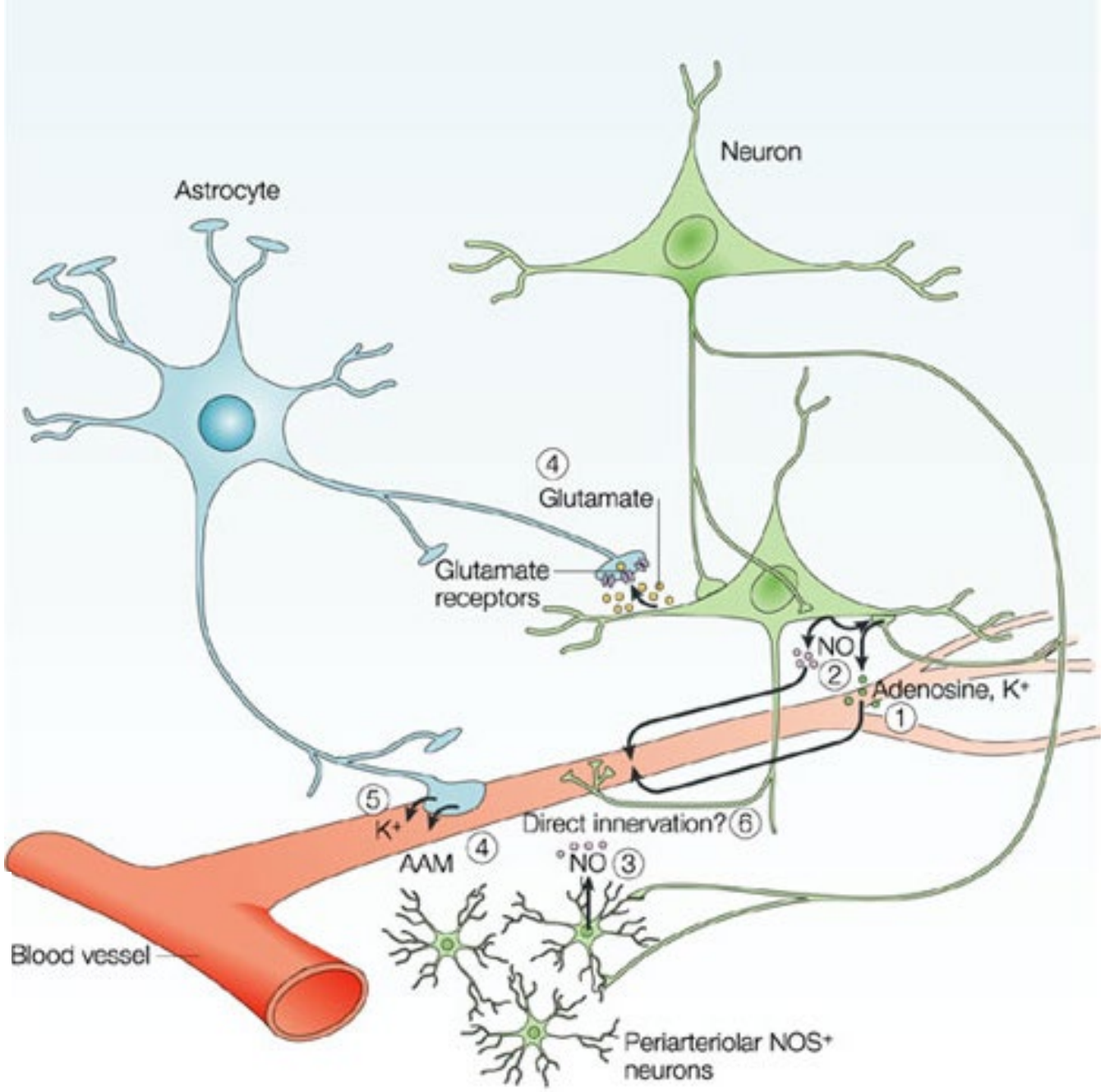
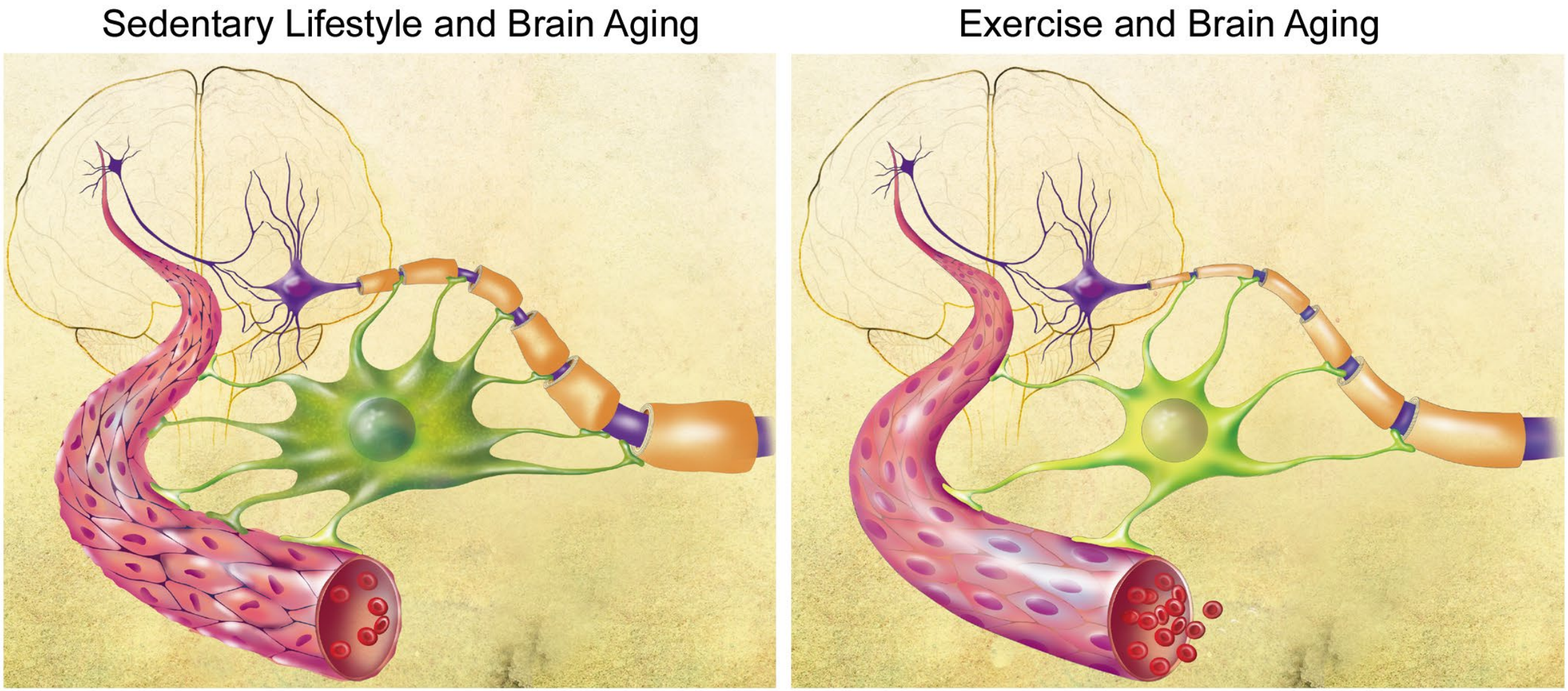


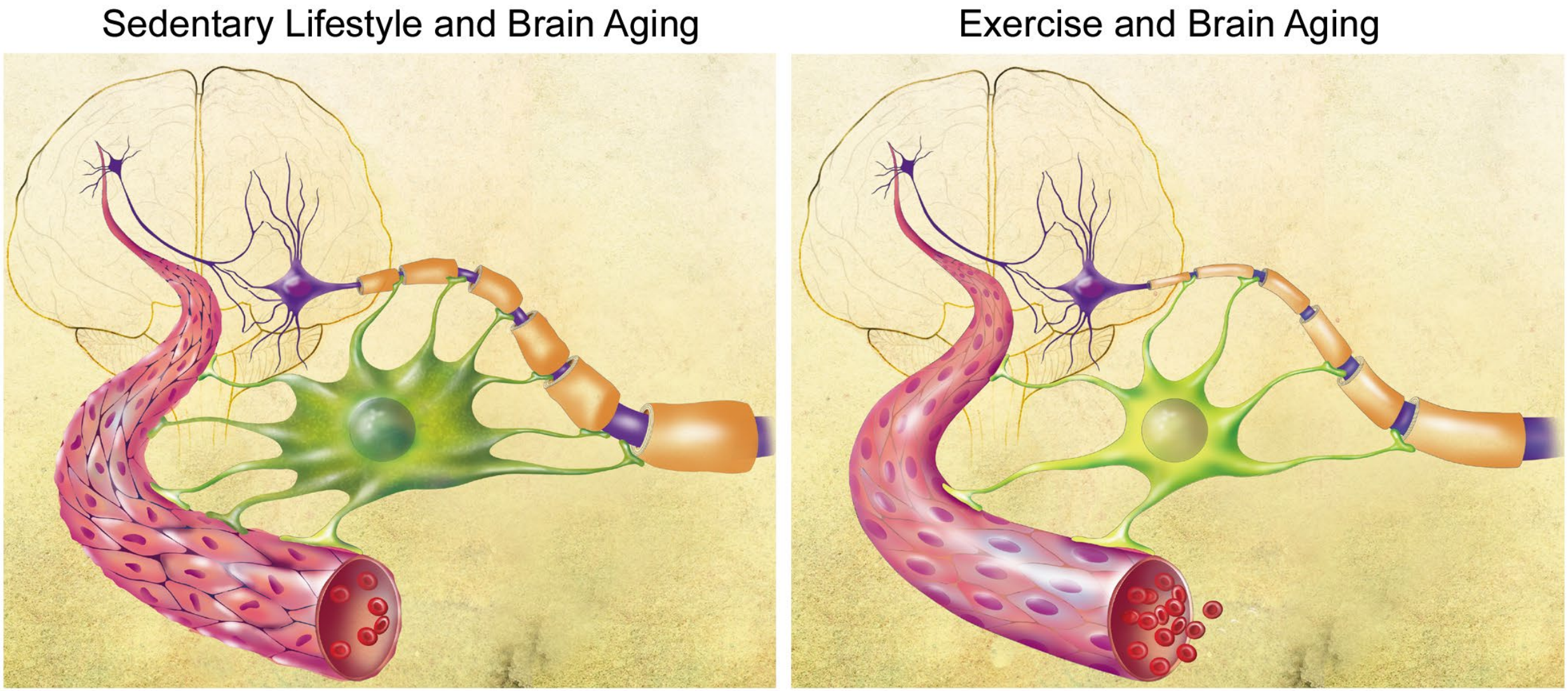
Nature Reviews | Neuroscience

Altered neuro-vascular coupling during aging



Latimer, 2011 PLoS One

Altered neuro-vascular coupling during aging



Latimer, 2011 PLoS One

Neuro-engineering perspective of neurovascular coupling for clinical applications

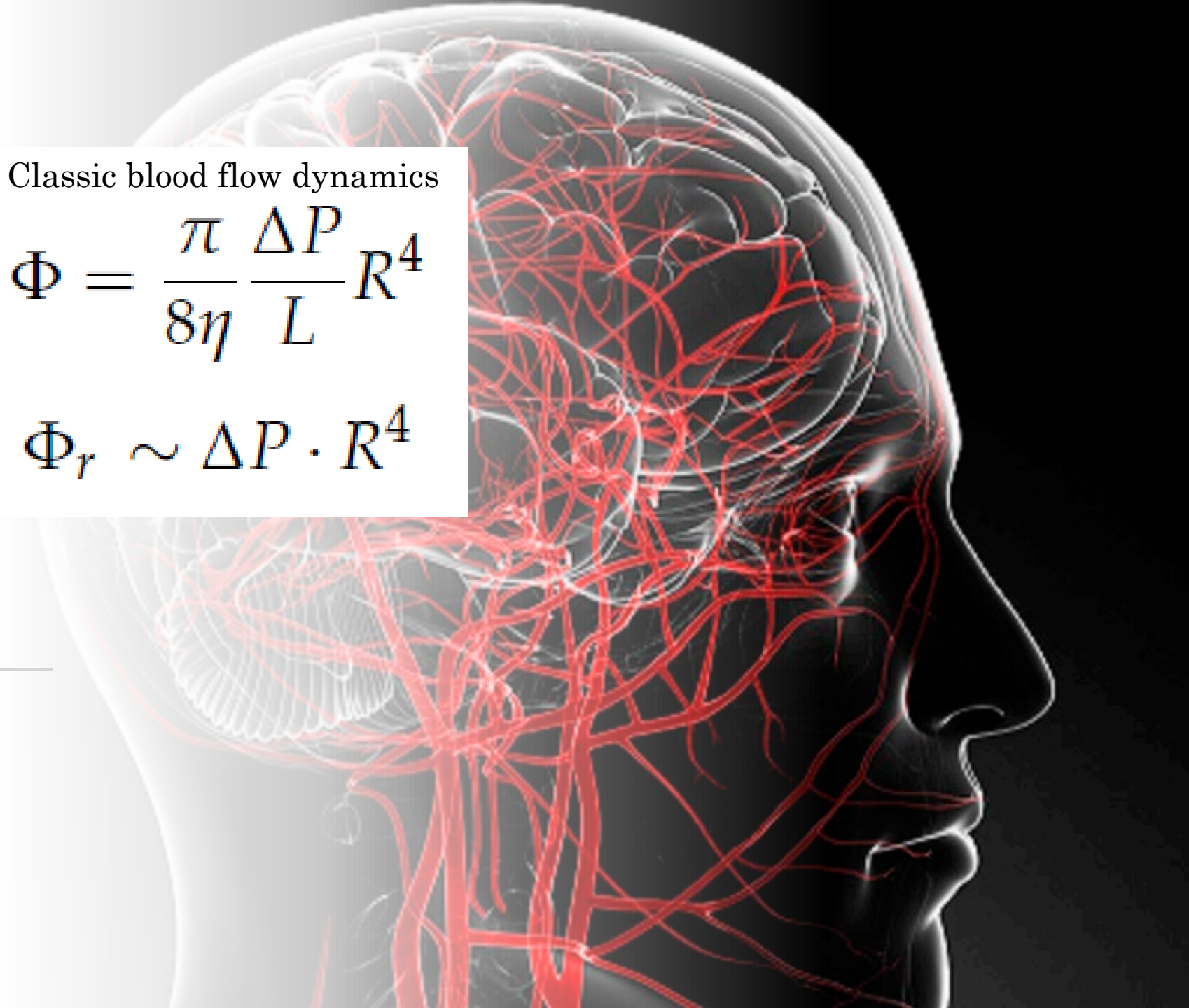
Application	Description
Imaging	Development of technologies such as MRI, PET, and fMRI to provide detailed maps of brain activity and blood flow
Modeling	Development of computational models to simulate the complex interactions between neurons, astrocytes, and blood vessels
Device Development	Development of tools and devices such as neurovascular stents, microfluidic devices, and TMS to modulate blood flow and neuronal activity in the brain
Drug Therapy	Development of drugs that target the production of signaling molecules such as nitric oxide and prostaglandins to modulate blood flow and improve outcomes in patients with neurological disorders

Cerebral blood flow

Classic blood flow dynamics

$$\Phi = \frac{\pi}{8\eta}\frac{\Delta P}{L}R^4$$

$$\Phi_r \sim \Delta P \cdot R^4$$



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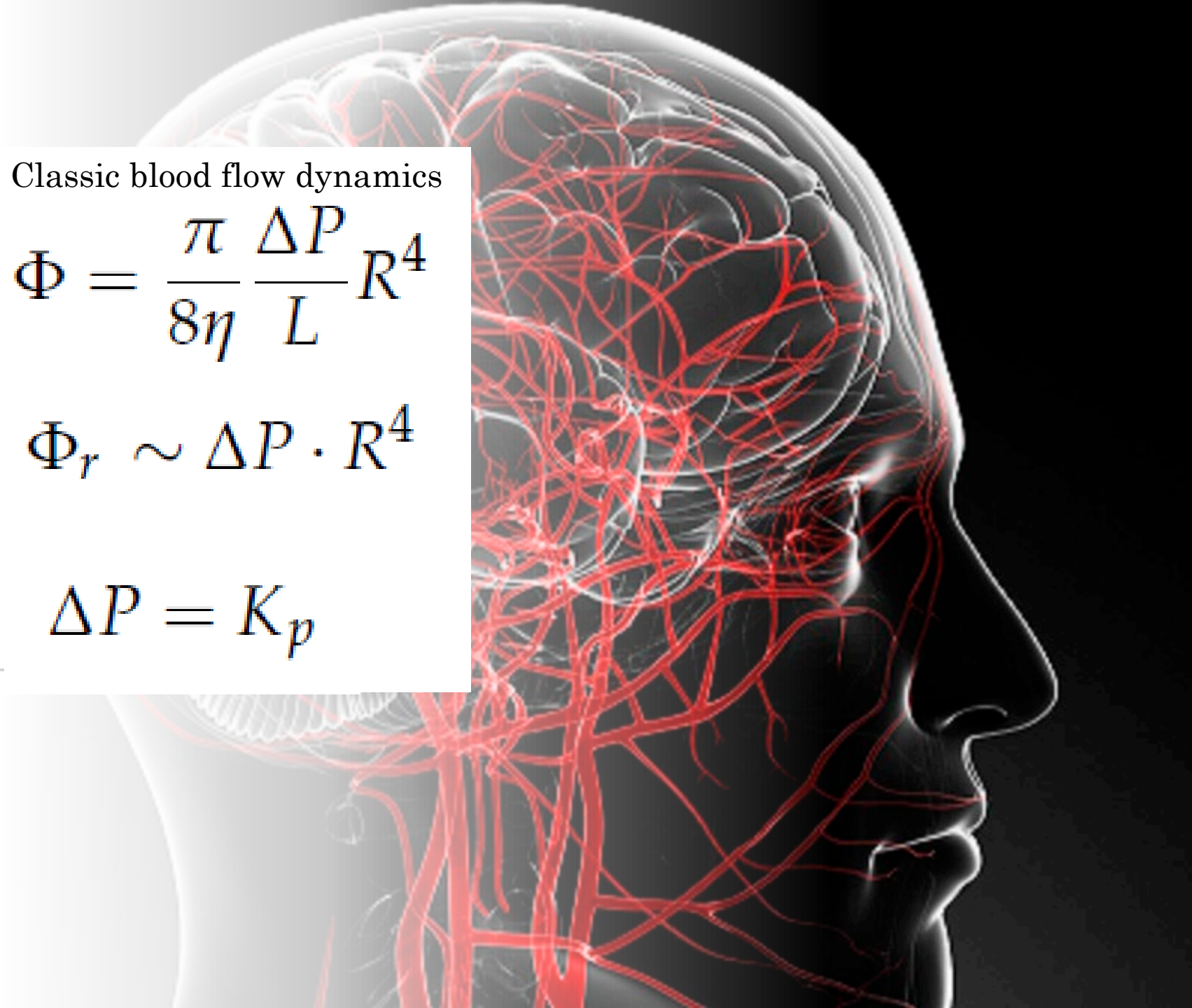

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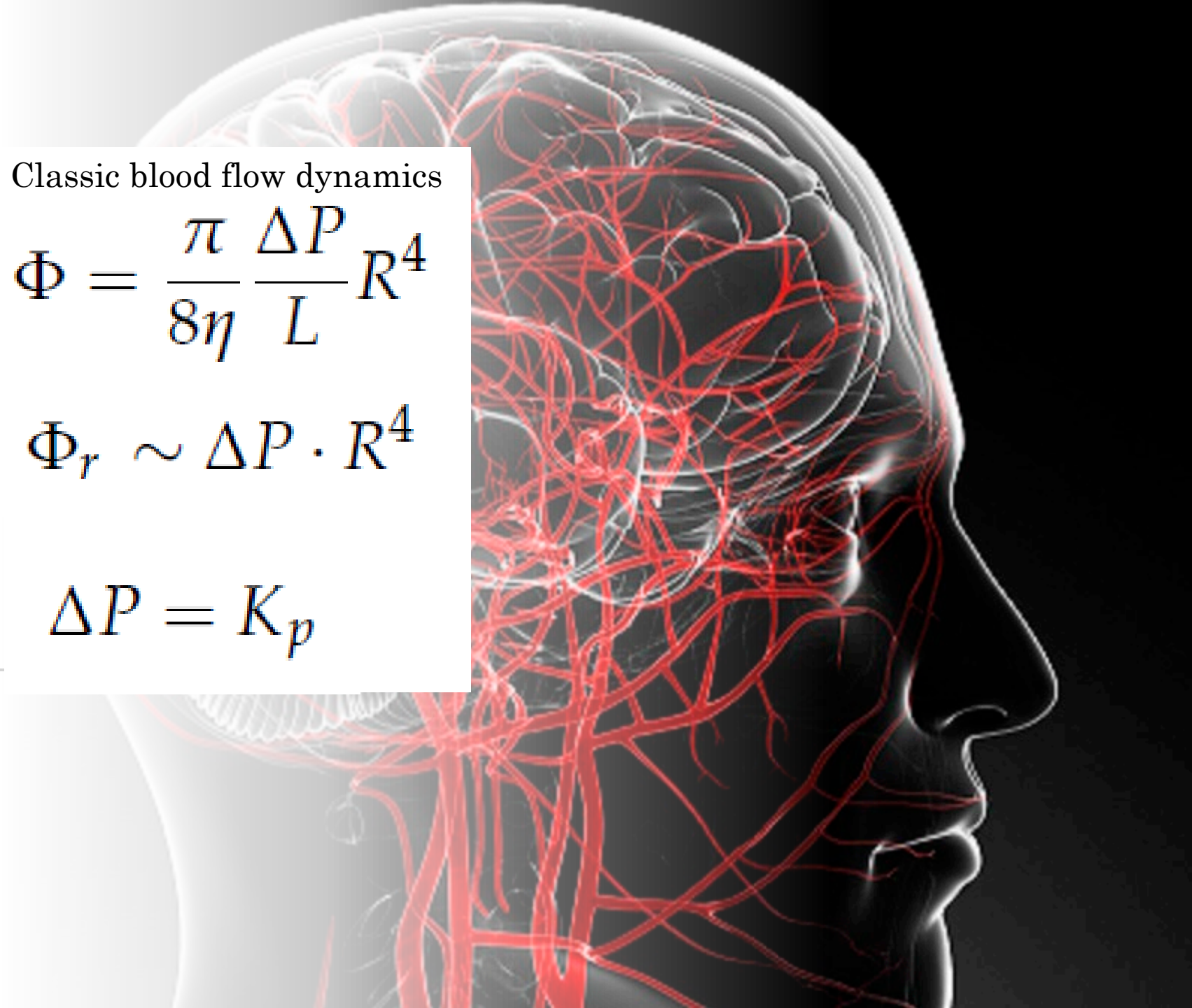

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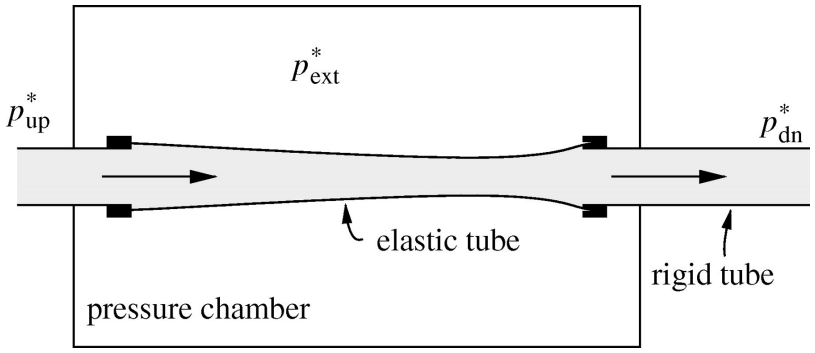
Cerebral autoregulation

$$\Delta P = K_p$$

$$\Phi_{nvc} \sim \partial R^4$$



Cerebral blood flow

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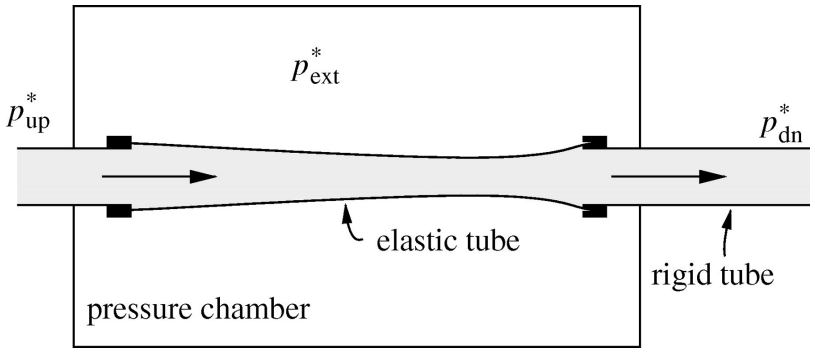
Cerebral autoregulation

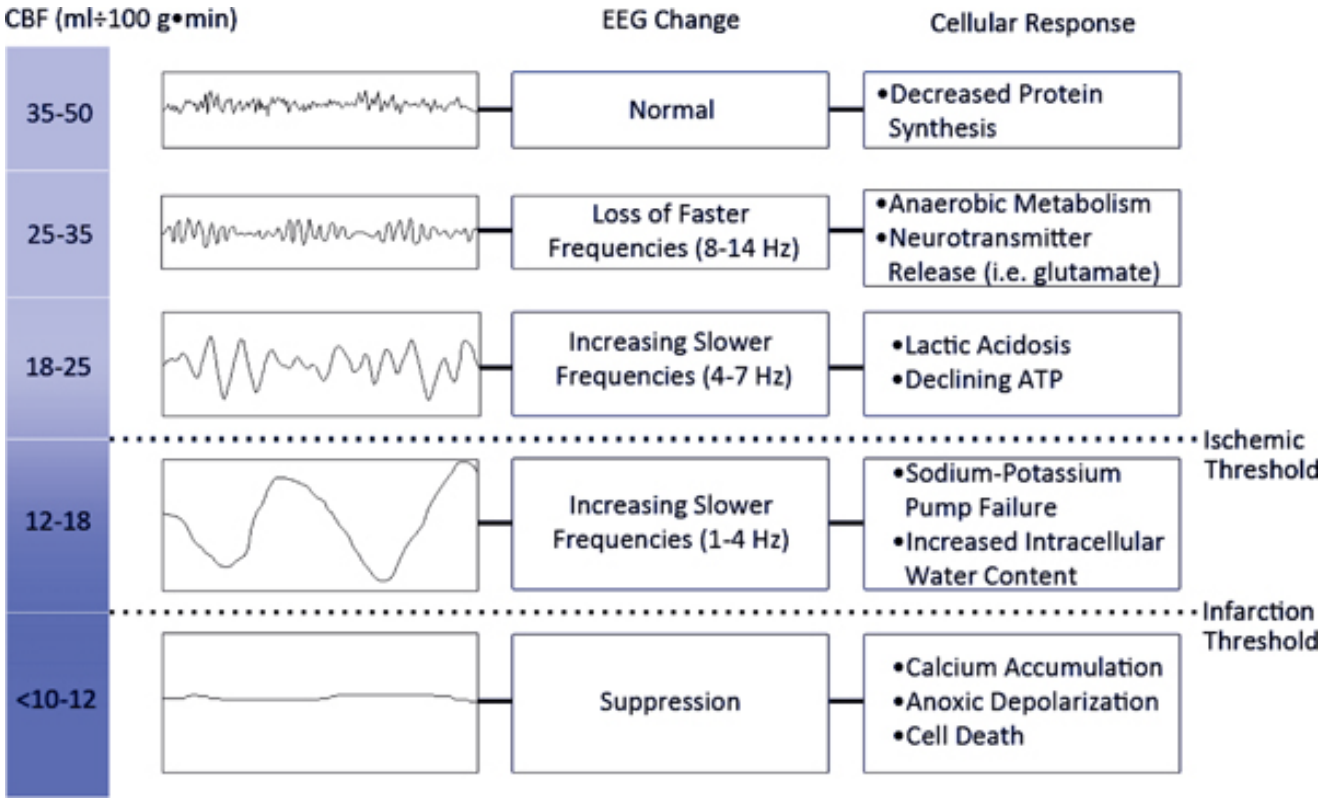
$$\Delta P = K_p$$

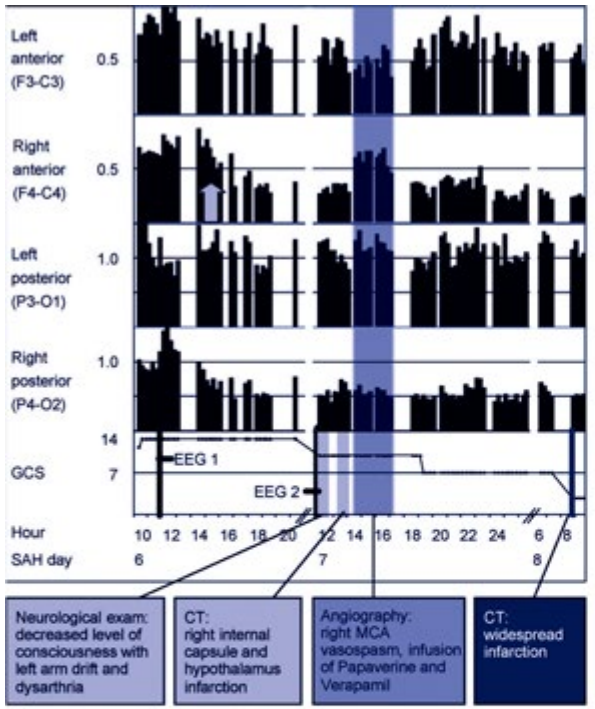
$$\Phi_{nvc} \sim \partial R^4$$

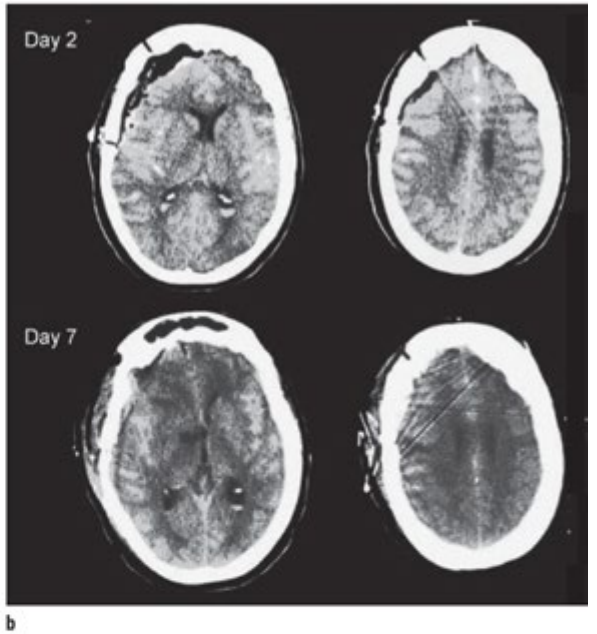
$$R_{cap} \sim \frac{1}{P_{VRS}}$$

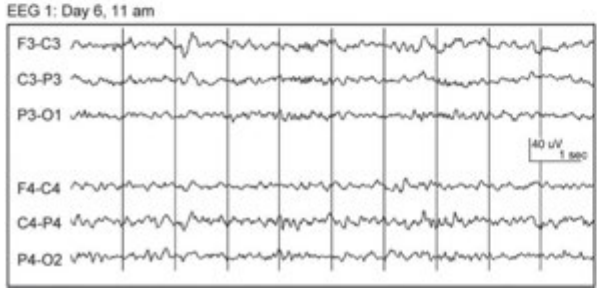


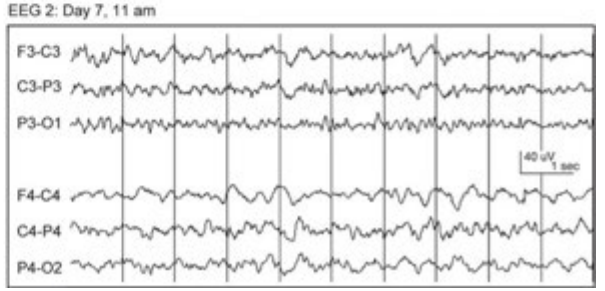
qEEG used for evaluation of NVC











Foreman & Claassen, 2012, Crit Care

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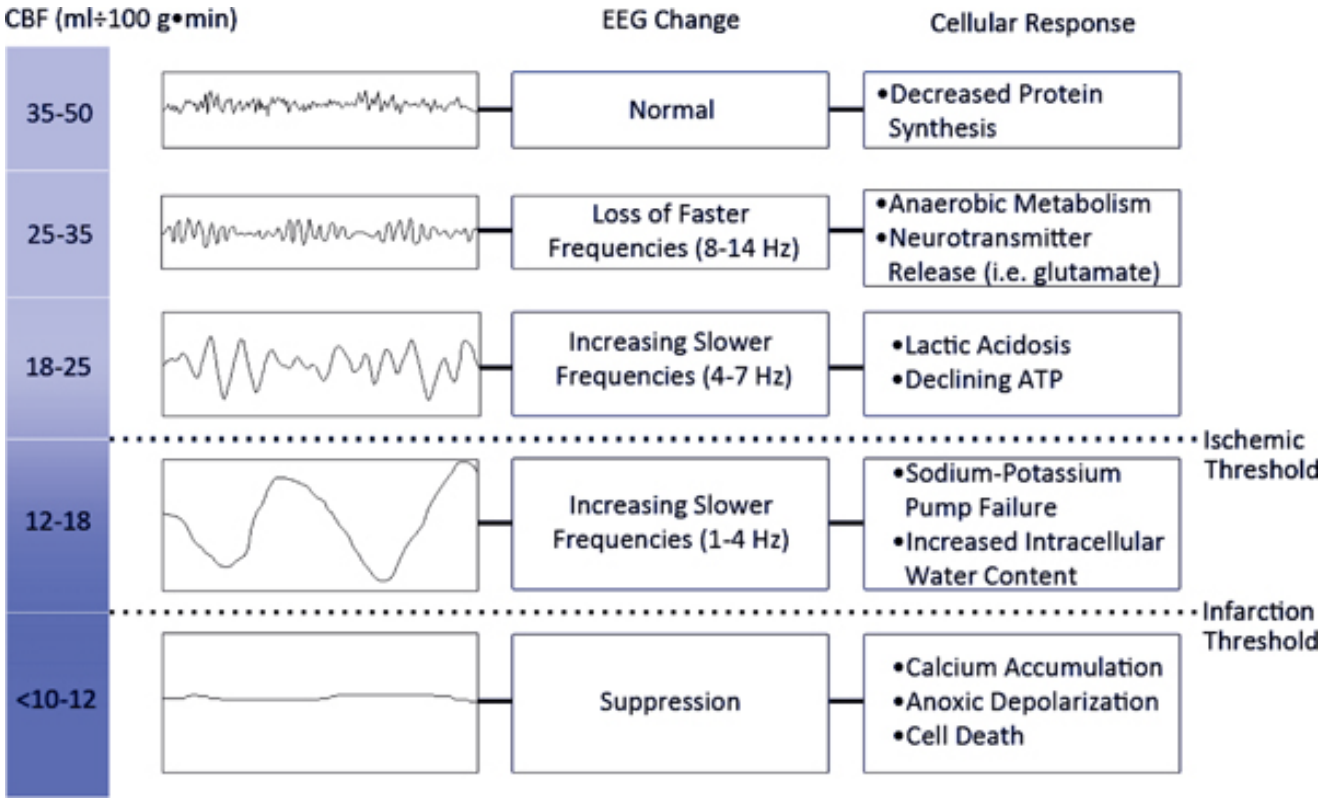
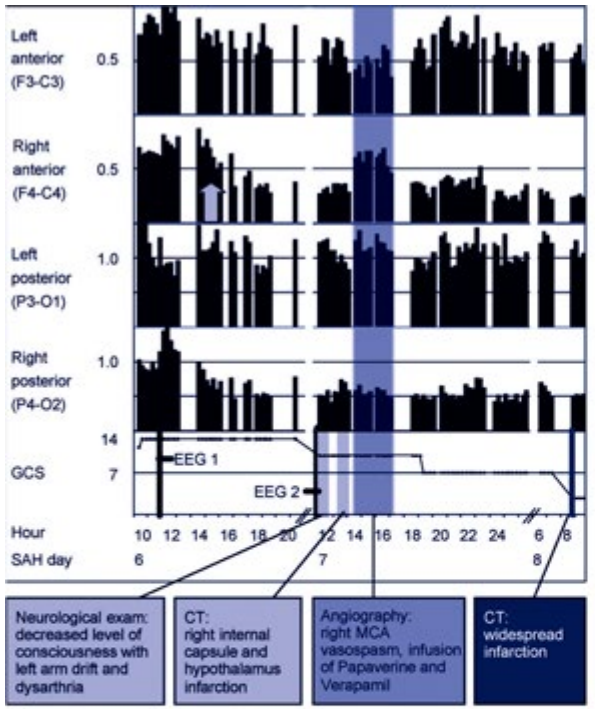
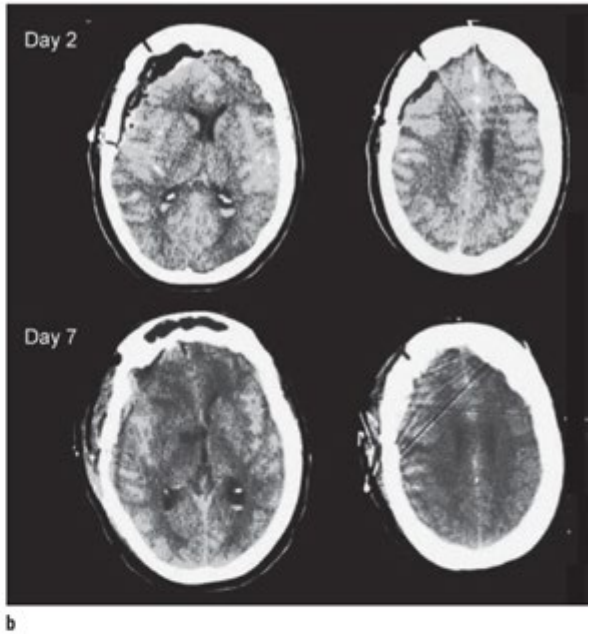
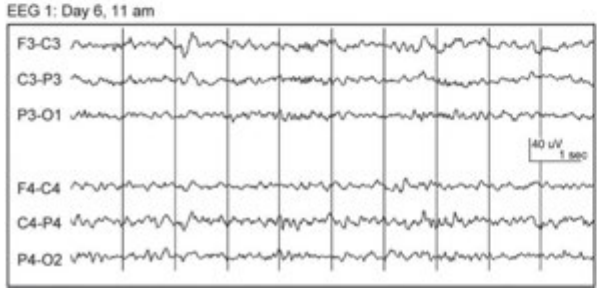
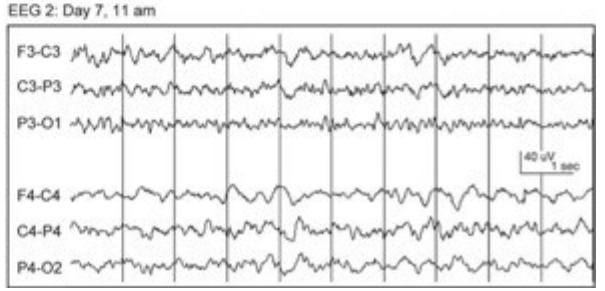






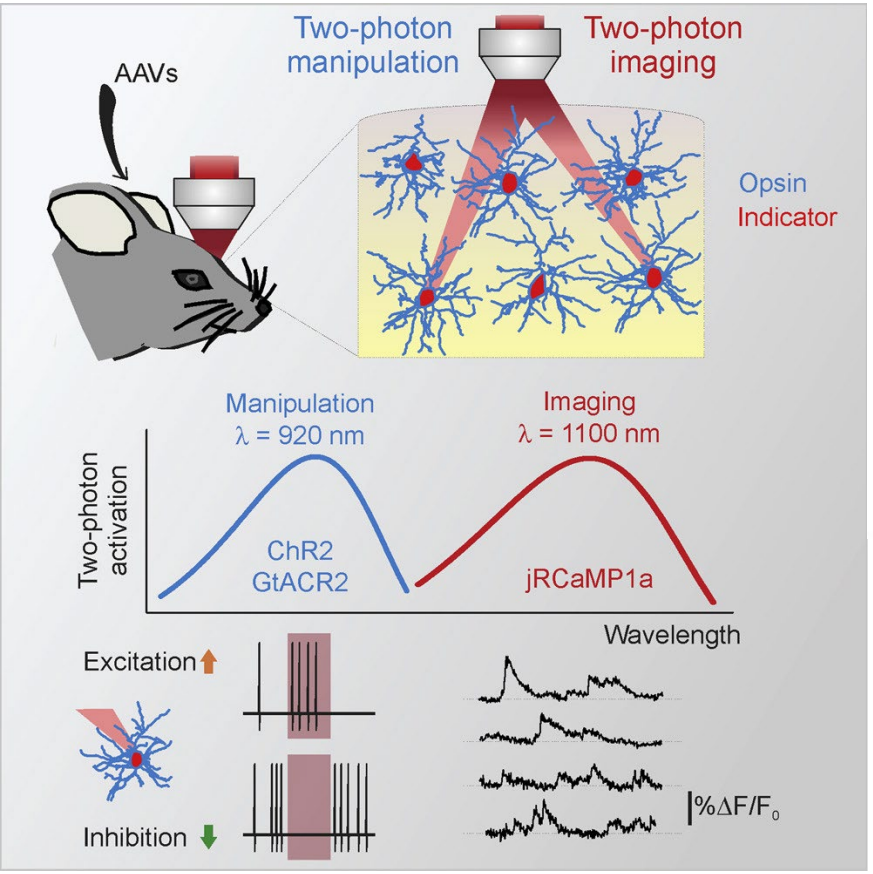


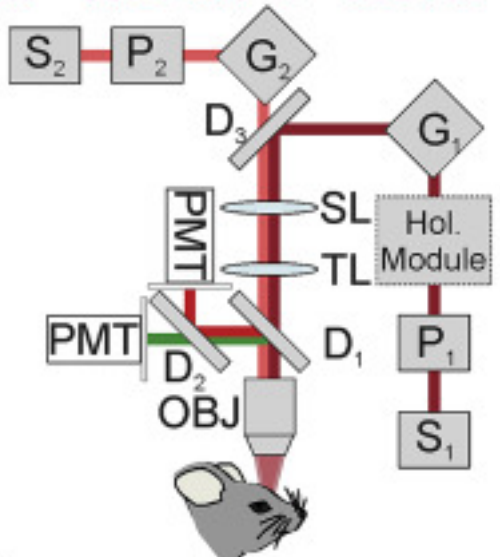


Foreman & Claassen, 2012, Crit Care

Neuro-engineering perspective of neurovascular coupling for pre-clinical applications

Neuroengineering Application	Description
Electrophysiology	Measuring neuronal activity in response to stimuli using techniques such as LFPs or multi-unit recordings, and correlating with changes in blood flow and oxygenation levels using imaging techniques
Optogenetics	Using light to control the activity of specific neurons in the brain and measuring resulting changes in blood flow and oxygenation levels using imaging techniques
Microfluidics	Designing and fabricating devices that manipulate fluids on a small scale to create artificial blood vessels or study the behavior of individual cells in response to changes in blood flow or oxygenation
Biomaterials	Developing new biomaterials, such as hydrogels or nanoparticles, for use in animal models to mimic brain tissue properties, deliver drugs, or imaging agents to specific brain regions

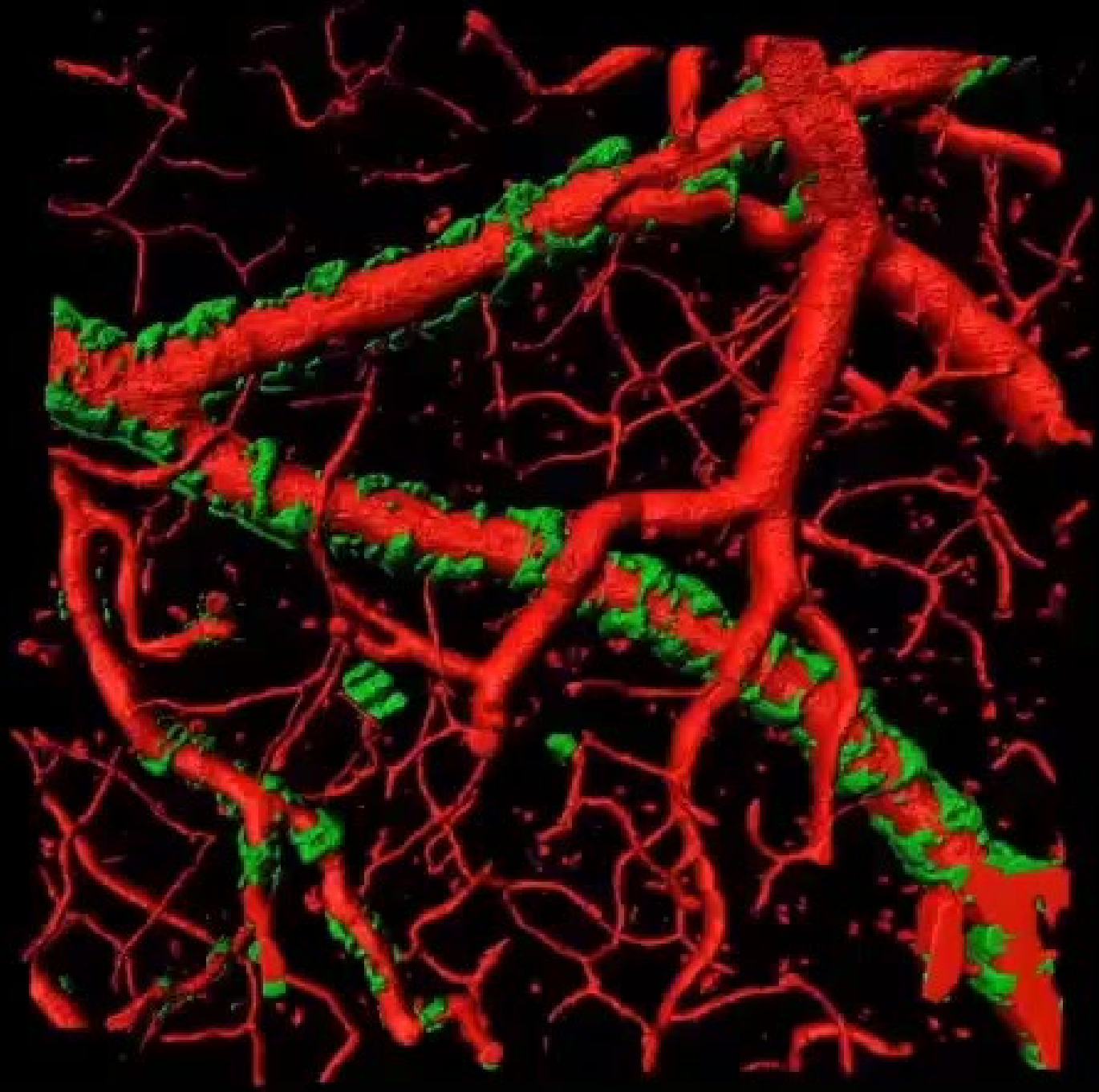


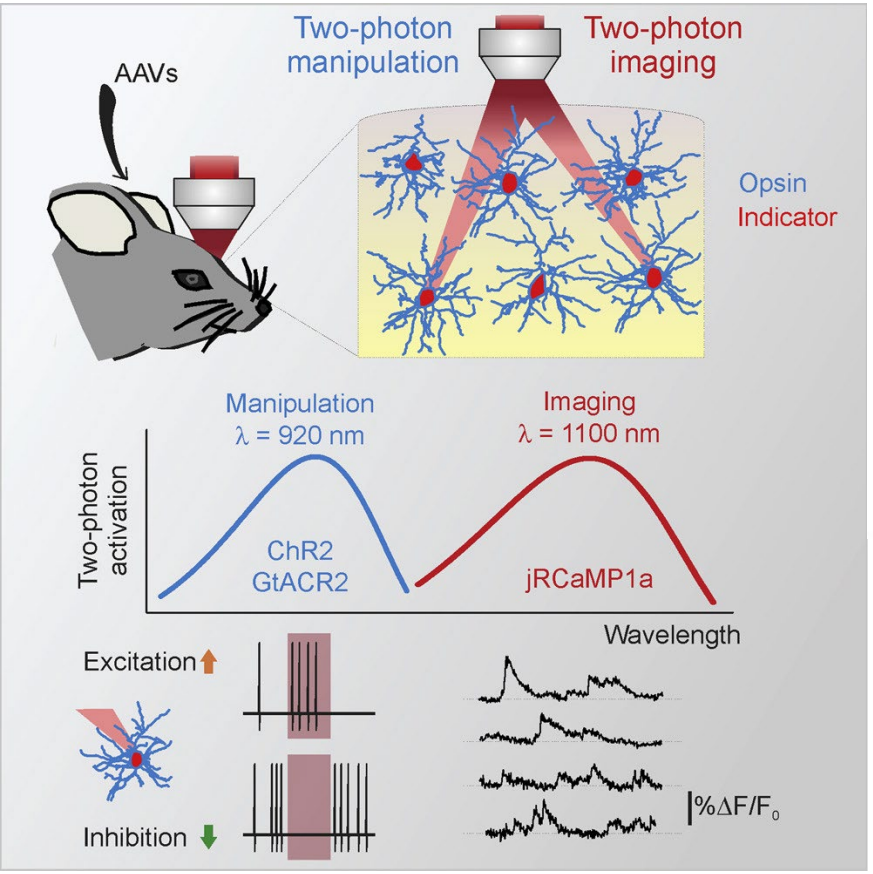


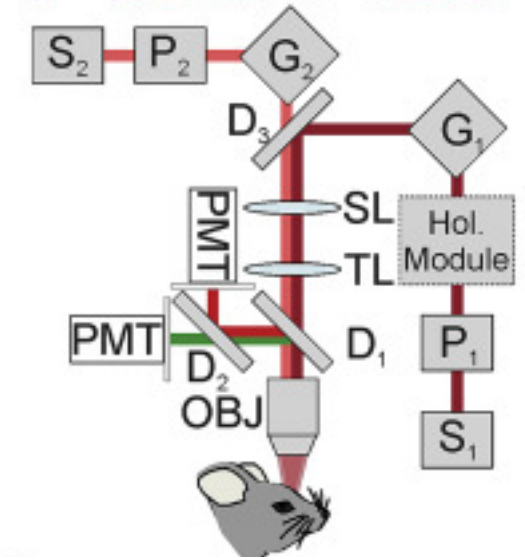
Forli et al., 2018, Cell Rep.

Advantages of 2P imaging over 1P imaging:

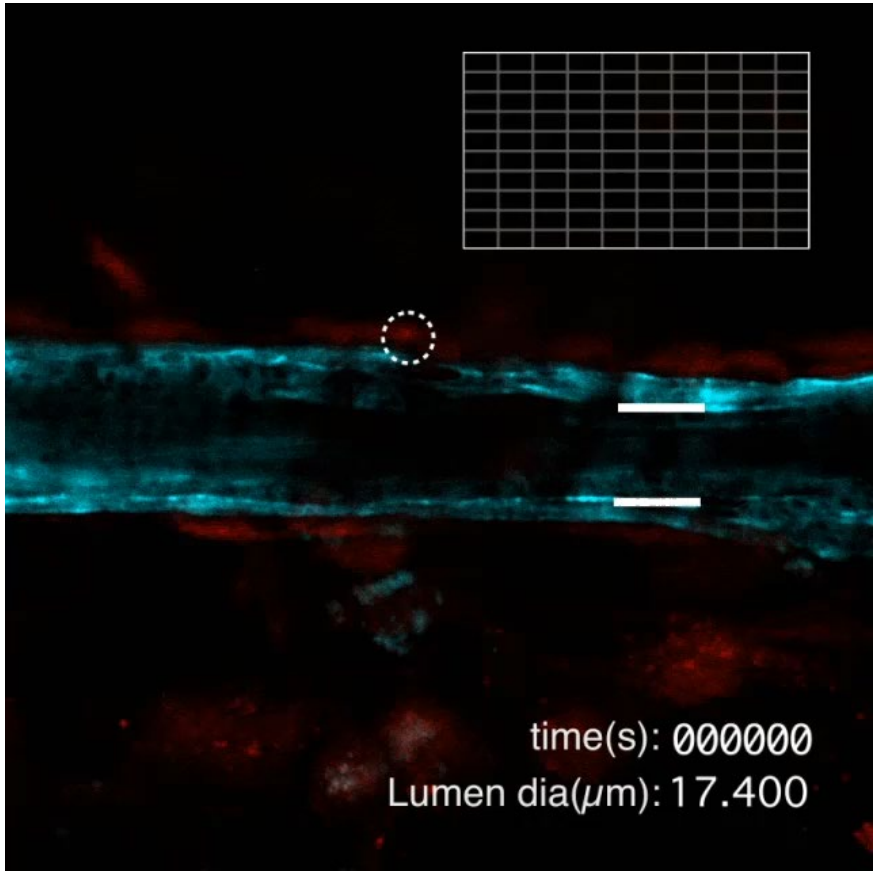
1. Reduced photodamage
2. Increased imaging depth
3. Increased spatial resolution
4. Reduced background fluorescence
5. Multiphoton excitation







Forli et al., 2018, Cell Rep.



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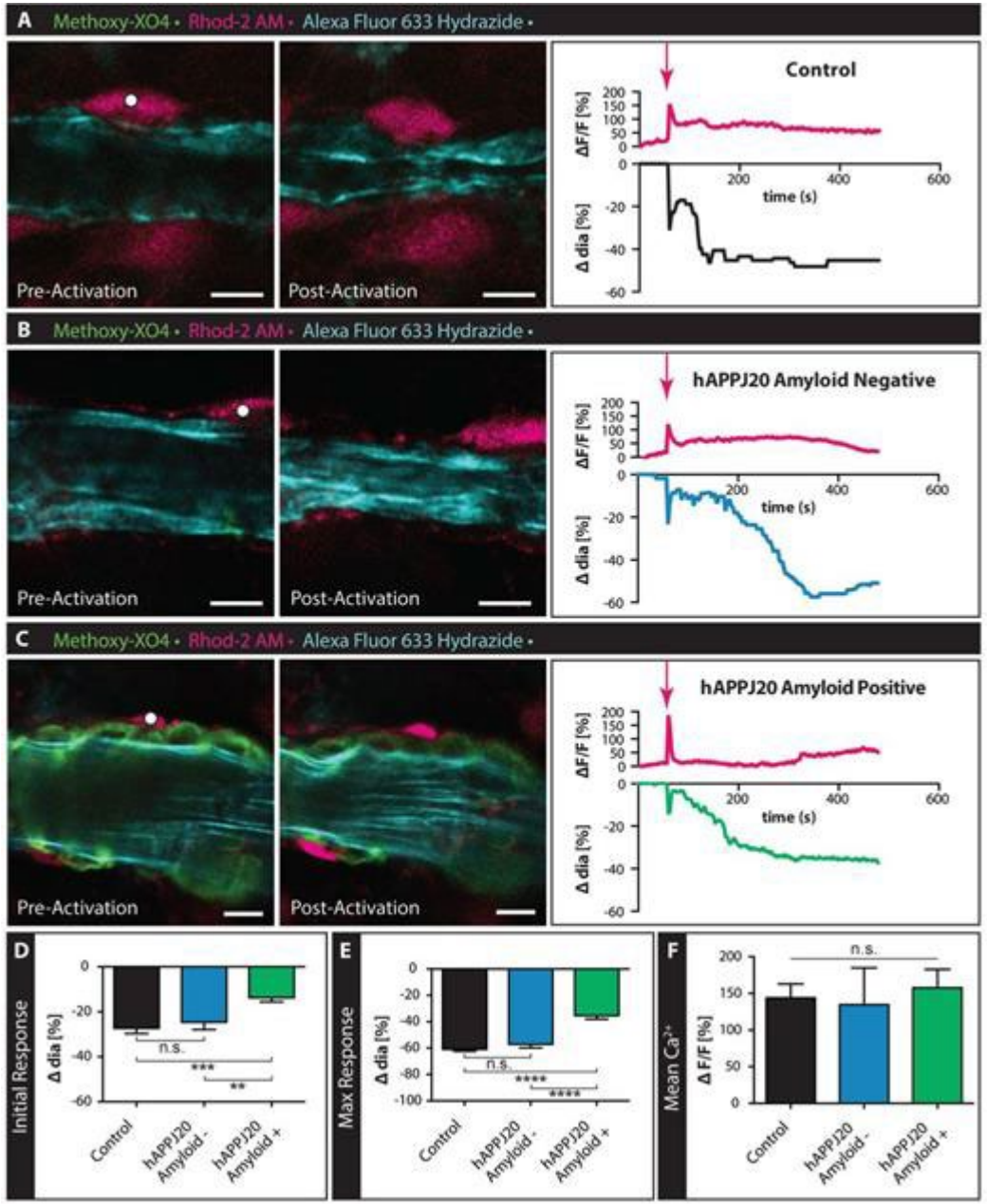
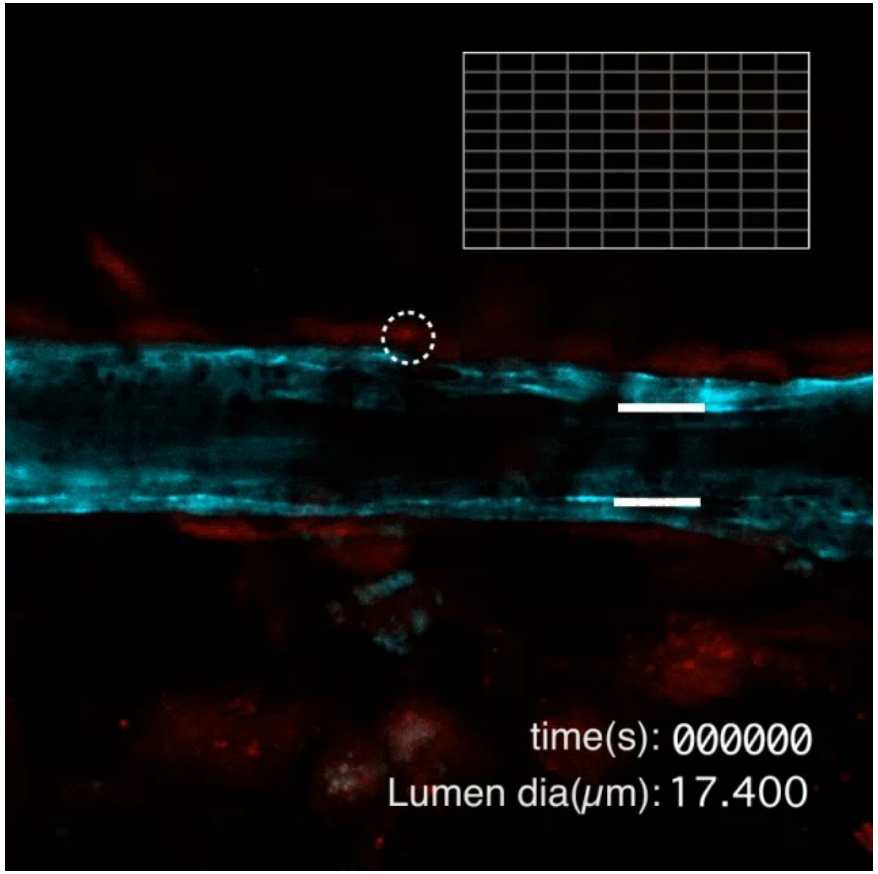
Kimbrough et al., 2015 Brain





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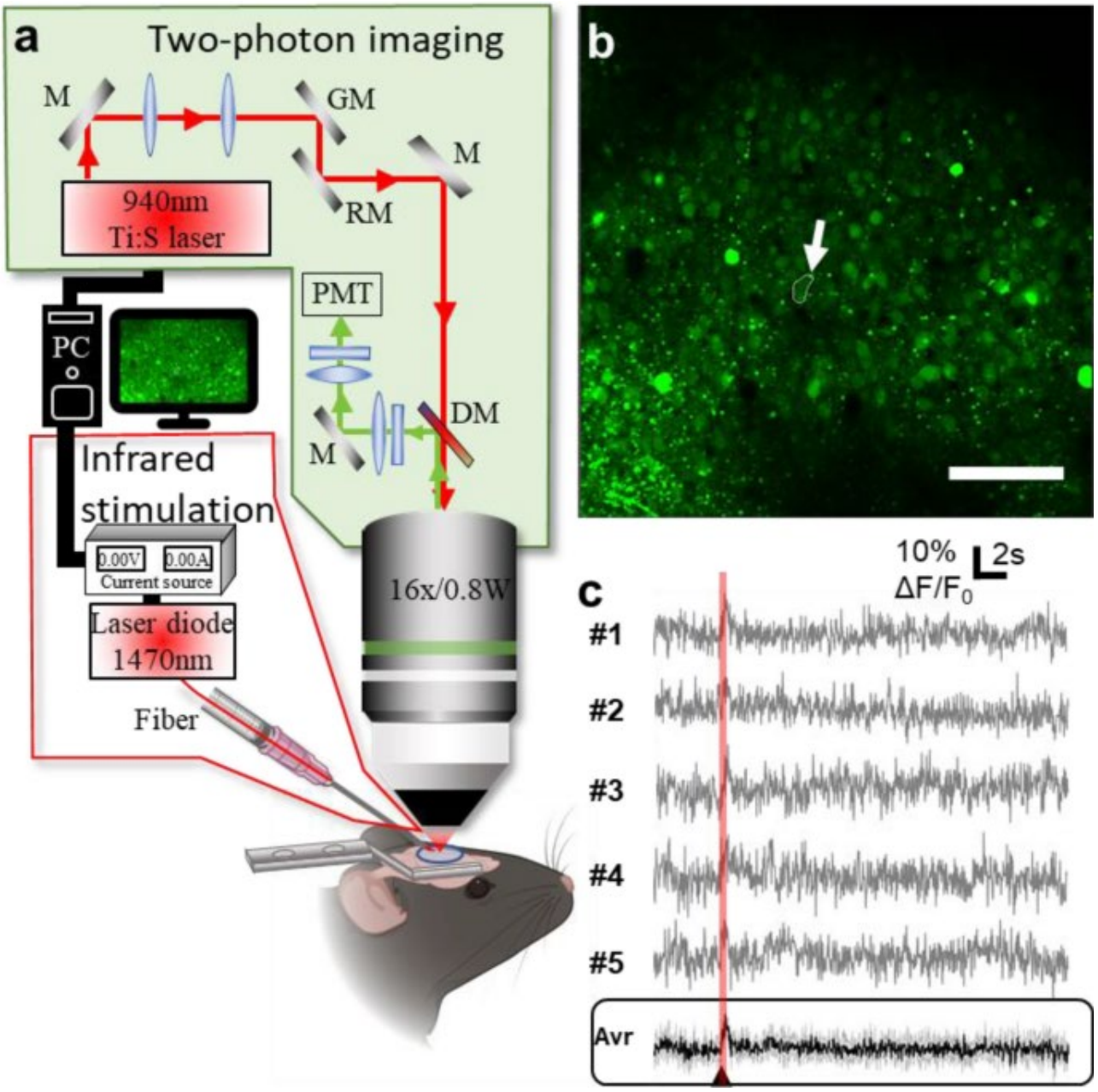
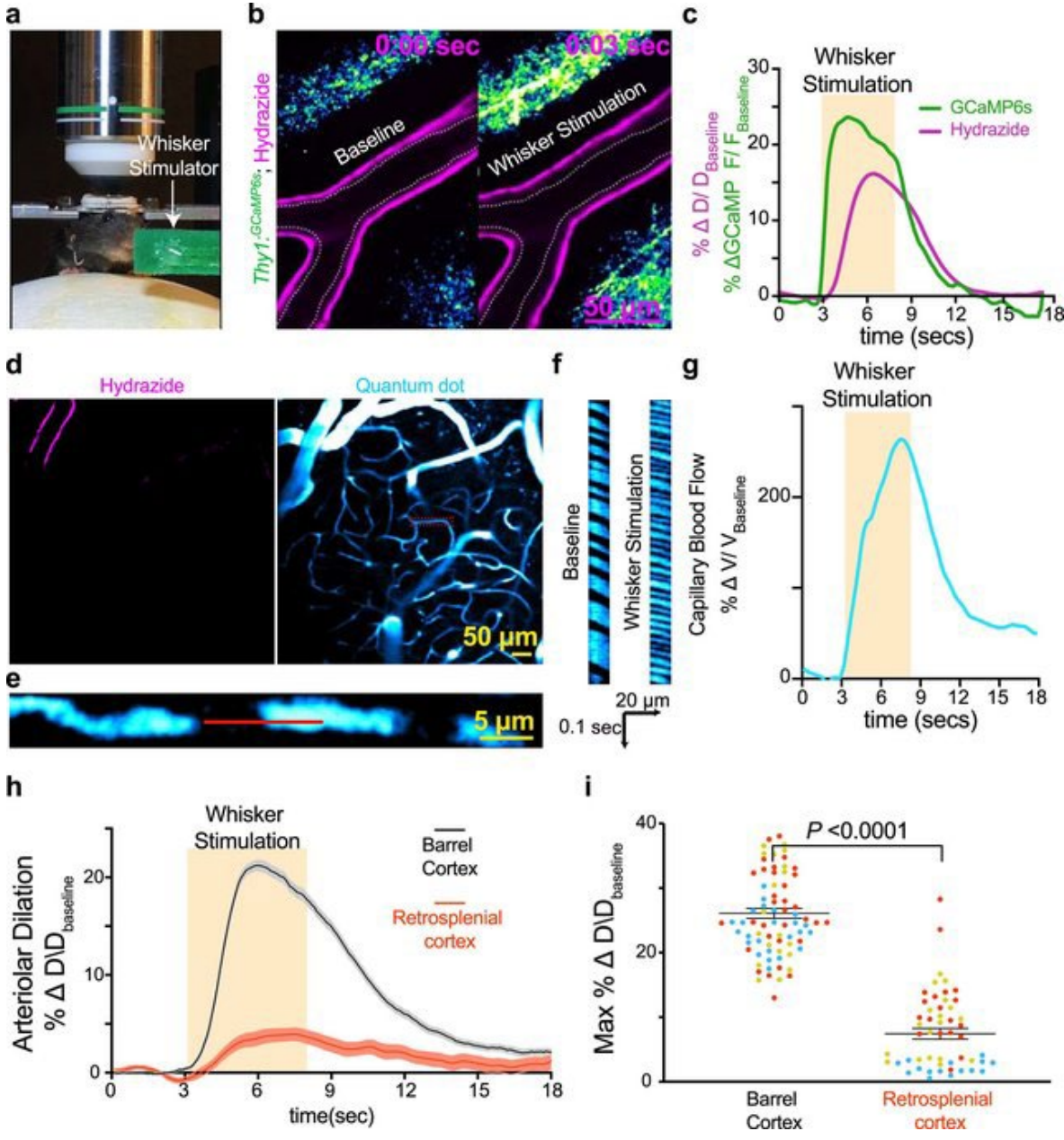
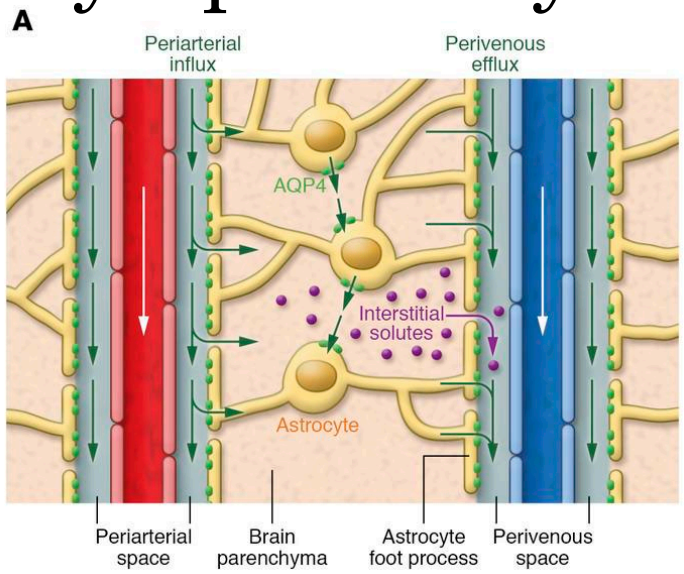
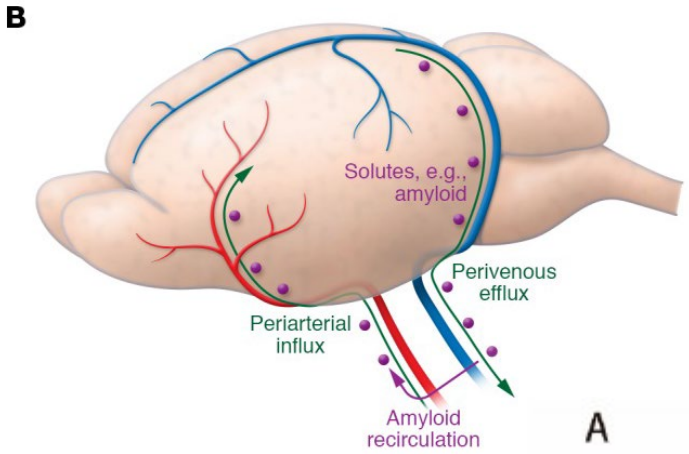




Rodney O'Connor & David Moreau. 2021 Nature

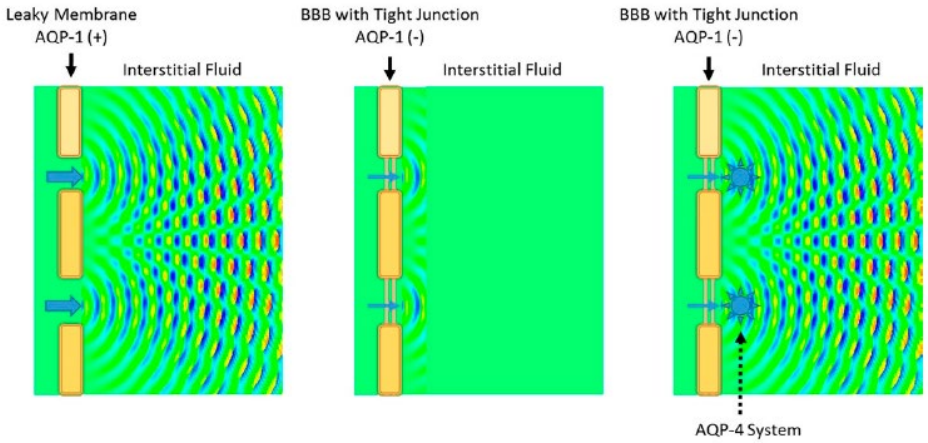
Glymphatic system: perivascular clearance in the brain

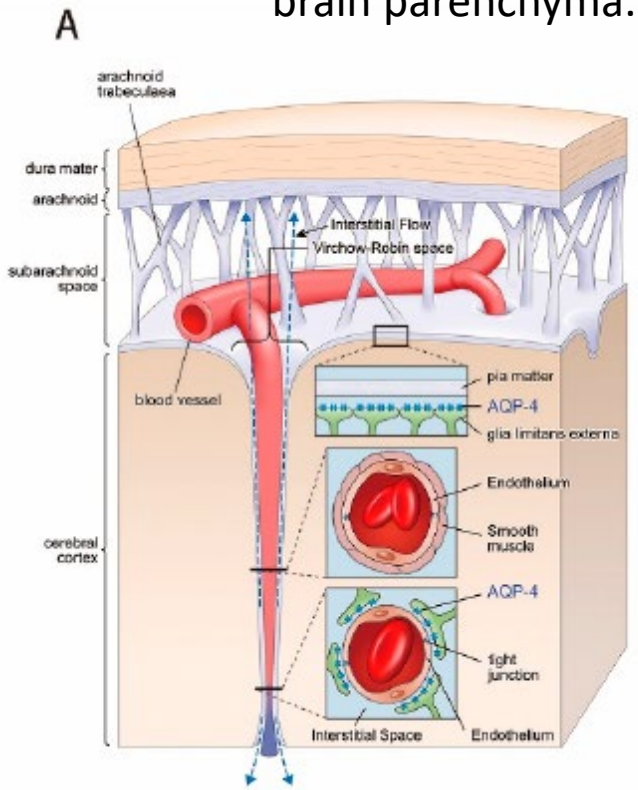


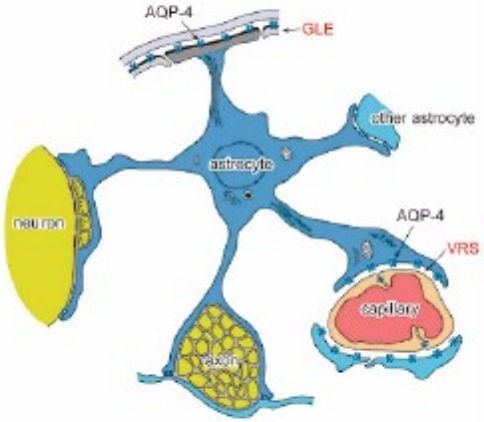


AQP4 in the brain is highly localized to astrocyte endfeet at the glia limitans externa and peri-capillary Virchow-Robin space (VRS).

VRS - fluid-filled canals surrounding perforating arteries, capillaries, and veins in brain parenchyma.







Louveau *et al.* 2017

Modeling NVU on a chip