OSTEOPATHY WITH HEART

NEW DEVELOPMENTS IN OSTEOPATHIC MEDICINE & CARDIOLOGY

Mary Goldman DO & Ryan Christensen DO

Michigan Osteopathic Association

Spring Conference 2025

Overview

- A.T. Still's view of the heart as the **central organ** of life, regulating nerves, circulation, and vitality.

- **Modern scientific discoveries** validating Still's ideas on **electromagnetic fields**, **vortex flow**, **CSF drainage**, and **acoustic signaling**.

- Integration of this knowledge into **clinical practice**.

Disclosures

•Dr. Christensen - Private Practice in OMT and Family Medicine, Clinical Faculty at MSU-COM. I have no personal disclosures, and this is a demonstration lecture on OMT.

•Dr. Goldman - Employee at OHCA in Utica, MI. I have no additional disclosures, and this is a demonstration lecture on OMT.

Learning Objectives

1. Understand the Heart-Brain connection evolved from Dr. AT Still's Heart as Mother philosophy
2. Describe the glymphatic system and ways to increase clearance from anatomical pathways
3. Apply osteopathic principles to neuroscience to help increase organism's success and improve allostasis
4. Describe new understandings of cardiac physiology based on physics

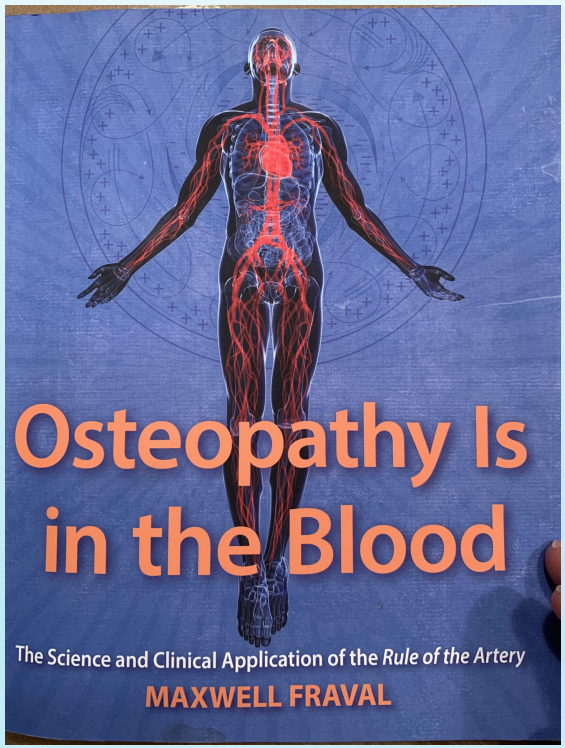
Six ways to incorporate new knowledge in your Osteopathic Medical Practice:

1. The heart is not just a pump: it works with suction and produces a vortical blood flow rather than working with pressure.
2. Blood conveys types of essential information, not just nutrients such as oxygen and glucose. Biosphere interactio
3. The vasculature acts as a fulcrum & restraint during embryologic development

Six ways to incorporate new knowledge in your Osteopathic Medical Practice:

4. The use of **perception** along with palpation to accurately identify presence and location of sensory information (somatovisceral/viscerosomatic)
5. The piezoelectric quality of the extracellular matrix means that squeezing or stretching it gives rise to electricity, so Balanced Ligamentous Tension or Balanced Membranous Tension can control life currents and revive suspended forces.
6. The heart as a generator of body warmth, allowing it to induce rhythmic thermal fluctuations in blood cells as they move to the cooler periphery.

With Thanks to Maxwell Fraval



Osteopathy Is in the Blood, The Science and Clinical Application of the Rule of the Artery
By Maxwell Fraval,
Published by Osteopathy's Promise to Children,
3706 Ruffin Rd., San Diego, CA 92123
www.the-promise.org

WHAT? WHY NOW?

2023 and forward data regarding a new understanding of an open circulatory system, vortex arterial blood flow, cardiac output driven by tissue metabolic demands, newly found structural lymph drainage channels and a 4th Meningeal Membrane, and new understanding of living anatomy through technological advancements in imaging and immunofluorescence, and the ability to use fresh cadaver research has demonstrated MANY ideas that we know to be true!

And it demonstrates unequivocally the findings of Still, Sutherland, and the great Osteopathic researchers of the past.

A. T. Still.

Philosophy of Osteopathy;

BY

ANDREW T. STILL,

DISCOVERER OF THE SCIENCE OF OSTEOPATHY AND
PRESIDENT OF THE AMERICAN SCHOOL
OF OSTEOPATHY.

PUBLISHED BY
A. T. STILL, KIRKSVILLE, MO
1899.

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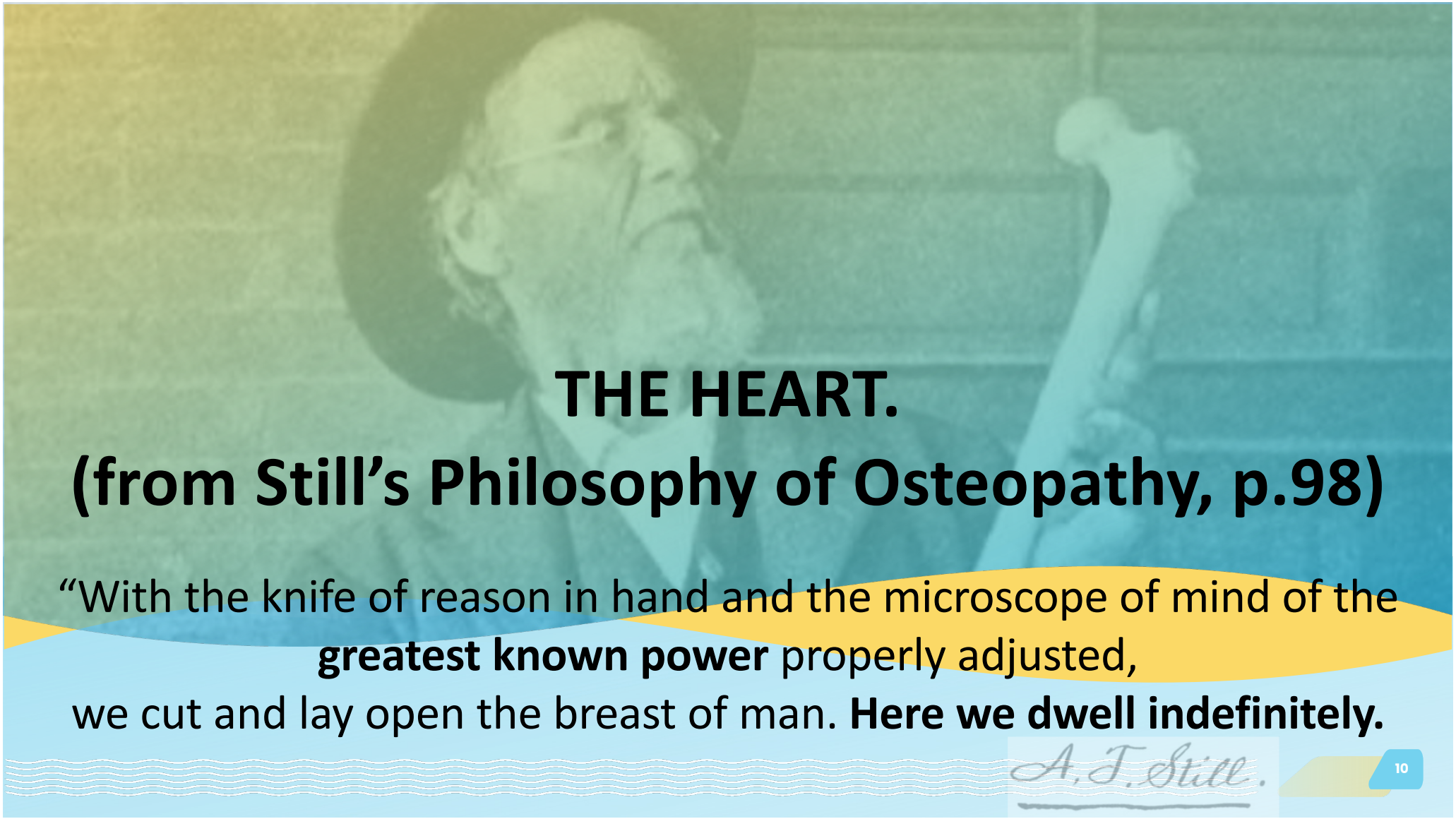


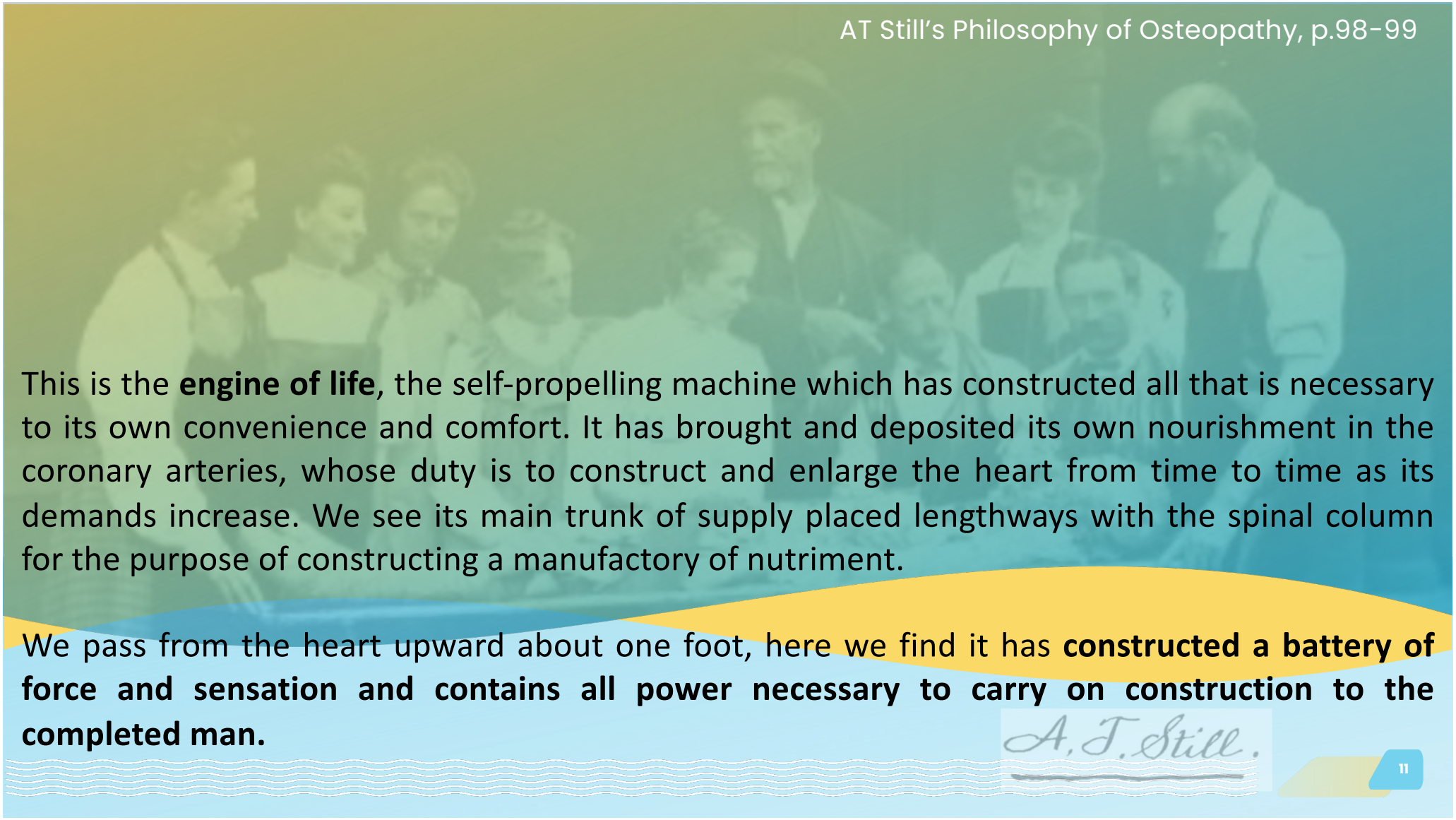
THE HEART.

(from Still's Philosophy of Osteopathy, p.98)

"With the knife of reason in hand and the microscope of mind of the **greatest known power** properly adjusted,
we cut and lay open the breast of man. **Here we dwell indefinitely.**

A. T. Still.

AT Still's Philosophy of Osteopathy, p.98-99



This is the **engine of life**, the self-propelling machine which has constructed all that is necessary to its own convenience and comfort. It has brought and deposited its own nourishment in the coronary arteries, whose duty is to construct and enlarge the heart from time to time as its demands increase. We see its main trunk of supply placed lengthways with the spinal column for the purpose of constructing a manufactory of nutriment.

We pass from the heart upward about one foot, here we find it has **constructed a battery of force and sensation and contains all power necessary to carry on construction to the completed man.**

A. T. Still.

In that brain or battery is found all the motor and sensory elements of life, with nerves to transmit all nerve powers and principles found in the human body.

There is not a known atom in the whole human make-up that has not been propelled by the heart through the channels by which it has provided for such purpose. Every muscle, bone, hair, and all other parts without an exception have traveled through this system of arteries to their separate destinations.

All are indebted to the heart for their material size, and all qualities of motion and life sustaining principles of the human body.

A. T. Still.

If the carotid artery should tire out and not be able to perform its duty the brain would tire out also, and cease to operate. Should the descending aorta come to a halt from any cause, all parts of the body depending upon that vessel would suffer a total loss of blood supply. Equally so with any other principal artery of limb or body, all mark a failure equal to the suspended supply. **The parts and principles of the human body depending upon the heart are numerous beyond computation.**

Every expulsive stroke of the heart throws into line armed and equipped for duty thousands and millions of operators, whose duties are to inspect, repair injuries and construct anew if need be from the crown of the head to the sole of the foot. **With the best eye of reason we see but dimly into the breast of man which contains the heart, the wonder of man and the secret of life.**

I have given these bulky descriptions of the forest and ocean to prepare the mind of man to begin the inspection of the machinery that has constructed the body of which he is the indweller. If we cannot swallow all, we can taste…"

A. T. Still.

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scientific reports

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OPEN

Osteopathy modulates brain–heart interaction in chronic pain patients: an ASL study

Francesco Cerritelli[1,3], Piero Chiacchiaretta[1,2]✉, Francesco Gambi[1,2], Raoul Saggini[4], Mauro Gianni Perrucci[1,2] & Antonio Ferretti[1,2]

In this study we used a combination of measures including regional cerebral blood flow (rCBF) and heart rate variability (HRV) to investigate brain–heart correlates of longitudinal baseline changes of chronic low back pain (cLBP) after osteopathic manipulative treatment (OMT). Thirty-two right-handed patients were randomised and divided into 4 weekly session of OMT (N = 16) or Sham (N = 16). Participants aged 42.3 ± 7.3 (M/F: 20/12) with cLBP (duration: 14.6 ± 8.0 m). At the end of the study, patients receiving OMT showed decreased baseline rCBF within several regions belonging to the pain matrix (left posterior insula, left anterior cingulate cortex, left thalamus), sensory regions (left superior parietal lobe), middle frontal lobe and left cuneus. Conversely, rCBF was increased in right anterior insula, bilateral striatum, left posterior cingulate cortex, right prefrontal cortex, left cerebellum and right ventroposterior lateral thalamus in the OMT group as compared with Sham. OMT showed a statistically significant negative correlation between baseline High Frequency HRV changes and rCBF changes at T2 in the left posterior insula and bilateral lentiform nucleus. The same brain regions showed a positive correlation between rCBF changes and Low Frequency HRV baseline changes at T2. These findings suggest that OMT can play a significant role in regulating brain–heart interaction mechanisms.

Ryan Christensen & Francesco Cerritelli

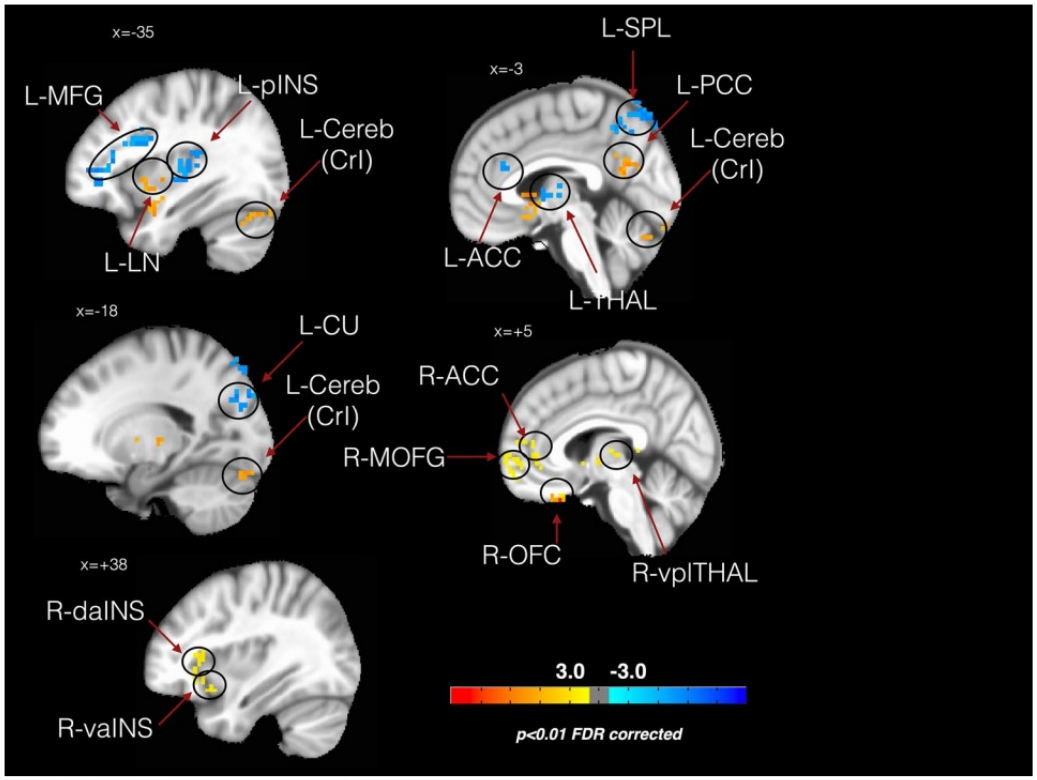

Figure 1. The effects of osteopathic treatment on regional cerebral flow. The figure shows CBF changes baseline-controlled group differences between treatment and sham group at T2 (referring to the contrast described in the text as (T2_OMT–T0_OMT) vs (T2_SHAM–T0_SHAM)—$p < 0.01$, false discovery rate (FDR) corrected). *L-MFG* left middle frontal gyrus, *L-pINS* left posterior insula, *L-LN* left lentiform nucleus, *L-Cereb*(*CrI*) left cerebellum (Crus I), *L-ACC* left anterior cingulate cortex, *L-SPL* left superior parietal lobe, *L-PCC* left posterior cingulate cortex, *L-THAL* left thalamus, *L-CU* left cuneus, *R-ACC* right anterior cingulate cortex, *R-MOFG* right mid orbitofrontal gyrus, *R-OFC* right orbito frontal cortex, *R-vplTHAL* right ventroposterior lateral thalamus, *R-daINS* right dorsal anterior insula, *R-vaINS* right ventral anterior insula.

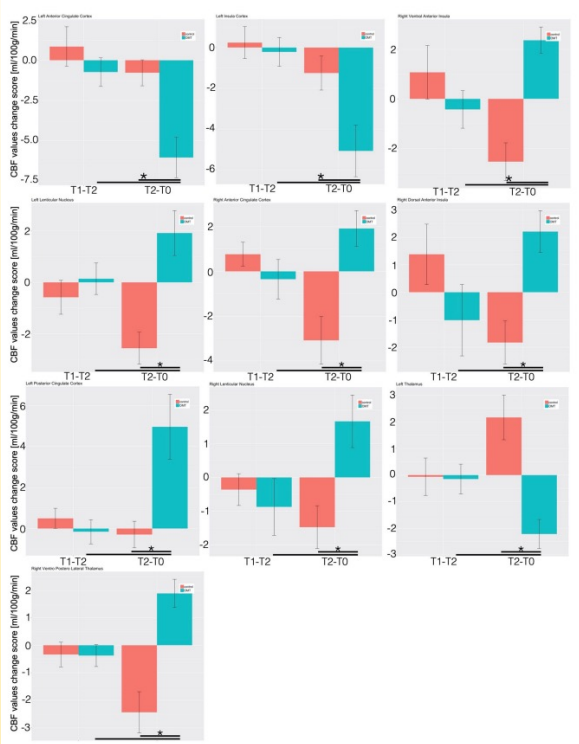

Figure 2. Longitudinal CBF delta changes. The figure shows the longitudinal CBF mean change within the regions of interest for the two groups. *Statistically significant differences ($p < 0.05$) between groups.

Scientific Reports | (2022) 12:4224 | https://doi.org/10.1038/s41598-022-08168-8 nature portfolio

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Communication

An Enactive–Ecological Model to Guide Patient-Centered Osteopathic Care

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Abstract: Osteopaths commonly face complexity and clinical uncertainty in their daily professional practice as primary contact practitioners. In order to effectively deal with complex clinical presentations, osteopaths need to possess well-developed clinical reasoning to understand the individual patient's lived experience of pain and other symptoms and how their problem impacts their personhood and ability to engage with their world. We have recently proposed (En)active inference as an integrative framework for osteopathic care. The enactivist and active inference frameworks underpin our integrative hypothesis. Here, we present a clinically based interpretation of our integrative hypothesis by considering the ecological niche in which osteopathic care occurs. Active inference enables patients and practitioners to disambiguate each other's mental states. The patients' mental states are unobservable and must be inferred based on perceptual cues such as posture, body language, gaze direction and response to touch and hands-on care. A robust therapeutic alliance centred on cooperative communication and shared narratives and the appropriate and effective use of touch and hands-on care enable patients to contextualize their lived experiences. Touch and hands-on care enhance the therapeutic alliance, mental state alignment, and biobehavioural synchrony between patient and practitioner. Therefore, the osteopath–patient dyad provides mental state alignment and opportunities for ecological niche construction. Arguably, this can produce therapeutic experiences which reduce the prominence given to high-level prediction errors—and consequently, the top-down attentional focus on bottom-up sensory prediction errors, thus minimizing free energy. This commentary paper primarily aims to enable osteopaths to critically consider the value of this proposed framework in appreciating the complexities of delivering person-centred care.

check for updates

Citation: Cerritelli, F.; Esteves, J.E. An Enactive–Ecological Model to Guide Patient-Centered Osteopathic Care. *Healthcare* **2022**, *10*, 1092. https://doi.org/10.3390/healthcare10061092

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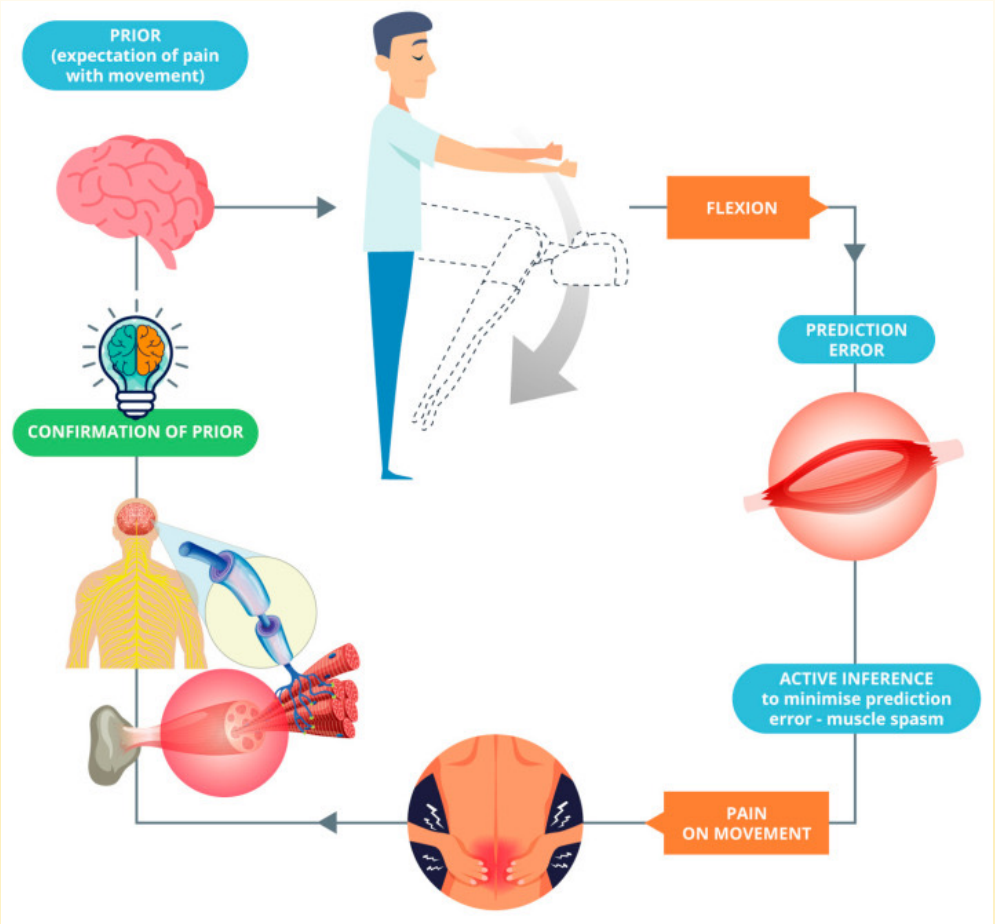

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Figure 1. The expectation of pain (prior) is confirmed by the movement (confirmation of prior through the active inference

New prediction ("The treatment was uncomfortable, but I feel much better") = Old prediction ("movement and touch are painful") + Osteopathic treatment delivered by a trusted practitioner – "I'm in safe hands" (learning rate × Prediction error from interoceptive, exteroceptive and proprioceptive inputs and sense of safety)

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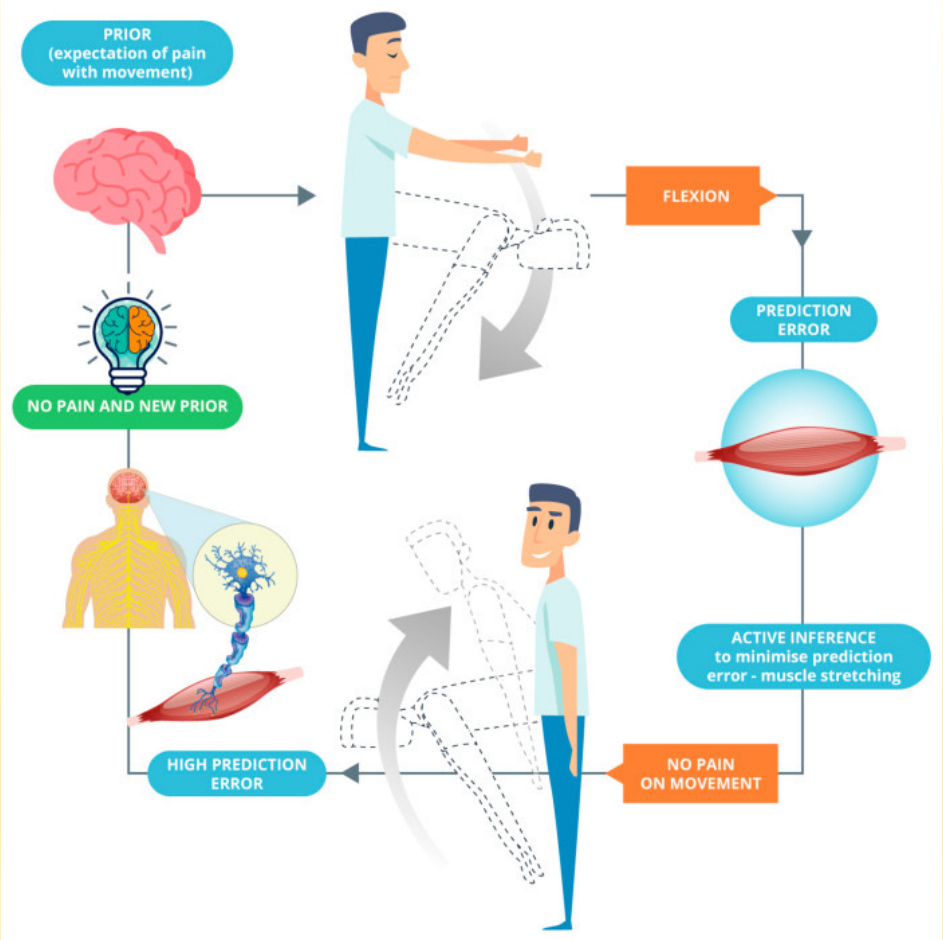
Figure 2- The expectation of pain (prior) is violated by feeling no pain during the movement, generating high prediction error and a new baseline. This is argued to be the cycle established after a manual osteopathic treatment.



"The concepts of body-mind unity, adaptation, and self-regulation are aligned with the principles of sense-making and autopoiesis central to enactivism. Osteopathy should move further and over the concept of a therapy centred to the body, which is informed by, arguably, models of care, including the biomedical. Indeed, human behaviour and function are complex, individual, and difficult to predict.

Ultimately, health and disease should be interpreted within the person's environment, which includes life and the way in which the person interacts with the external world."

Intro Practical:
Getting to the HEART
Self-Treatment & Grounding

G.D. Hulett, B.S., D.O., A Text Book of The Principles of Osteopathy, wrote in 1904:

"When the student, in taking up the study of osteopathy, is told that the osteopath is successful by virtue of his complete knowledge of anatomy and physiology, he glories in the assertion. But when he learns, as he certainly will, that the most expert is equipped with only a meager supply, he is likely to be disappointed

"It is a perennially recurring surprise to the students of the biological sciences, to learn that in comparison with what is yet to be determined, the total bulk of demonstrable fact relating to these sciences is infinitesimal." … "**True, in anatomy we are comparatively well grounded, but our knowledge of physiology and its related sciences is extremely unsatisfactory and must remain so for long. Why need we then apologize for an incomplete statement of the principles of osteopathy?"**

These words were written in 1904 and still apply, so **D**ig **O**n!

The following lecture is intended to review some of the scientific advances made in recent years.


CSF FLOW UPDATES
The GLYMPHATIC SYSTEM
SLYM: A NEW 4th DURAL MEMBRANE

Functions of the Lymphatic System

- Preserve homeostasis working with the interstitial spaces of the extracellular matrix
- Defend against harmful bacteria, fungi, viruses, cancer cells & parasites
- Collect and transport digestive fat, fat-soluble vitamins & amino acids
- Transport white blood cells
- Return excess interstitial fluid to the blood

Lymph is made up of:

- Plasma which leaks through vessel walls and combines with large molecule excess proteins and large particulate matter in the interstitial fluid, so capillaries cannot absorb it, so lymph must enter the lymphatic capillaries to be removed
- As water is reabsorbed sequentially during the movement of lymph towards the venous system, the tissue containing the high concentration of proteins and large particulate matter will be palpably more viscous (compared to arterial or venous fluid)

Tissues still believed not perfused by the lymphatic system:

- Epidermis
- Cornea
- Bone marrow
- Cartilage and endomysium of muscles

Path of lymphatic flow:

- Lymph nodes return more lymph back to the venous system than the thoracic duct and lymphatic duct (which empty into the left and right subclavian veins)
- The right thoracic duct drains the right thorax, upper right limb, head and neck; the left lymphatic duct drains the rest of the body
- The right thoracic duct may have significantly more flow than the left, depending on where between T5 to T9 the thoracic duct transfers across the front of the spine as it brings lymph cephalad from the lower limbs and pelvis

Dynamics of moving fluid into the lymphatic vessel is not passive drainage

- ECM (extracellular matrix) pumps fluid into the lymphatic vessel
- Contractile actomyosin filaments attached to the terminal lymphatics rhythmically push the lymph into the lymphangion
- Lymphangion is the “little heart” of the lymphatic system due to the peristaltic motion it produces and the role that the T-type Ca^{2+} channels play in lymphatic pacemaking
- The ANS, body temperature, caffeine, and hormones affect contractions, too

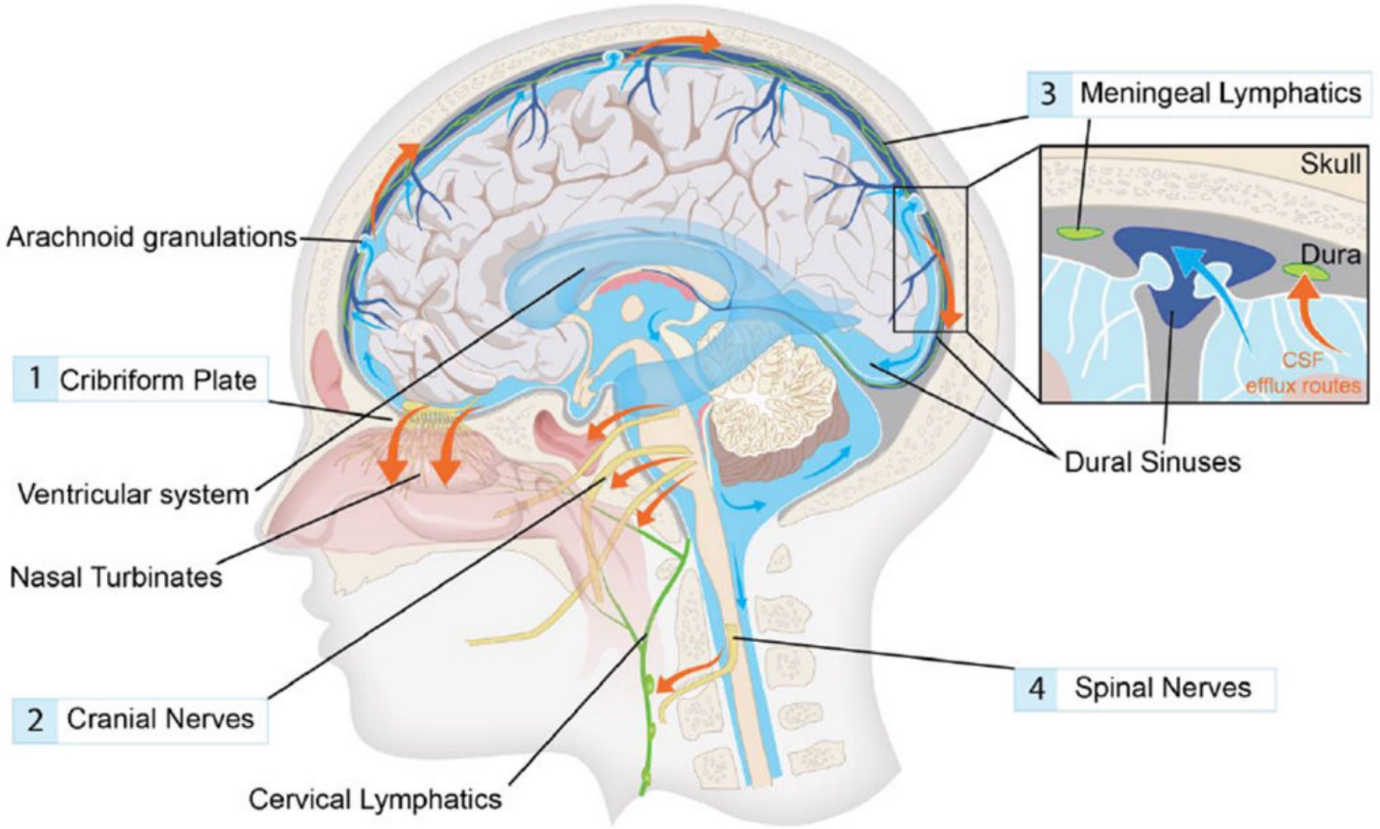
Lymphatic drainage of the heart

- The heart has a continuous spiral wringing motion that pushes lymph out into atypical, valveless channels
- Most of the drainage is from the left ventricle and it ends up in the right lymphatic duct
- The right side of the heart lymphatic drainage is more variable, but ends in the left lymphatic duct, allowing the twisting of the heart to wring out lymphatic fluids from the myocardium

Lymphatic drainage to the heart: consideration in treatment of cardiac damage

- Infarction of the R interventricular area → impacts drainage up to the bundle of His and the AV node, which drains into the left thoracic duct and resultant lymphedema may cause delays in AV conduction
- The sinoatrial node drains into the right lymphatic duct
- Pericardium drains mostly to the left thoracic duct
- Mitral valve drains left thoracic duct; tricuspid valve drains to right thoracic duct
- Myocardial Infarction results in lymphangiogenesis, with resultant fibrotic scar, which may be lessened with VEGFC-C156S

Lymphatic drainage of the Brain



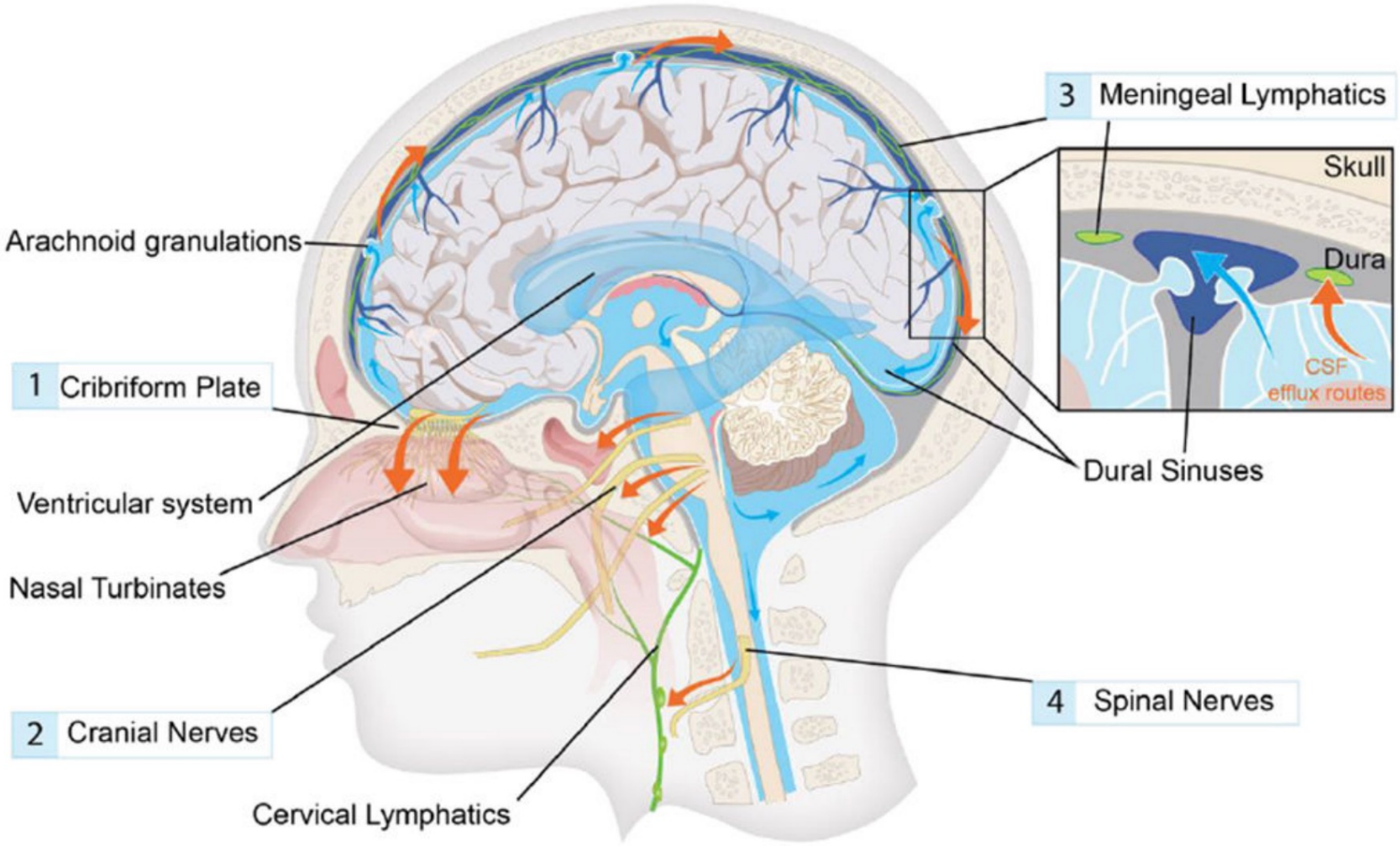
The glymphatic pathway in neurological disorders.

Martin Kaag Rasmussen#1, Humberto Mestre#2,3, and Maiken Nedergaard1,2,3,* 1Center for Translational Neuromedicine, Faculty of Health and Medical Sciences, University of Copenhagen, 2200, Copenhagen, Denmark 2Center for Translational Neuromedicine, Department of Neurosurgery, University of Rochester Medical Center, Rochester, NY 14642, USA 3Department of Neuroscience, University of Rochester Medical Center, Rochester, NY 14642, USA

https://pmc.ncbi.nlm.nih.gov/articles/PMC6261373/pdf/nihms-995539.pdf

Figure 2. Cerebrospinal fluid efflux in humans.

Cerebrospinal fluid (CSF) produced in the choroid plexus flows from the ventricles to the subarachnoid space of the brain and spinal cord. CSF contained in the subarachnoid space keeps the central nervous system buoyant and serves as a fluid source for glymphatic influx. Egress sites of cranial cerebrospinal fluid (red arrows) fall into three functionally distinct categories, namely the perineural sheaths surrounding cranial and spinal nerves,[20,24] dural lymphatic vessels,[18,19,] and arachnoid granulations.[1] The contribution and significance of each egress pathway is still a matter of debate. A main perineural egress site in both rodents and human is along the olfactory nerve through the cribriform plate (1) towards lymphatic vessels of the nasal mucosa.[16,20] From here the CSF is drained to the cervical lymph nodes.[43] Other significant perineural efflux pathways in rodents are the trigeminal, the glossopharyngeal, vagal, and spinal accessory nerves (2).[20] Dural lymphatic vessels have also been shown to carry CSF towards the cervical lymphatic system (3). In rodents, these vessels exit the skull along the pterygopalatine artery, the veins that drain the sigmoid sinus and retroglenoid vein, and the foramina of the cranial nerves.[18,19] In humans, meningeal lymphatic vessels have been visualized with MRI and were located around the dural sinuses, middle meningeal artery and cribiform plate.[25] Arachnoid granulations are protrusions of the arachnoid membrane where CSF flows into the sagittal sinus, and constitute the only known egress site that drains directly to the blood stream.[1] Traditionally, this site was thought to be the main cerebrospinal fluid egress site, but evidence suggests that under physiological intracranial pressure virtually no CSF leaves to the blood stream.[1] The main egress site of CSF in the spinal cord is along the spinal nerves (4).


3 Meningeal Lymphatics
Skull
Dura
CSF
efflux routes
Arachnoid granulations
1 Cribriform Plate
Ventricular system
Nasal Turbinates
Dural Sinuses
2 Cranial Nerves
Cervical Lymphatics
4 Spinal Nerves

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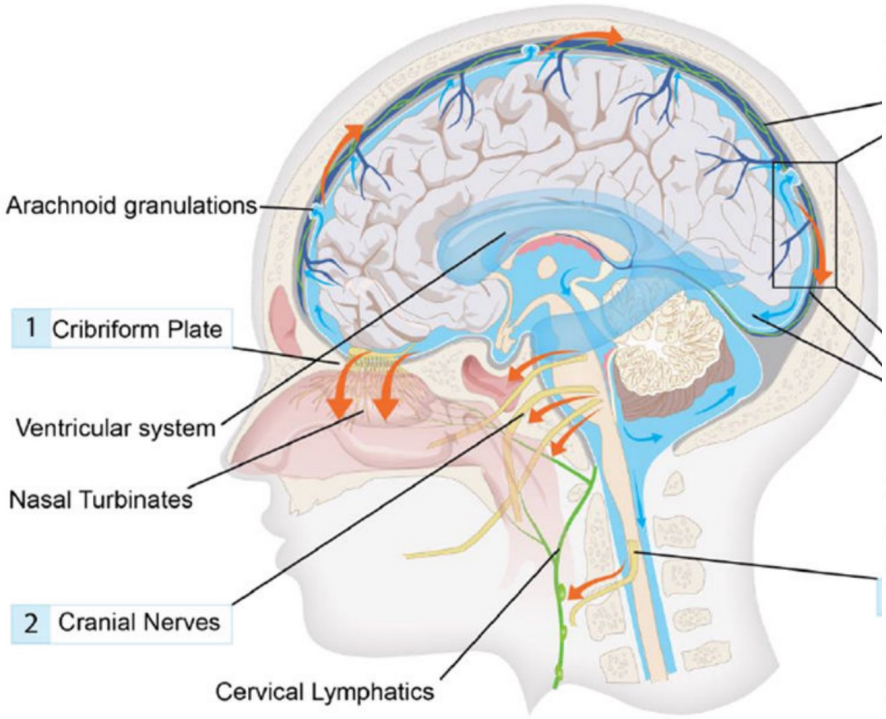
Rasmussen et al.



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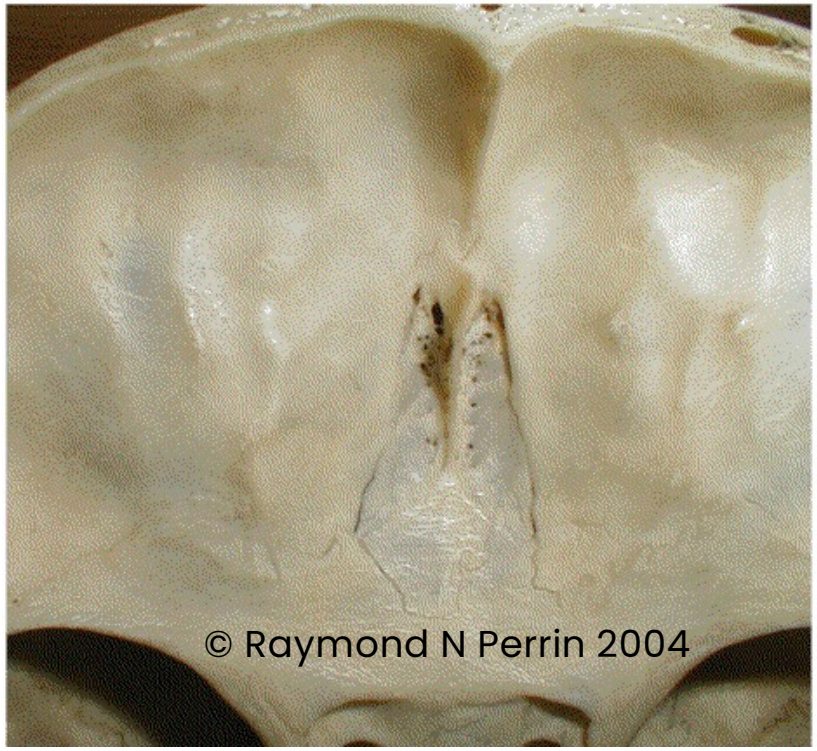
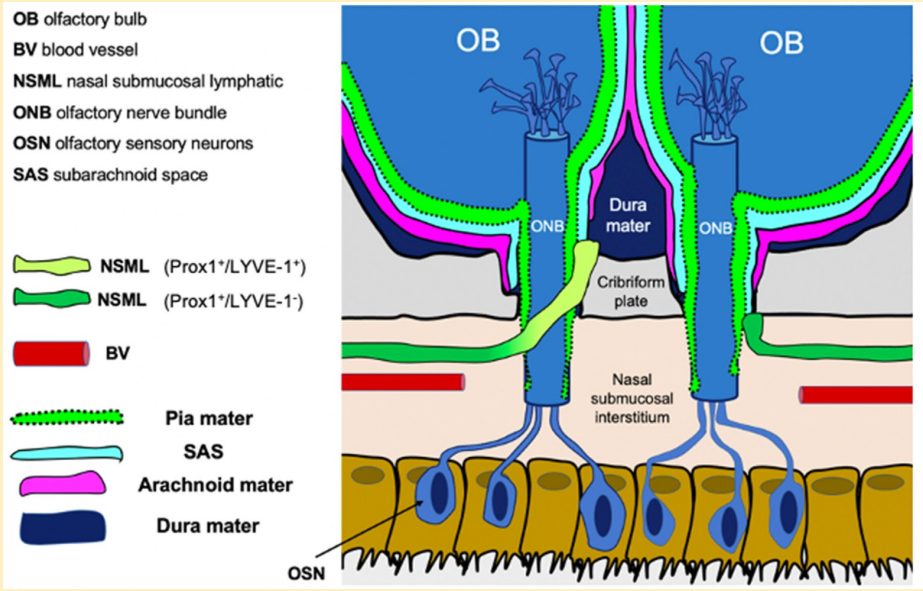
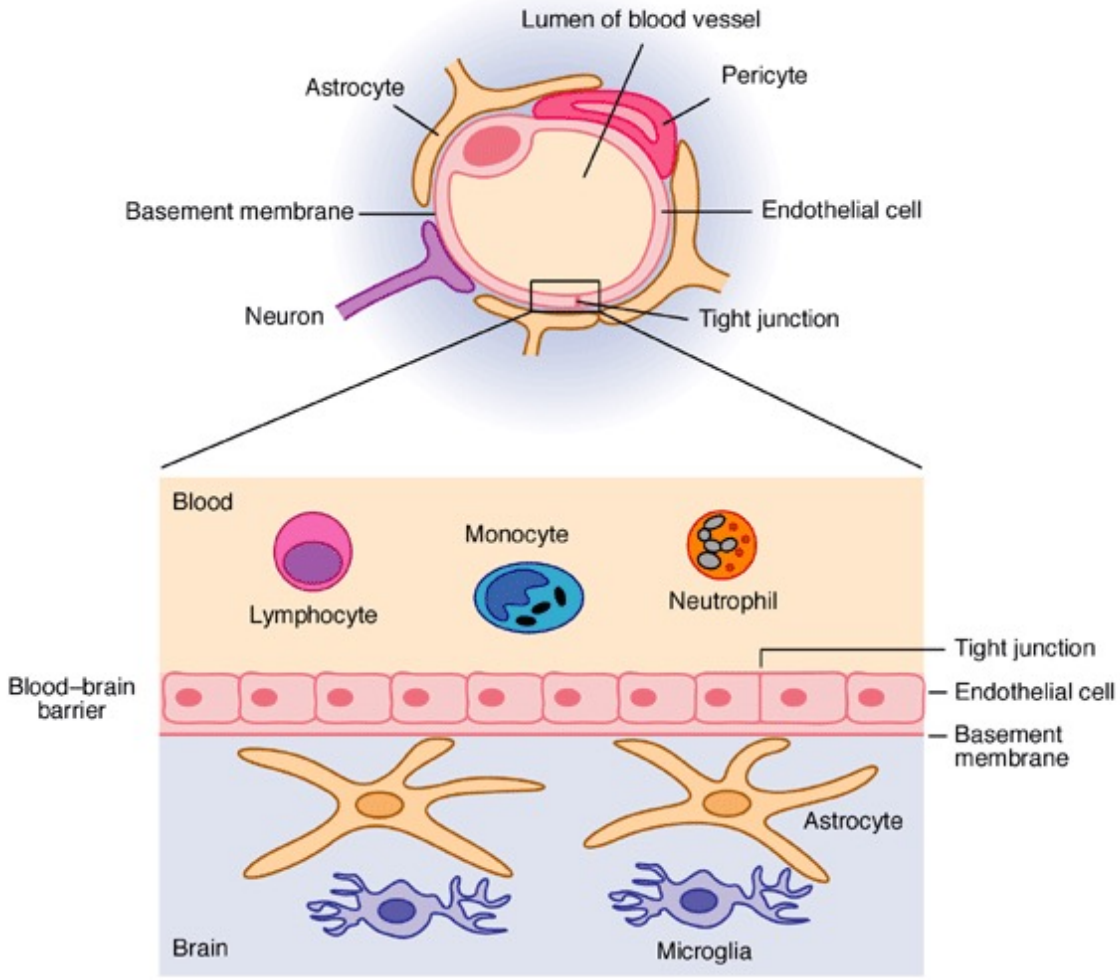
CRIBIFORM PLATE AND CSF DRAINAGE

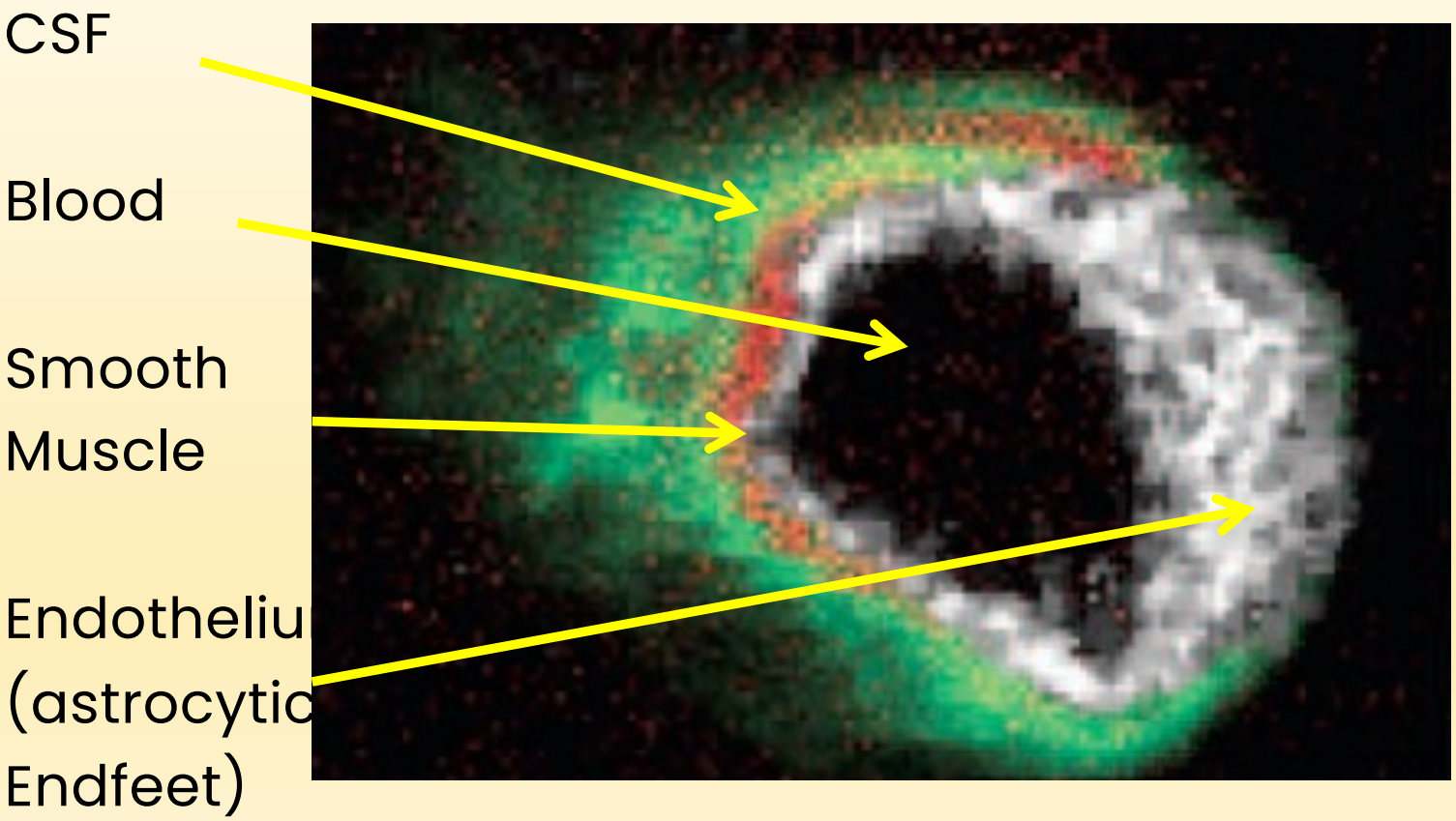


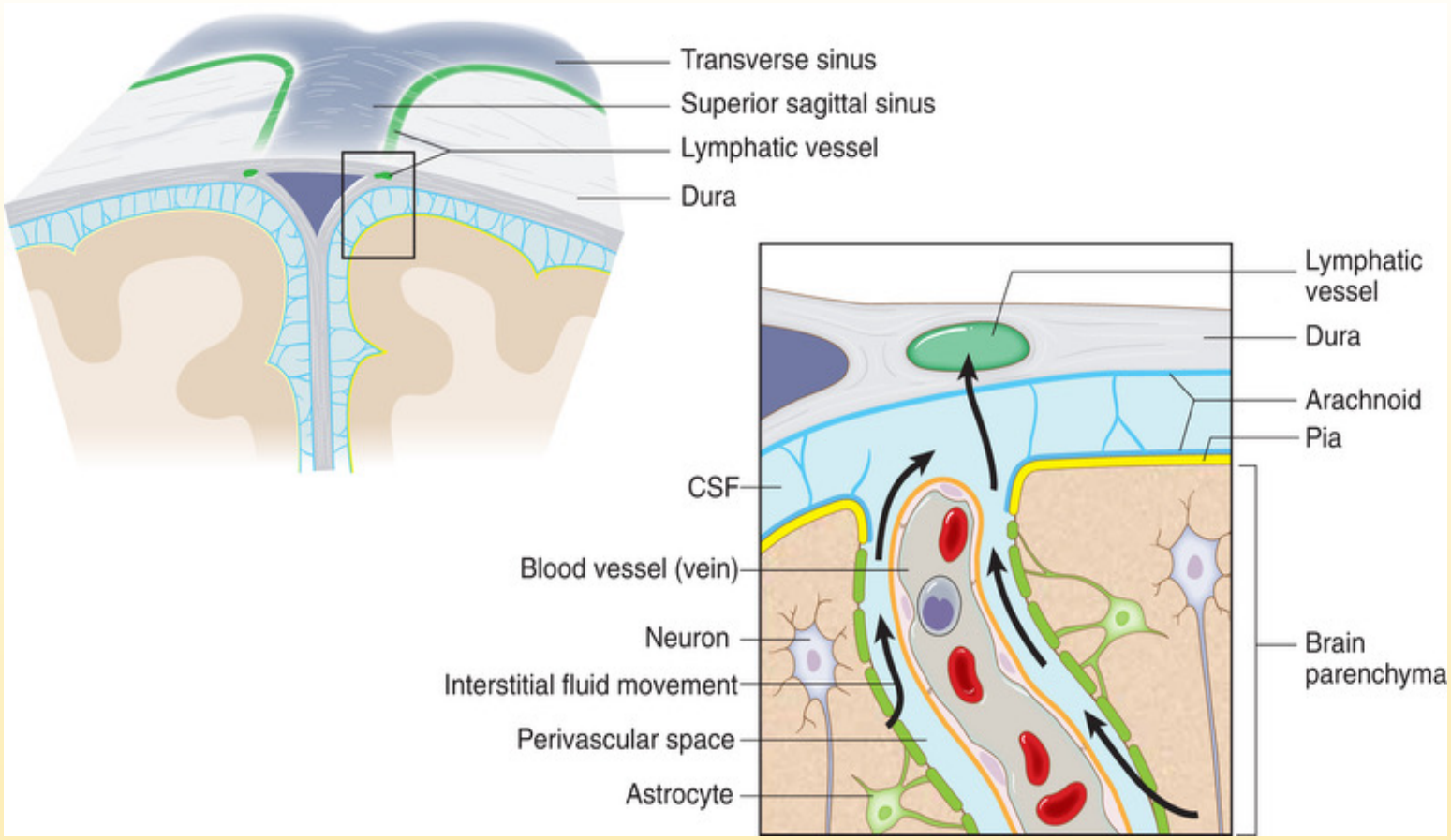
SPERA IN 2023 VIA IMMUNOFLUORESCENT PROBES
INITIALLY IN MICE AND NOW IN HUMANS





The blood–brain barrier (BBB)


CSF
Blood
Smooth
Muscle
Endotheliu
(astrocytic
Endfeet)

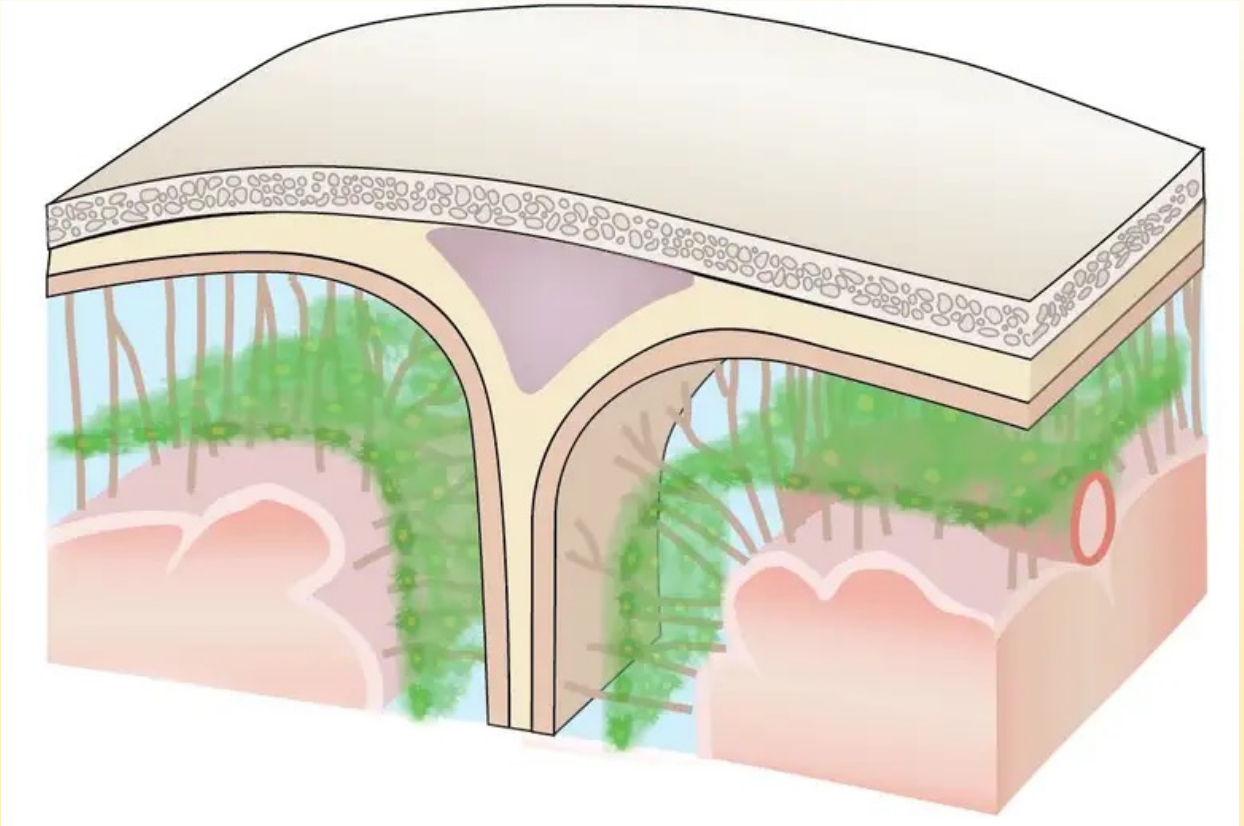


Antoine Louveau et al. **Structural and functional features of central nervous system lymphatic vessels**. *Nature*, 2015; DOI: 10.1038/nature14432

The SLYM (Subarachnoid Lymphatic-Like Membrane)

Cross section of the skull (top) and outer layer of the brain, showing the subarachnoid lymphatic-like membrane in green
A cross-section of the skull (top) and the outer layer of the brain, showing the subarachnoid lymphatic-like membrane in green

University of Copenhagen



The Glymphatic System

- An extra layer lines the brain The traditional view is that the brain is surrounded by three layers, the dura, arachnoid, and pia mater.
- Møllgård et al. found a fourth meningeal layer called the subarachnoid lymphatic-like membrane (SLYM).
- SLYM is immunophenotypically distinct from the other meningeal layers in the human and mouse brain and represents a tight barrier for solutes of more than 3 kilodaltons, effectively subdividing the subarachnoid space into two different compartments.
- SLYM is the host for a large population of myeloid cells, the number of which increases in response to inflammation and aging, so this layer represents an innate immune niche ideally positioned to surveil the cerebrospinal fluid

Reference:

Møllgård K, Beinlich F , Kusk P et al.
A mesothelium divides the subarachnoid space into functional compartments.
Science
2023 Jan 6;379(6627):84-88. doi:10.1126/science.adc8810. Epub 2023 Jan 5.

It is extremely thin, with a width of just a few cells or, in places, even one cell. The SLYM hadn’t been noticed before, partly because the membrane disintegrates when the brain is removed from the skull in post-mortems, says Maiken Nedergaard at the University of Rochester Medical Center in New York.

Functionally, the closeness of SLYM with the endothelial lining of the meningeal venous sinus permits direct exchange of small solutes between cerebrospinal fluid and venous blood, The functional characterization of SLYM provides fundamental insights into brain immune barriers and fluid transport.

Current CSF Drainage Understanding (BEFORE)

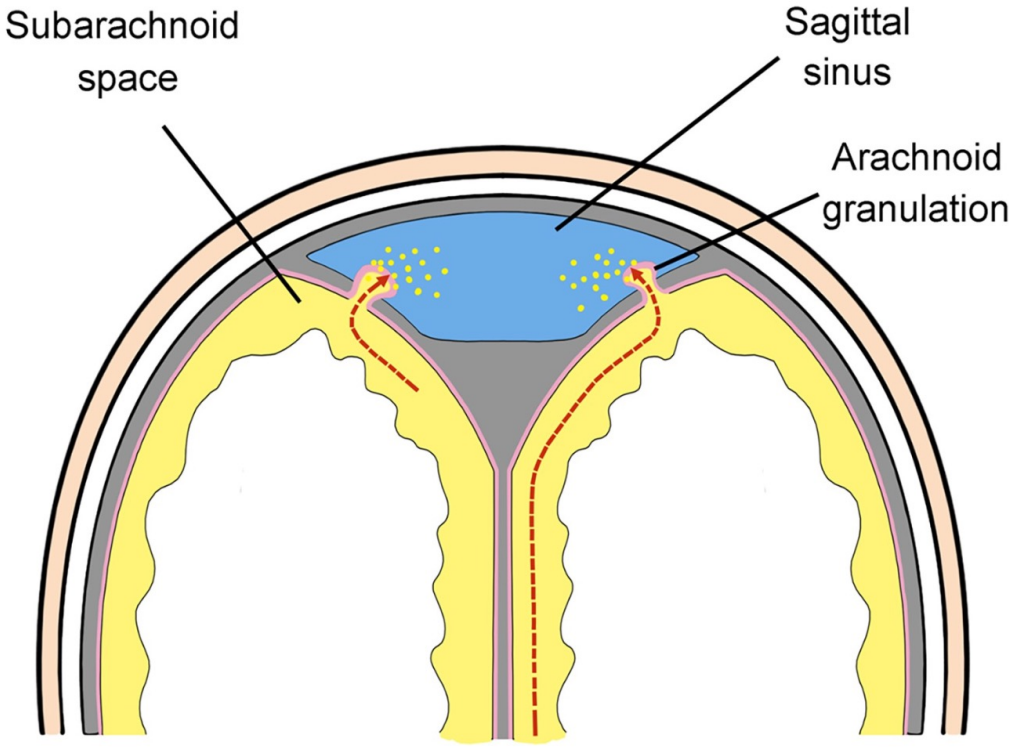


Fig 1. Cross-section diagram of the accepted model of CSF drainage in humans. CSF (yellow) in the subarachnoid space is thought to diffuse through protrusions of the arachnoid meninges (arachnoid granulations) into the sagittal sinus vein (blue).

https://doi.org/10.1371/journal.pone.0285269.g001

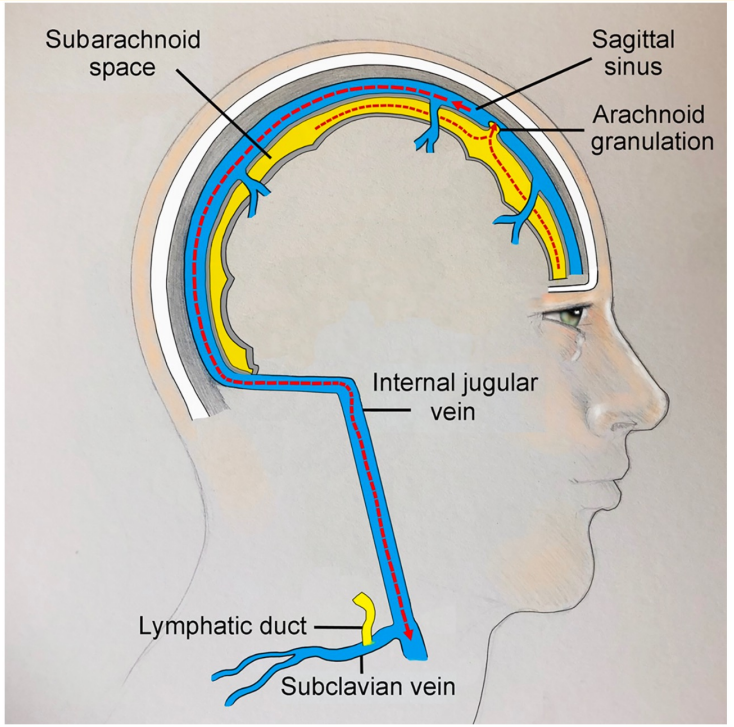


Fig 2. Sagittal view of the current model of CSF drainage. CSF (yellow) drains from the subarachnoid space through arachnoid granulations into the sagittal sinus vein (blue). Sagittal sinus venous blood exits the cranium through the jugular foramen to enter the internal jugular vein.

https://doi.org/10.1371/journal.pone.0285269.g002

RESEARCH ARTICLE

Identification of a novel path for cerebrospinal fluid (CSF) drainage of the human brain

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Abstract

How cerebrospinal fluid (CSF) drains from the human brain is of paramount importance to cerebral health and physiology. Obstructed CSF drainage results in increased intra-cranial pressure and a predictable cascade of events including dilated cerebral ventricles and ultimately cell death. The current and accepted model of CSF drainage in humans suggests CSF drains from the subarachnoid space into the sagittal sinus vein. Here we identify a new structure in the sagittal sinus of the human brain by anatomic cadaver dissection. *The CSF canalicular system* is a series of channels on either side of the sagittal sinus vein that communicate with subarachnoid cerebrospinal fluid via Virchow-Robin spaces. Fluorescent injection confirms that these channels are patent and that flow occurs independent of the venous system. Fluoroscopy identified flow from the sagittal sinus to the cranial base. We verify our previous identification of CSF channels in the neck that travel from the cranial base to the subclavian vein. Together, this information suggests a novel path for CSF drainage of the human brain that may represent the primary route for CSF recirculation. These findings have implications for basic anatomy, surgery, and neuroscience, and highlight the continued importance of gross anatomy to medical research and discovery.

OPEN ACCESS

Citation: Pessa JE (2023) Identification of a novel path for cerebrospinal fluid (CSF) drainage of the human brain. PLoS ONE 18(5): e0285269. https://doi.org/10.1371/journal.pone.0285269

Editor: Alvan Ukachukwu, Duke University Medical Center: Duke University Hospital, UNITED STATES

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Fig 3. Demonstration of the venous sagittal sinus. The sagittal sinus is a midline venous structure (between arrows) in the dura. CSF channels travel on either side of this venous sinus.

https://doi.org/10.1371/journal.pone.0285269.g003

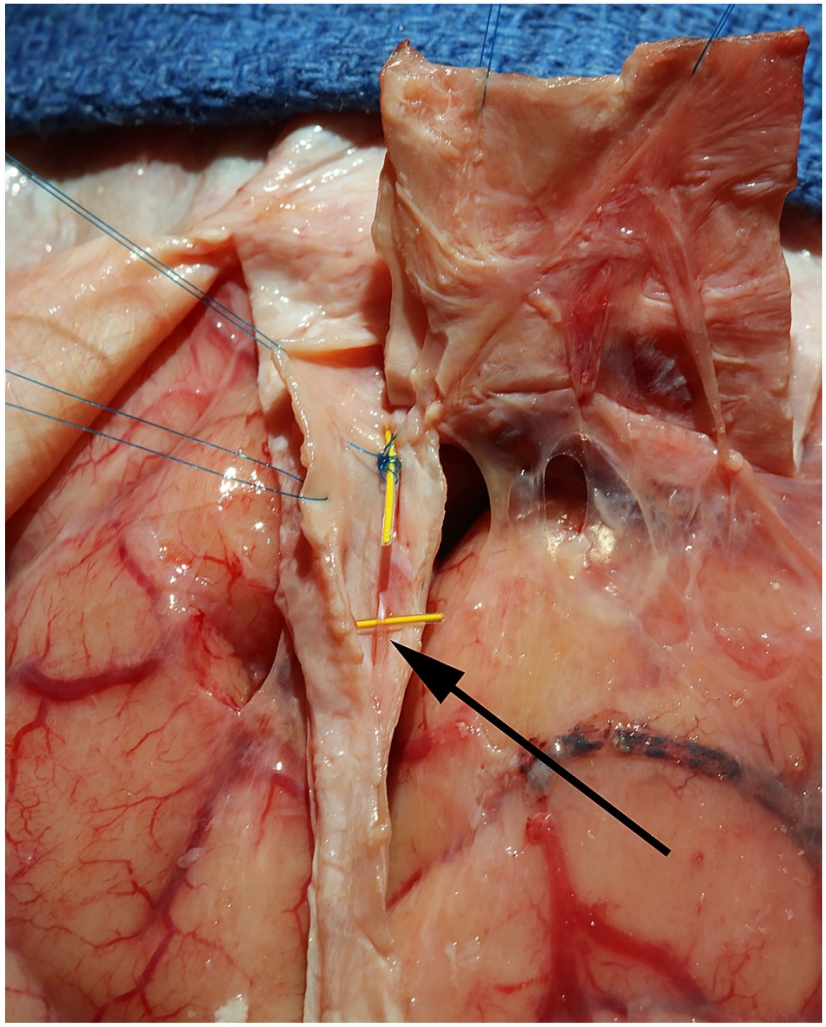

Fig 4. CSF channels in the sagittal sinus. Blood was evacuated from the venous sagittal sinus and is held open with blue sutures. The right CSF channel system (arrow) is identified over the yellow marker in a 90's year-old female specimen.

https://doi.org/10.1371/journal.pone.0285269.g004

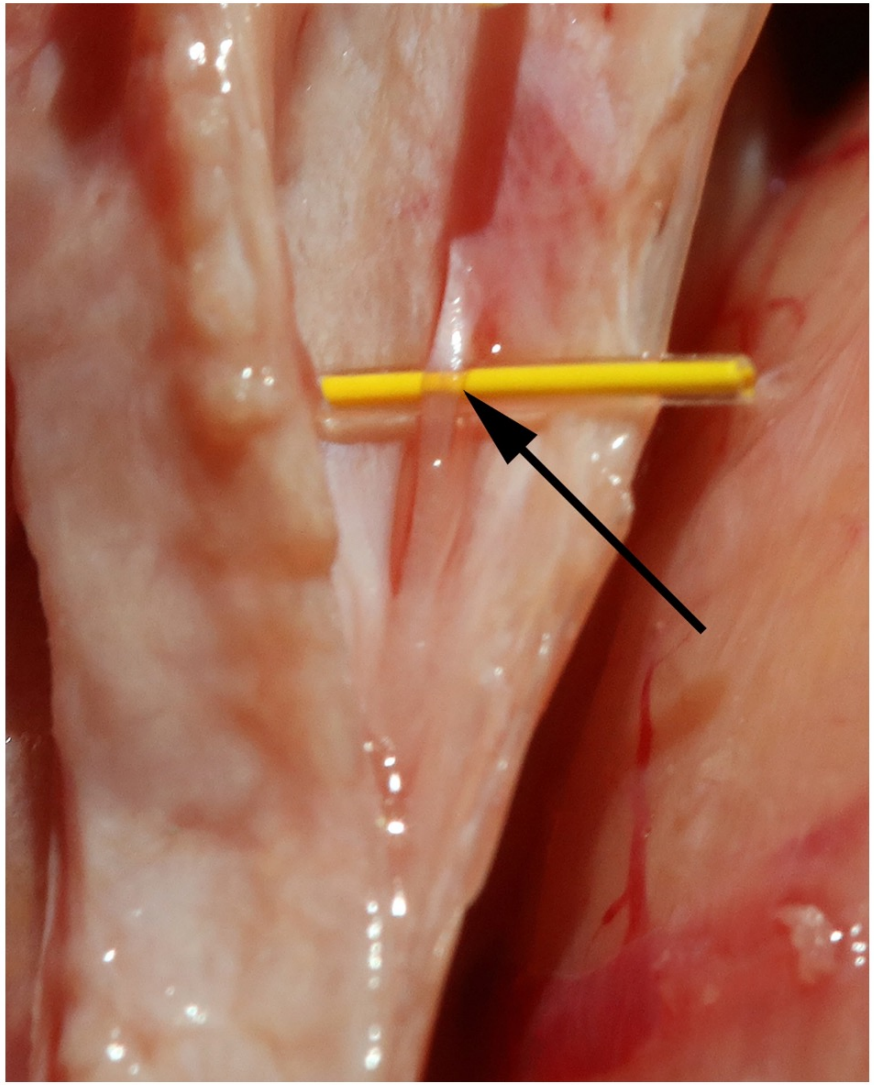

Fig 5. CSF channels in the sagittal sinus. This is a macro view of CSF channels (arrow) in the sagittal sinus.

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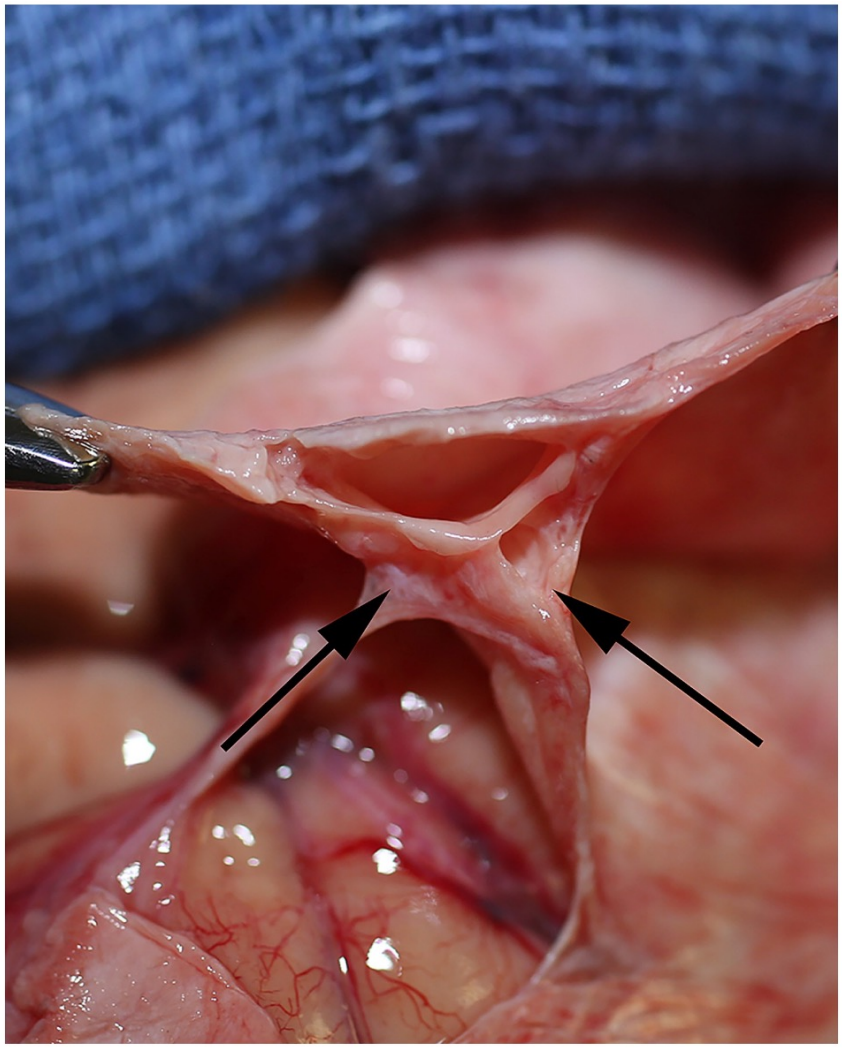


Fig 7. CSF channels in the sagittal sinus. Clamps suspend dura and show the empty venous sinus and bilateral CSF channels (arrows). The right side is widely patent, whereas the left has been obliterated by infiltrating carcinoma. The arachnoid meninges travel to these CSF channels.

https://doi.org/10.1371/journal.pone.0285269.g007

Table 1. Characterization of the CSF canalicular system. The CSF canalicular system provides an anatomic route for CSF drainage directly from the arachnoid meninges to the subclavian vein, and is independent of the venous sagittal sinus.

Privileged	Does not involve intermediary lymphatics or blood vessels
Direct route	From arachnoid meninges to the subclavian vein
May be primary path	Secondary path to scalp lymphatics and lymph nodes
Drains to subclavian vein	CSF recycled into the vascular circulation
Analogous to nerves	Terminal CSF drainage of both brain and nerves is subclavian vein
Canalicular structure	Channels are embedded in surrounding tissue
Plexiform	Travel as a group of channels
Lack valves / muscular wall	Usually single-cell layer thickness

https://doi.org/10.1371/journal.pone.0285269.t001

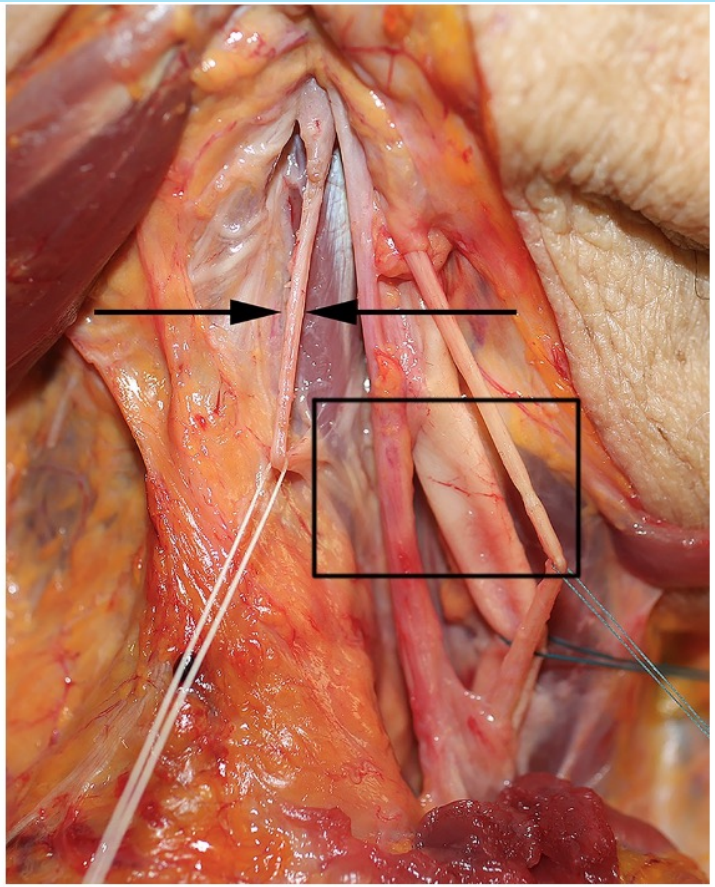


Fig 18. Cervical CSF system. Neck dissection in an 80's year-old female specimen verifies the terminal CSF drainage system in the neck (arrow). The structures of the carotid sheath are seen in the rectangle and include (from left to right) the internal jugular vein, carotid artery, and vagus nerve.

https://doi.org/10.1371/journal.pone.0285269.g018

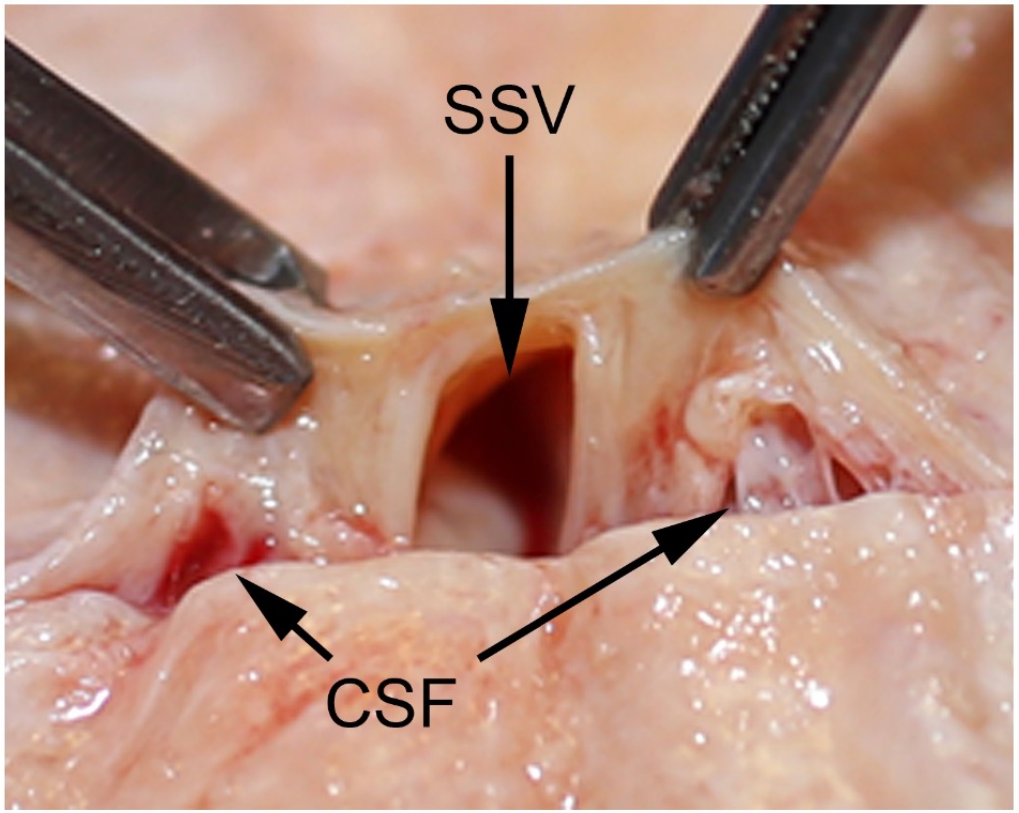


Fig 22. The location of CSF canalicular system relative to the venous sagittal sinus. Macro view shows the centrally-located sagittal sinus vein (SSV) accompanied by CSF channels (CSF) located on either side.

https://doi.org/10.1371/journal.pone.0285269.g022

PESSA CSF CANALICULAR SYSTEM INCLUDED (AFTER) NEW GROSS ANATOMY SYSTEM FOUND 2023

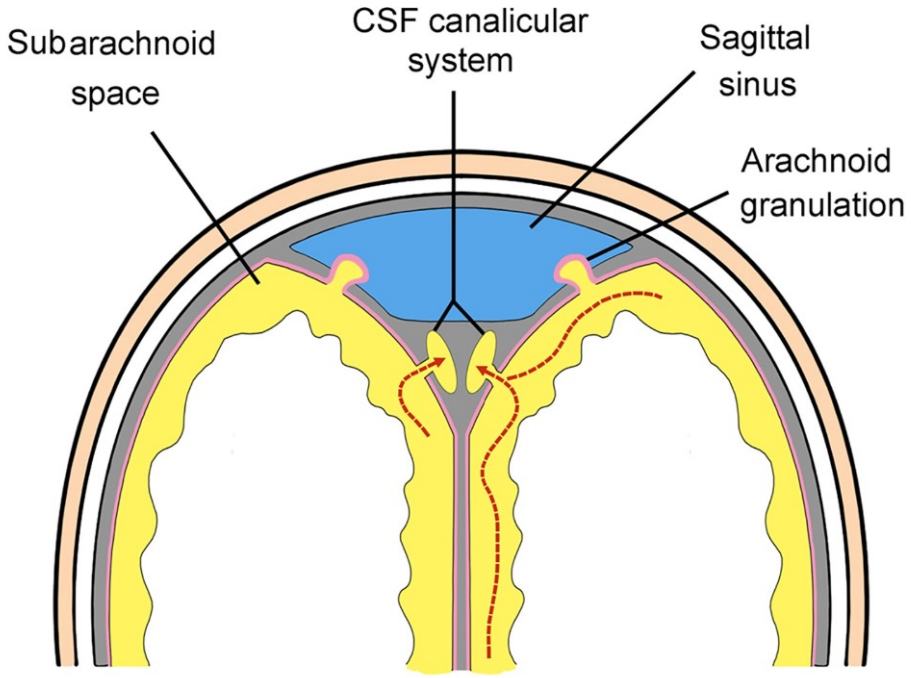


Fig 19. A cross-section diagram of the CSF canalicular system. The CSF canalicular system is located on either side of the venous sagittal sinus. CSF (yellow) flows from the subarachnoid space into CSF channels.

https://doi.org/10.1371/journal.pone.0285269.g019

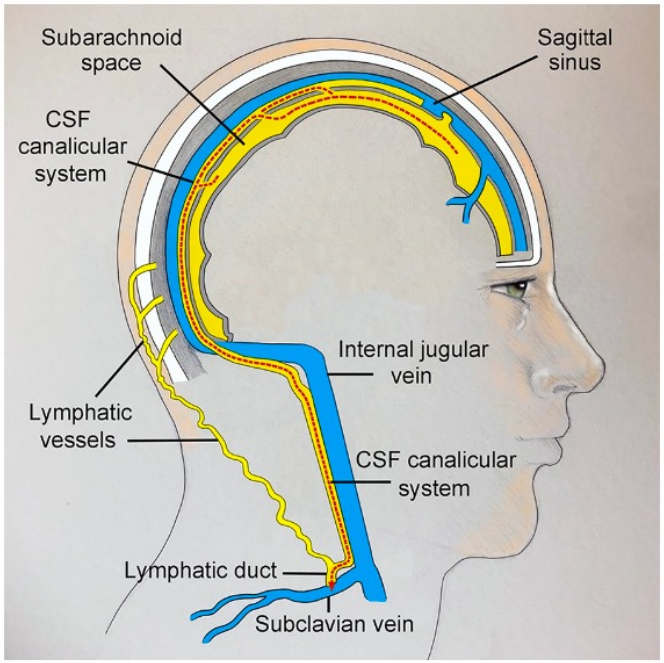
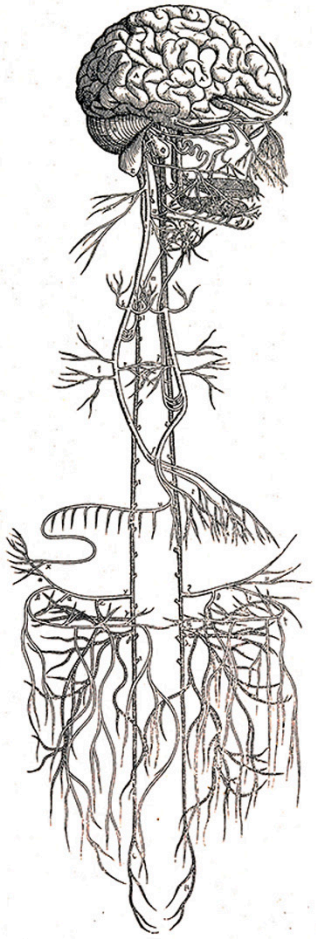


Fig 20. Sagittal view of the CSF canalicular system. The CSF canalicular system provides an anatomic CSF (yellow) to drain from the subarachnoid space directly to the subclavian vein.

https://doi.org/10.1371/journal.pone.0285269.g020



Human and nonhuman primate meninges harbor lymphatic vessels that can be visualized noninvasively by MRI

Martina Absinta[1†], Seung-Kwon Ha[1†], Govind Nair[1], Pascal Sati[1], Nicholas J Luciano[1], Maryknoll Palisoc[2], Antoine Louveau[3], Kareem A Zaghloul[4], Stefania Pittaluga[2], Jonathan Kipnis[3], Daniel S Reich[1]*

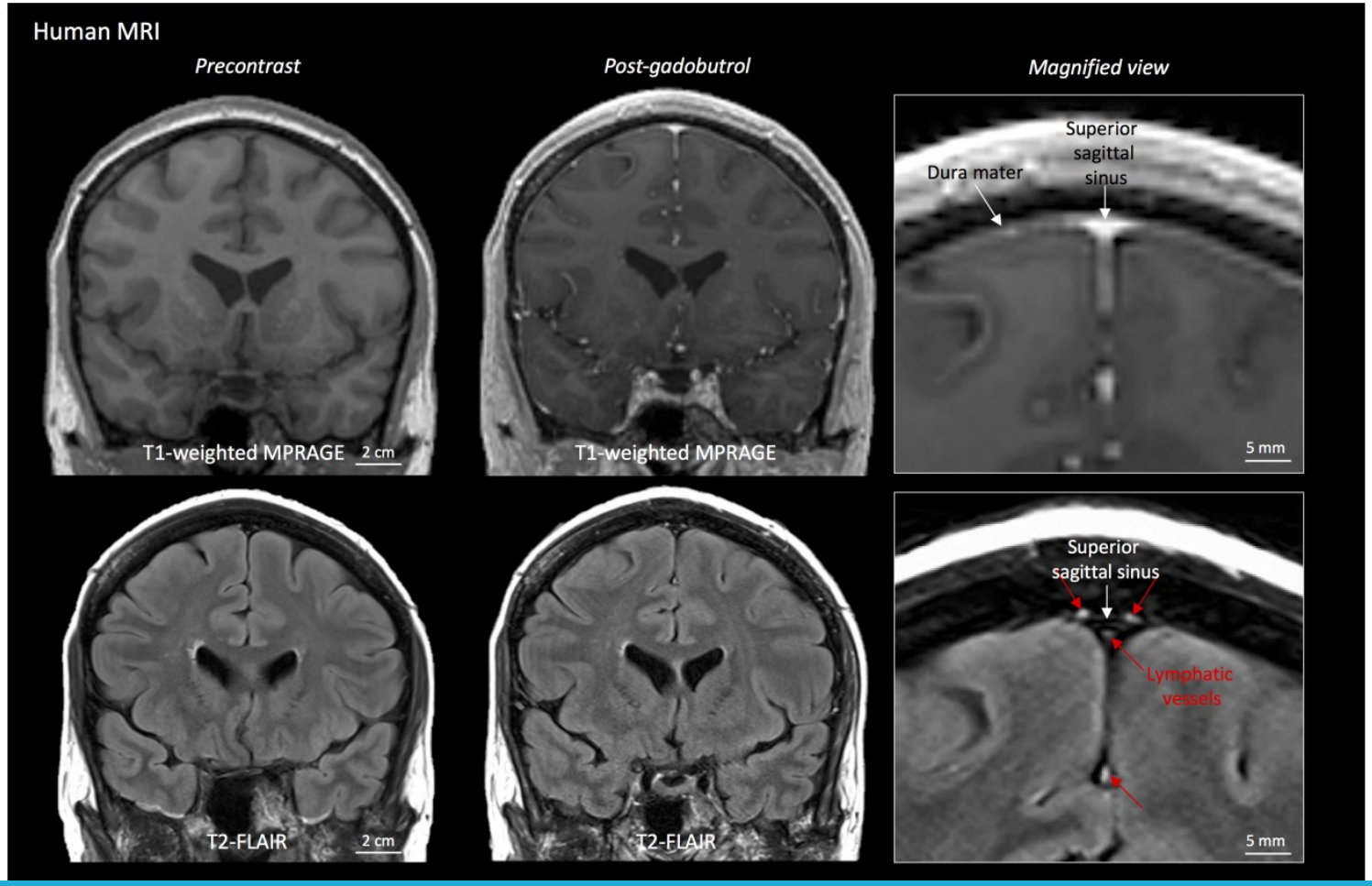
[1]Translational Neuroradiology Section, National Institute of Neurological Disorders and Stroke, National Institutes of Health, Bethesda, United States; [2]Hematopathology Section, Laboratory of Pathology, National Cancer Institute, National Institutes of Health, Bethesda, United States; [3]Center for Brain Immunology and Glia, Department of Neuroscience, School of Medicine, University of Virginia, Charlottesville, United States; [4]Surgical Neurology Branch, National Institute of Neurological Disorders and Stroke, National Institutes of Health, Bethesda, United States

Abstract Here, we report the existence of meningeal lymphatic vessels in human and nonhuman primates (common marmoset monkeys) and the feasibility of noninvasively imaging and mapping them in vivo with high-resolution, clinical MRI. On T2-FLAIR and T1-weighted black-blood imaging, lymphatic vessels enhance with gadobutrol, a gadolinium-based contrast agent with high propensity to extravasate across a permeable capillary endothelial barrier, but not with gadofosveset, a blood-pool contrast agent. The topography of these vessels, running alongside dural venous sinuses, recapitulates the meningeal lymphatic system of rodents. In primates, meningeal lymphatics display a typical panel of lymphatic endothelial markers by immunohistochemistry. This discovery holds promise for better understanding the normal physiology of lymphatic drainage from the central nervous system and potential aberrations in neurological diseases.

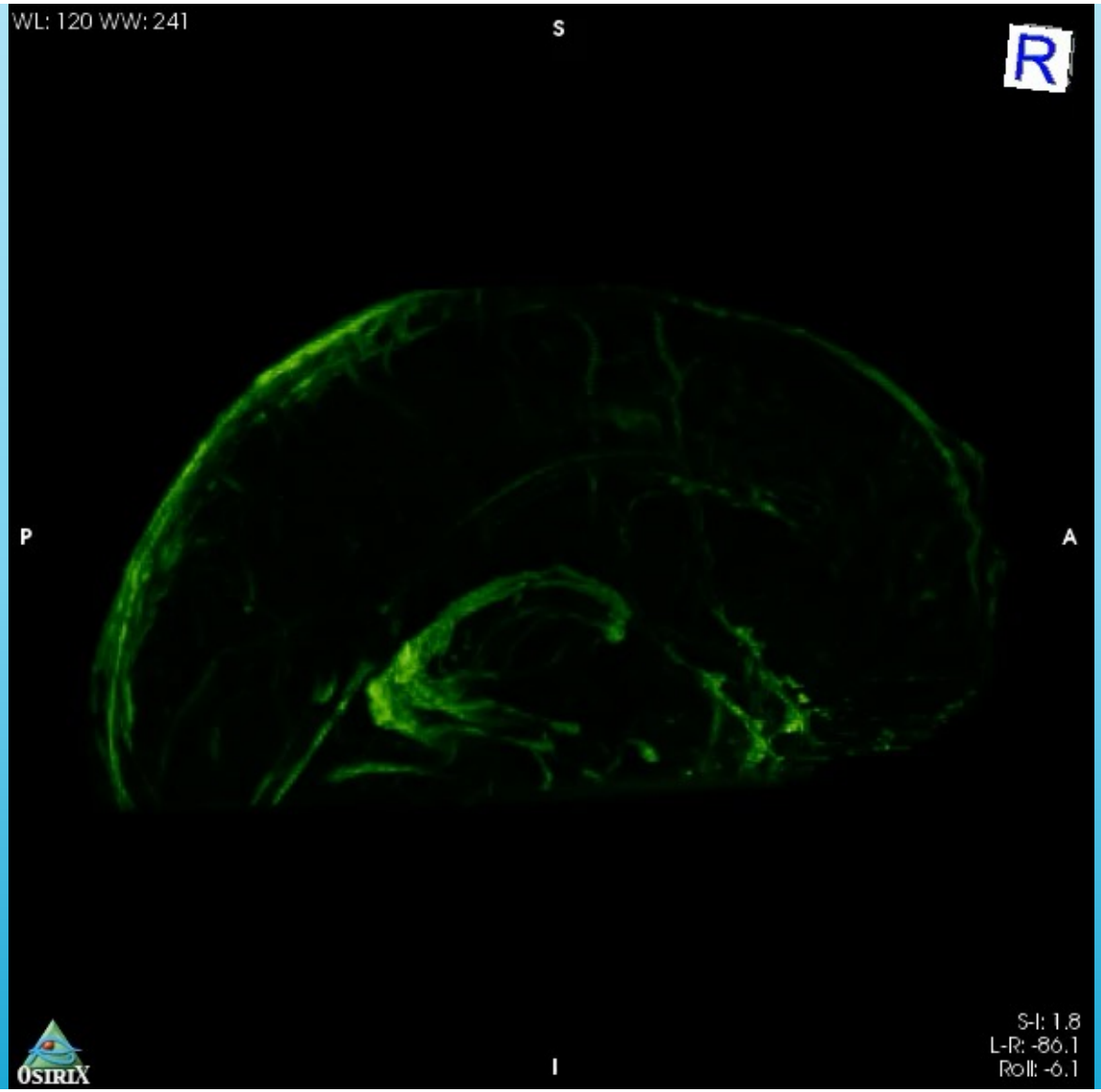
DOI: https://doi.org/10.7554/eLife.29738.001

Martina Absinta, Seung-Kwon Ha, Govind Nair, Pascal Sati, Nicholas J Luciano, Maryknoll Palisoc, Antoine Louveau, Kareem A Zaghloul, Stefania Pittaluga, Jonathan Kipnis, Daniel S Reich (2017) Human and nonhuman primate meninges harbor lymphatic vessels that can be visualized noninvasively by MRI eLife 6:e29738

https://doi.org/


Human MRI
Precontrast
Post-gadobutrol
Magnified view
Dura mater
Superior sagittal sinus
T1-weighted MPRAGE
2 cm
T1-weighted MPRAGE
5 mm
Superior sagittal sinus
Lymphatic vessels
T2-FLAIR
2 cm
T2-FLAIR
5 mm

3D-rendering of dural lymphatics (green) in a 47 year old woman from skull-stripped subtraction T1-black-blood images (horizontal view, 180 degrees, 7 frames/minute).
https://doi.org/10.7554/eLife.29738.014

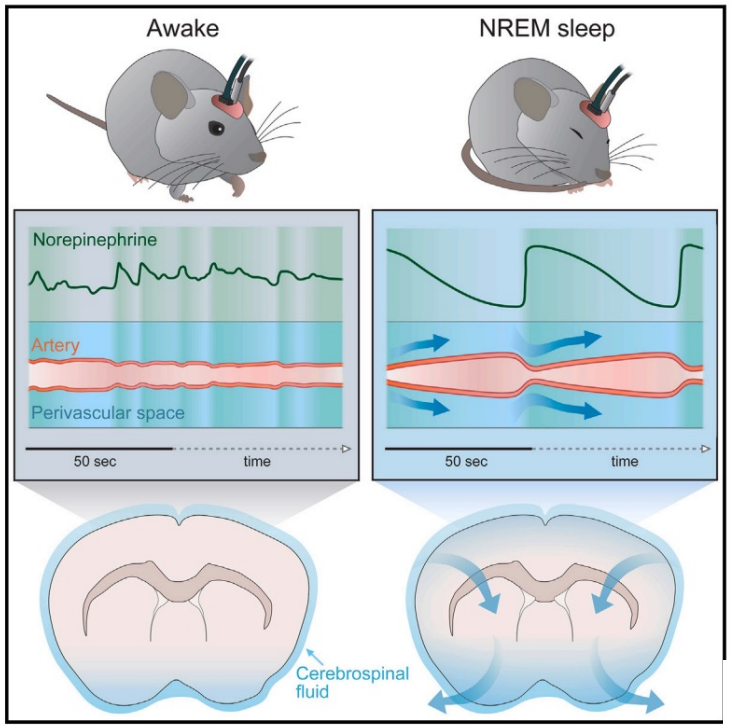


Cell

Article

Norepinephrine-mediated slow vasomotion drives glymphatic clearance during sleep

Graphical abstract



Authors

Natalie L. Hauglund, Mie Andersen, Klaudia Tokarska, ..., Pia Weikop, Hajime Hirase, Maiken Nedergaard

Correspondence

nedergaard@sund.ku.dk

In brief

Norepinephrine oscillations during NREM sleep drive synchronized changes in cerebral blood volume and cerebrospinal fluid, promoting glymphatic clearance. Optogenetic and pharmacological manipulations confirm that vasomotion, regulated by norepinephrine, acts as a pump for brain fluid transport.

Highlights

- Norepinephrine release from the locus coeruleus drives slow vasomotion in NREM sleep
- Infraslow norepinephrine oscillations control opposing changes in blood and CSF volumes
- Norepinephrine oscillation frequency during NREM sleep predicts glymphatic clearance
- The sleep aid zolpidem suppresses norepinephrine oscillations and glymphatic flow

Hauglund et al., 2025, Cell *188*, 606–622
February 6, 2025
https://doi.org/10.1016/j.cell.2024.11.027

CellPress

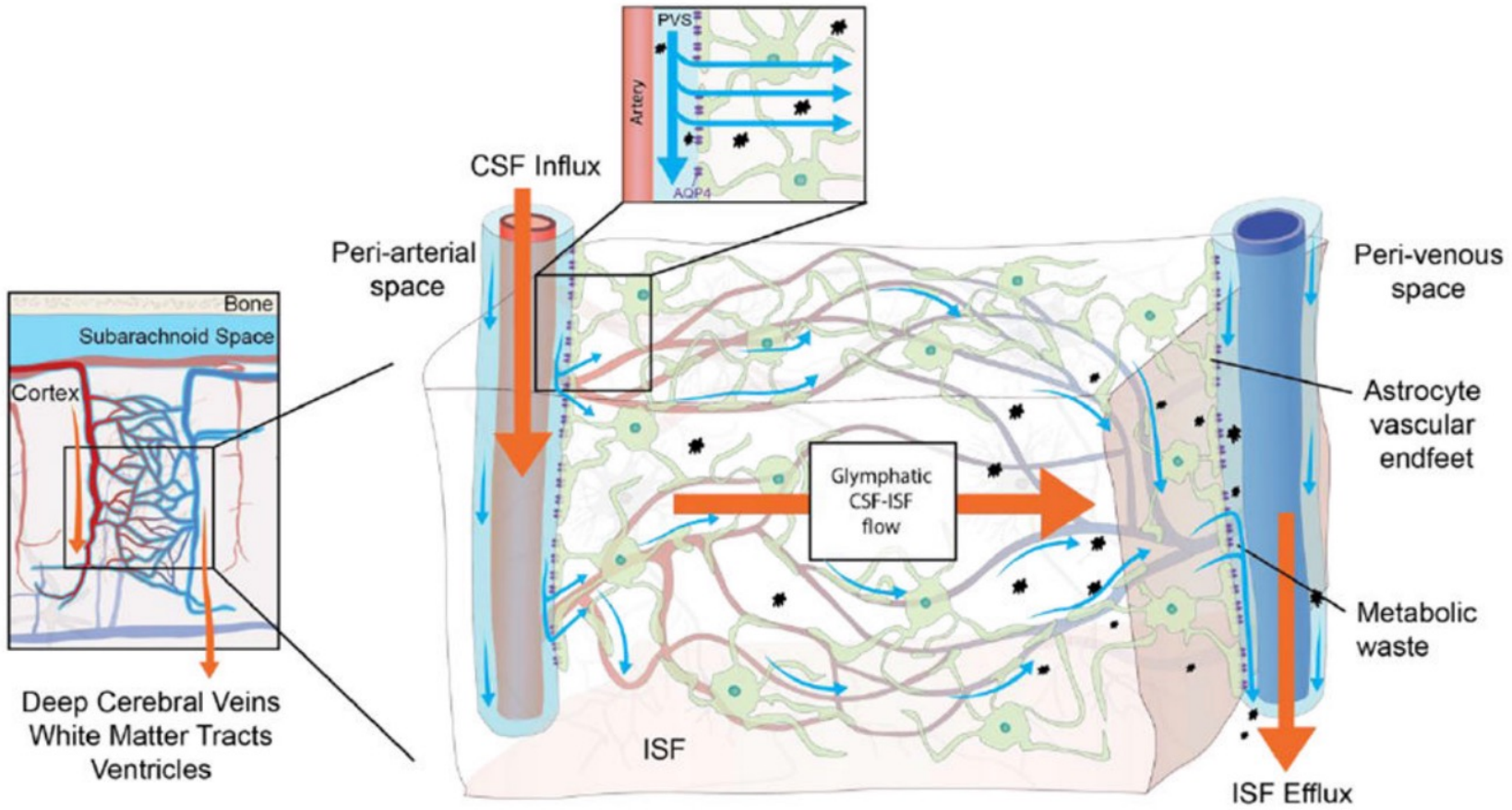
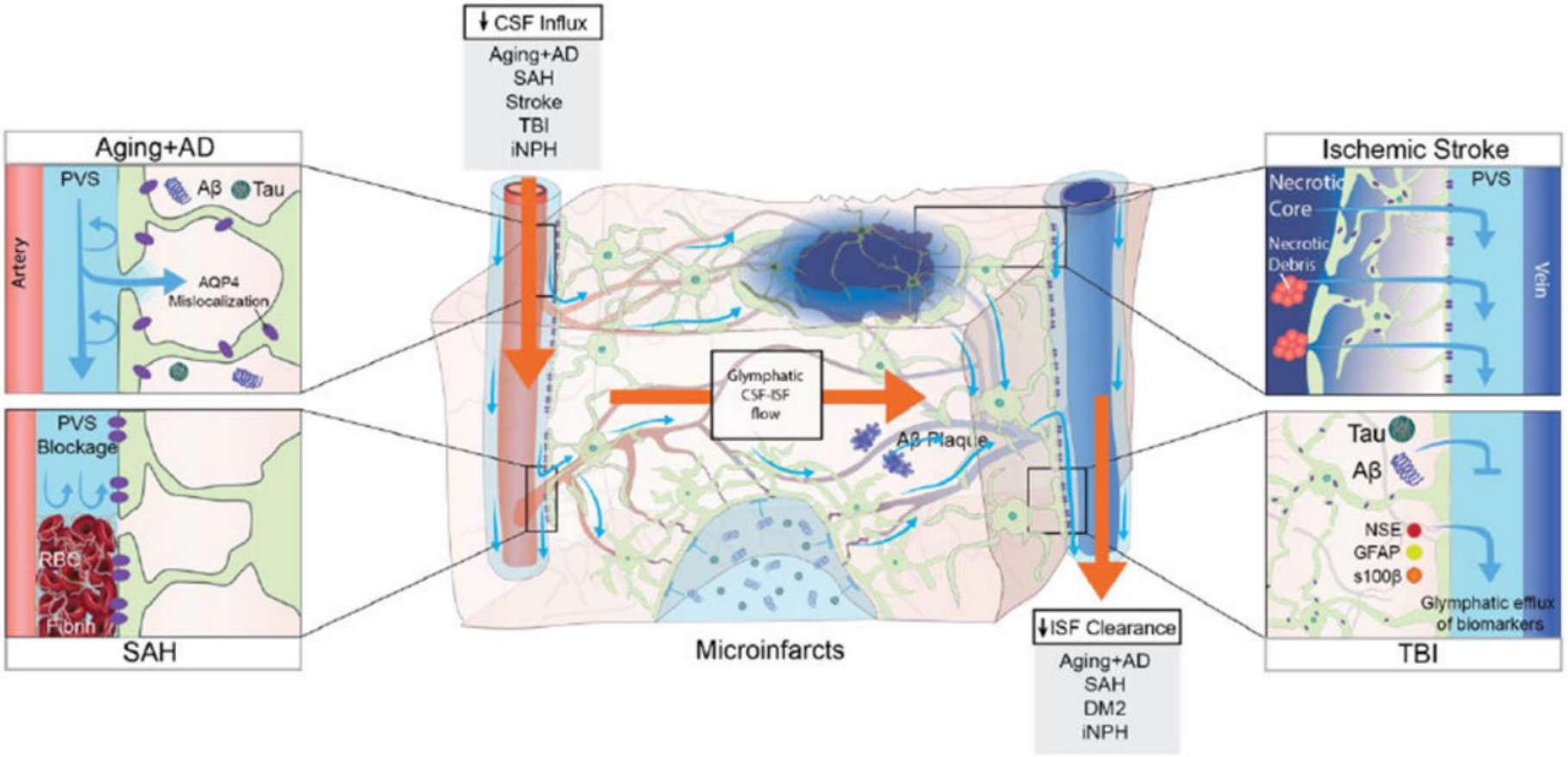

PVS
Artery
AQP4
CSF Influx
Peri-arterial space
Peri-venous space
Bone
Subarachnoid Space
Cortex
Astrocyte vascular endfeet
Glymphatic CSF-ISF flow
Metabolic waste
Deep Cerebral Veins
White Matter Tracts
Ventricles
ISF
ISF Efflux

Figure 1. The glymphatic pathway.
Rodent studies have shown that CSF from the subarachnoid space is driven into the perivascular space of major cerebral arteries on the brain surface from where it flows along the artery as it branches into penetrating arteries.[12,13,22,39]A similar pattern of CSF flow has been shown in patients undergoing MRI in combination with intrathecal contrast agent.[15,46] In these patients it was observed that the CSF contrast agent flows along the large leptomeningeal cerebral arteries in an anterograde fashion, and that presence of contrast agent in the subarachnoid space precedes parenchymal uptake in adjacent brain regions.[15] The microscopic details of CSF flow within the brain thus far all stem from animal research. These studies have shown that the perivascular space runs along the entire penetrating artery, known as the Virchow-Robin space, and continues to follow the vessel as it branches into arterioles and capillaries.[12,13,21] In the murine brain, CSF influx into the extracellular space happens at every level of the perivascular space after entry to the brain parenchyma and is facilitated by a polarized expression of the AQP4 water channel towards the astrocytic end-feet that line the perivascular space.[12] Whether a similar parenchymal CSF flow occurs in human brain has not yet been proven, but humans also harbor intracerebral perivascular spaces and polarized AQP4 expression towards astrocytic end-feet.[55,58] The basis of fluid movement within the interstitium is still a matter of debate. Bulk flow clearance of ISF is a long-standing observation, which could be driven by multiple factors such as CSF inflow, arterial pulsatility, hydrostatic pressure gradients between the arterial and venous perivascular spaces, and osmotic gradients.[8] Rodent studies show that ISF and its solutes move towards the venous perivascular space, where the fluid is taken up and drained by convection out of the brain parenchyma.[12] This directional flow removes solutes from the brain parenchyma accumulated during neural activity.[12]


CSF Influx
Aging+AD
SAH
Stroke
TBI
iNPH
Aging+AD
PVS
Aβ
Tau
Artery
AQP4
Mislocalization
PVS
Blockage
RBC
Fibrin
SAH
Glymphatic
CSF-ISF
flow
Aβ Plaque
Microinfarcts
ISF Clearance
Aging+AD
SAH
DM2
iNPH
Ischemic Stroke
Necrotic
Core
Necrotic
Debris
PVS
Vein
Tau
Aβ
NSE
GFAP
s100β
Glymphatic efflux
of biomarkers
TBI

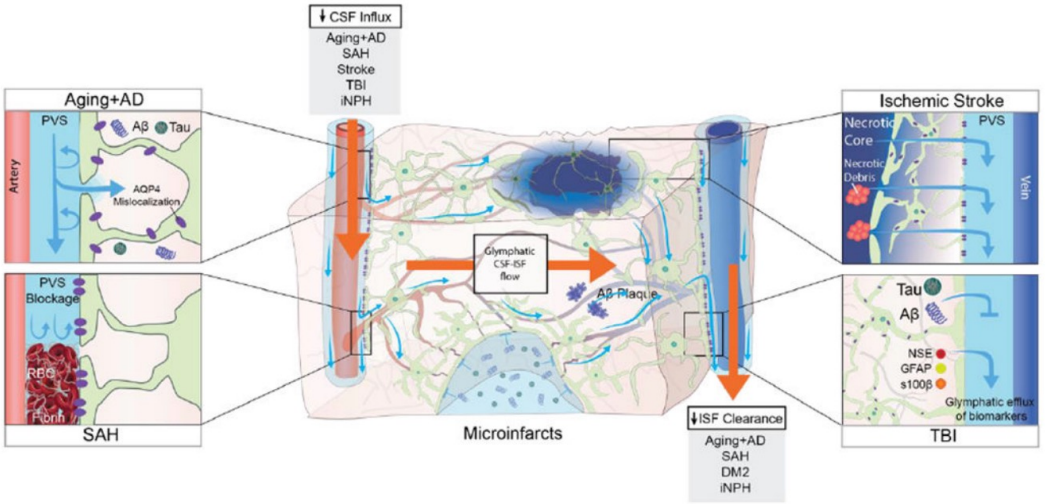


Figure 4. Pathological changes to the glymphatic pathway.

Aging and several diseases have been associated with a decrease in CSF influx to the glymphatic pathway and/or reduced clearance efficacy both in animals and in humans. In aging mice, the flow changes are likely caused by reduced vascular compliance, increased AQP4 expression and AQP4 mislocalization away from the astrocytic end-feet, which all cause reduced parenchymal influx of CSF.[23] In a human postmortem study, AQP4 expression increased with age, albeit without AQP4 mislocalization.[55] In murine models of AD, soluble and insoluble Aβ plaques provoke AQP4 mislocalization and impaired CSF influx.[34,56] In AD patients, CSF clearance rate is reduced and exhibits an inverse relationship with Aβ levels.[16] Post-mortem studies of AD patients identified AQP4 mislocalization and an increase in total AQP4 expression in AD patients compared to non-AD subjects.[55] In hemorrhagic stroke in mice and gyrenchephalic non-human primates, blood components leaking into the PVS, especially fibrin/fibrinogen deposits, occlude the PVS, which leads to reduced CSF influx.[61–63] In rodent models of ischemic stroke, necrotic cores are formed within the brain parenchyma, around which reactive astrocytes create a barrier (glial scar) to contain the injury and the toxic agents that form upon necrosis.[64] Contents of the necrotic core leak through the permeable glial scar into the PVS.[64] In mice, cerebral microinfarcts lead to a transient global reduction in glymphatic influx, and prolonged trapping of solutes within the infarct cores, probably due to reduced interstitial fluid turnover.[60] TBI in mice leads to reduced glymphatic clearance, and biomarkers of the injured parenchyma are transported through the glymphatic pathway towards the cervical lymphatic system.[42] In iNPH patients, glymphatic function is broadly impaired and characterized by both a delayed influx and a reduced clearance rate following intrathecal contrast injection.[15] In rat models of diabetes mellitus type 2 (DM2), CSF tracers remain trapped within the brain parenchyma for prolonged periods, suggesting that perivenous efflux is decreased.[68] This finding has not yet been replicated in humans, but we speculate

› Proc Natl Acad Sci U S A. 2024 Oct 15;121(42):e2407246121. doi: 10.1073/pnas.2407246121. Epub 2024 Oct 7.

The perivascular space is a conduit for cerebrospinal fluid flow in humans: A proof–of–principle report

Erin A Yamamoto [# 1], Jacob H Bagley [# 1 2], Mathew Geltzeiler [3], Olabisi R Sanusi [1], Aclan Dogan [1], Jesse J Liu [1], Juan Piantino [4]

Affiliations + expand

PMID: 39374384 PMCID: PMC11494350 DOI: 10.1073/pnas.2407246121

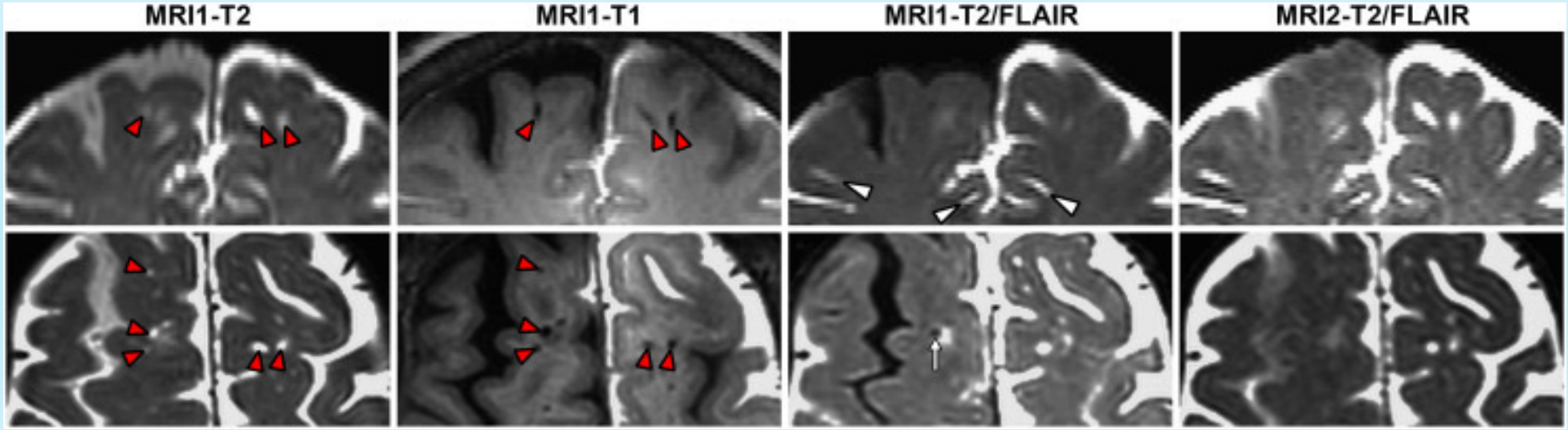
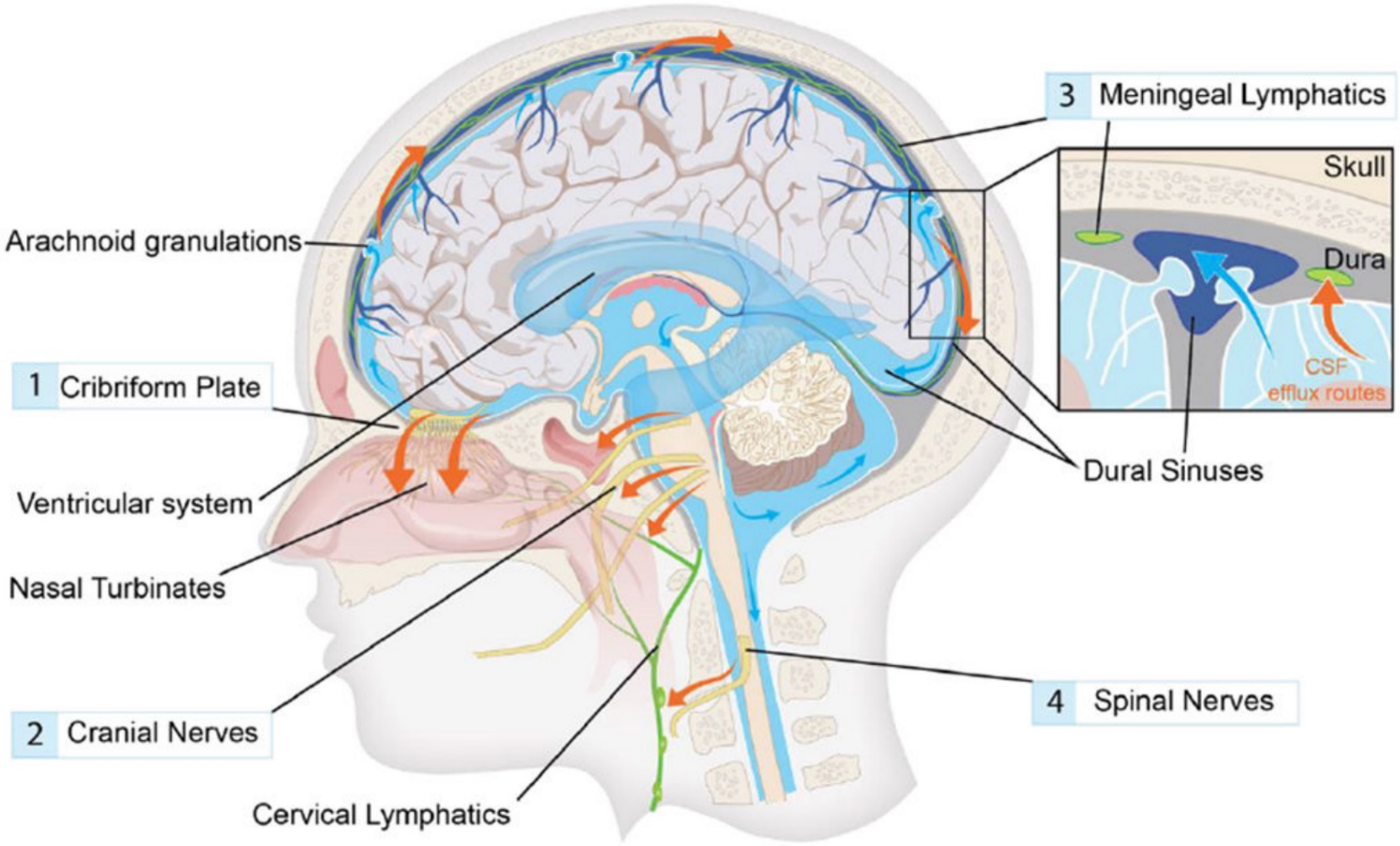


Fig. 1. Visualization of perivascular spaces by intrathecal contrast-enhanced brain MRI. Intrathecal contrast-enhanced brain MRI in coronal (*A*–*D*) and axial planes (*E*–*H*). T2 (*A* and *E*), T1 (*B* and *F*), and T2/FLAIR (*C* and *G*) sequences from timepoint 1, and T2/FLAIR from timepoint 2 (*D* and *H*) are shown. Some MV-PVSs decrease in signal intensity while others increase between timepoints 1 and 2. Red arrowheads: MV-PVS on T1 and T2 sequences. White arrow: Postcontrast, nonenhancing MV-PVS. White arrowheads: Enhancing MV-PVSs (*D* and *H*).


3 Meningeal Lymphatics
Skull
Dura
CSF
efflux routes
Arachnoid granulations
1 Cribriform Plate
Ventricular system
Nasal Turbinates
Dural Sinuses
2 Cranial Nerves
Cervical Lymphatics
4 Spinal Nerves

Practical 2:
Lymphatic Drainage of the Cranium

Treatment – Balanced Membranous Tension

Evaluation:

- ❖ evaluate the patient's soft tissues, assessing for areas where motion is restricted or asymmetrical.

Disengagement and Exaggeration:

- ❖ compressing or decompress to move tissue/joint into a position of ease (indirect method)
- ❖ then exaggerate the joint by flexing, extending, rotating, or side-bending it in all planes of motion (direct method).

Balance Point:

- ❖ seek a "balance point" or "wobble point," a feeling of release or softening that indicates the tissue has returned to a state of balance
- ❖ this can be found by palpating for changes in tissue quality or utilizing the patient's respiratory cycle.

Holding and Release:

- ❖ hold the joint in the balance position until a release or softening is felt then slowly return the tissue to its normal position.

2nd method of treatment:

- Use of **primary respiration** in the extracellular matrix (ECM) to return the syphoning forces in the subclavian veins.
  - Tissue respiration helps to guide excess fluids into the terminal lymphangions, important because 30% of lymph is reabsorbed in the lymph glands with tissue respiration.
  - Liver and GI tract produce 70% of the lymph

Treatment sequence

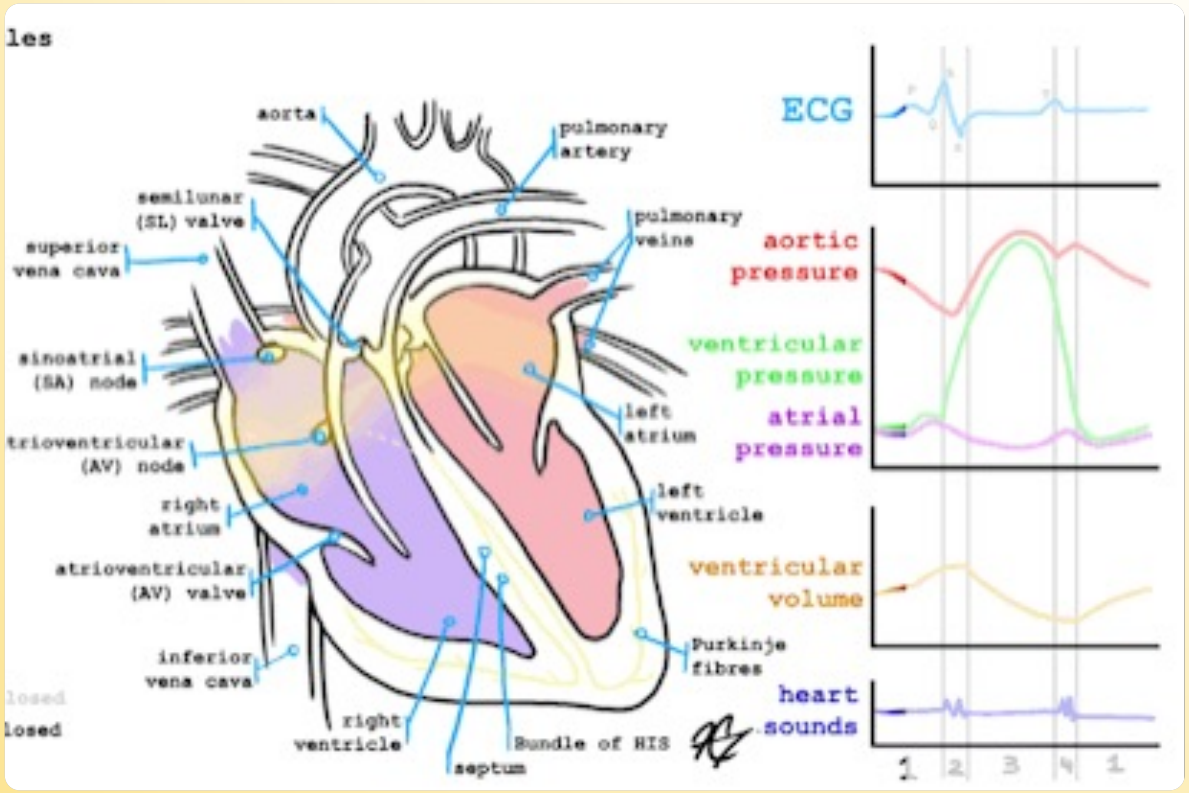
1. Analyze lower extremity syphoning strength of lymph nodes at the groin
2. Assess mesenteric stem at the umbilicus for BMT. The root of the mesentery contains the superior mesenteric vein, lymphatics and lymph nodes, and autonomic nerves
3. Follow mesenteric stem into the left upper quadrant and then the right lower quadrant for points of pain (indicates inflammation or congestion). Gentle compression and then lifting enhances lymphatic syphoning

4. At the lowest point of the mesenteric stem is the caecum area where the ileocecal valve is often tight. Use balanced tension maintained until that point of tension as the inherent forces are engaged, continuing until a release or softening, or improved fluid function occurs.
5. Repeat balanced membranous tension to ascending, descending, and sigmoid colon.
6. Assess the cisterna chyli and treat with BMT.
7. Assess the crossover of the lymphatic duct and treat with BMT.
8. The left clavicle and 1st left rib influence the emptying of the heart's left ventricle lymph into the junction of the internal jugular and subclavian veins

10. Assess the anterior dural girdle and its functional link to the free border of the tentorium
11. Assess the drainage of the superior and inferior sagittal sinus, the cavernous, petrosal and basilar sinuses in relation to the reciprocal tension membrane.
12. Assess the inherent motion and function of the ethmoid and the cribriform plate (glymphatic cranial function).


BEYOND THE PUMP

The Heart- Beyond a Pump



Traditional view: The heart has been regarded primarily as a mechanical pump driving blood circulation.

Emerging research: Suggests that the heart plays several other roles, influencing bioenergetics, circulation, and even thought formation. This presentation explores five key studies that collectively argue that the heart's role extends beyond pumping blood.

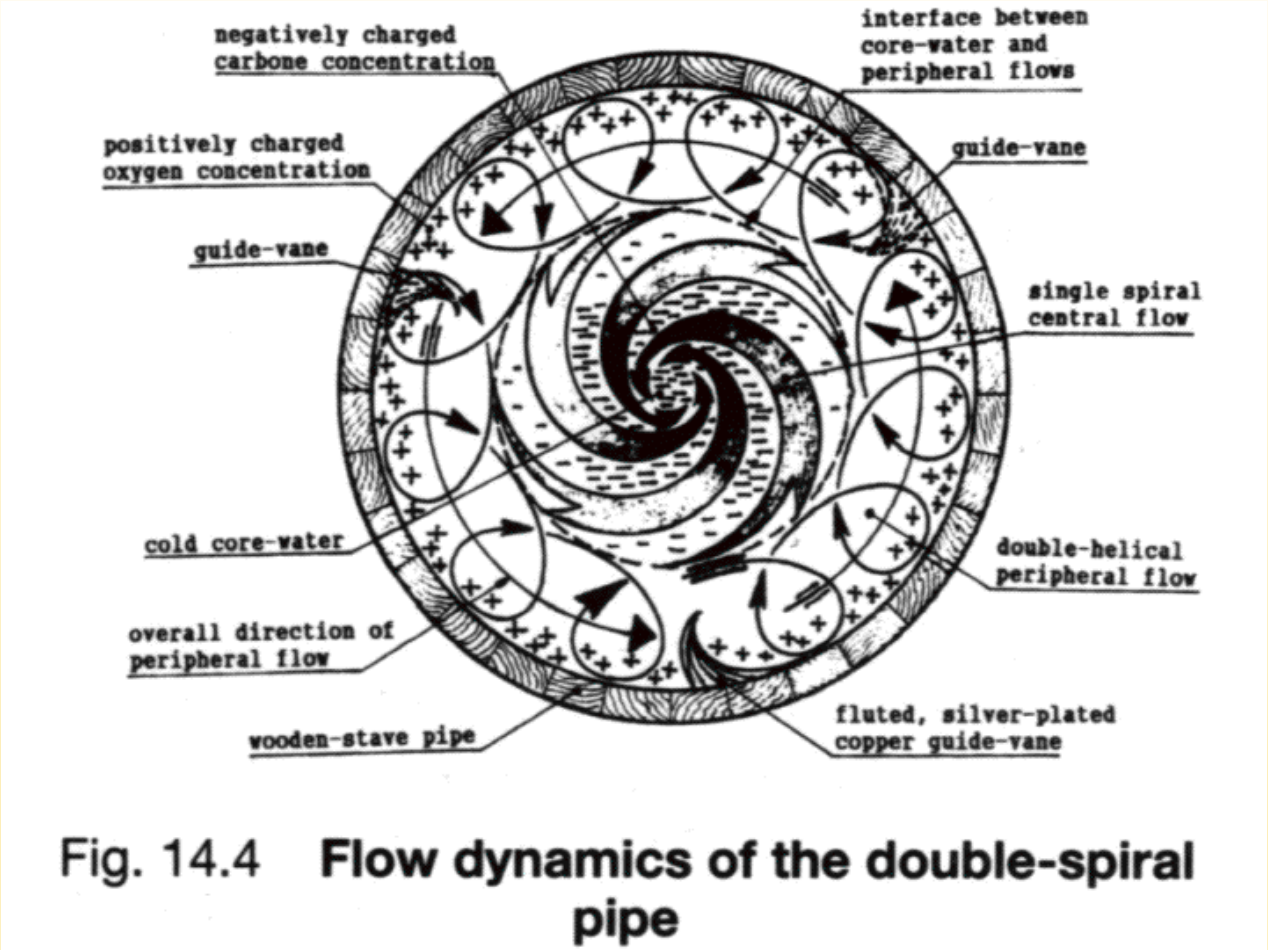


Fig. 14.4 **Flow dynamics of the double-spiral pipe**

Coates J Living Energies Gateway Books 1996

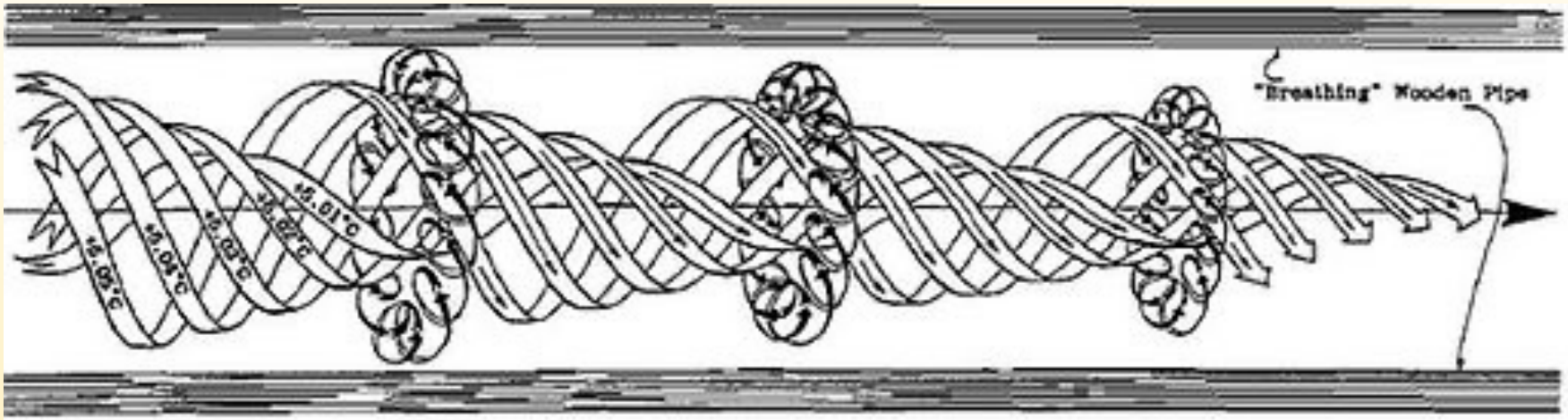
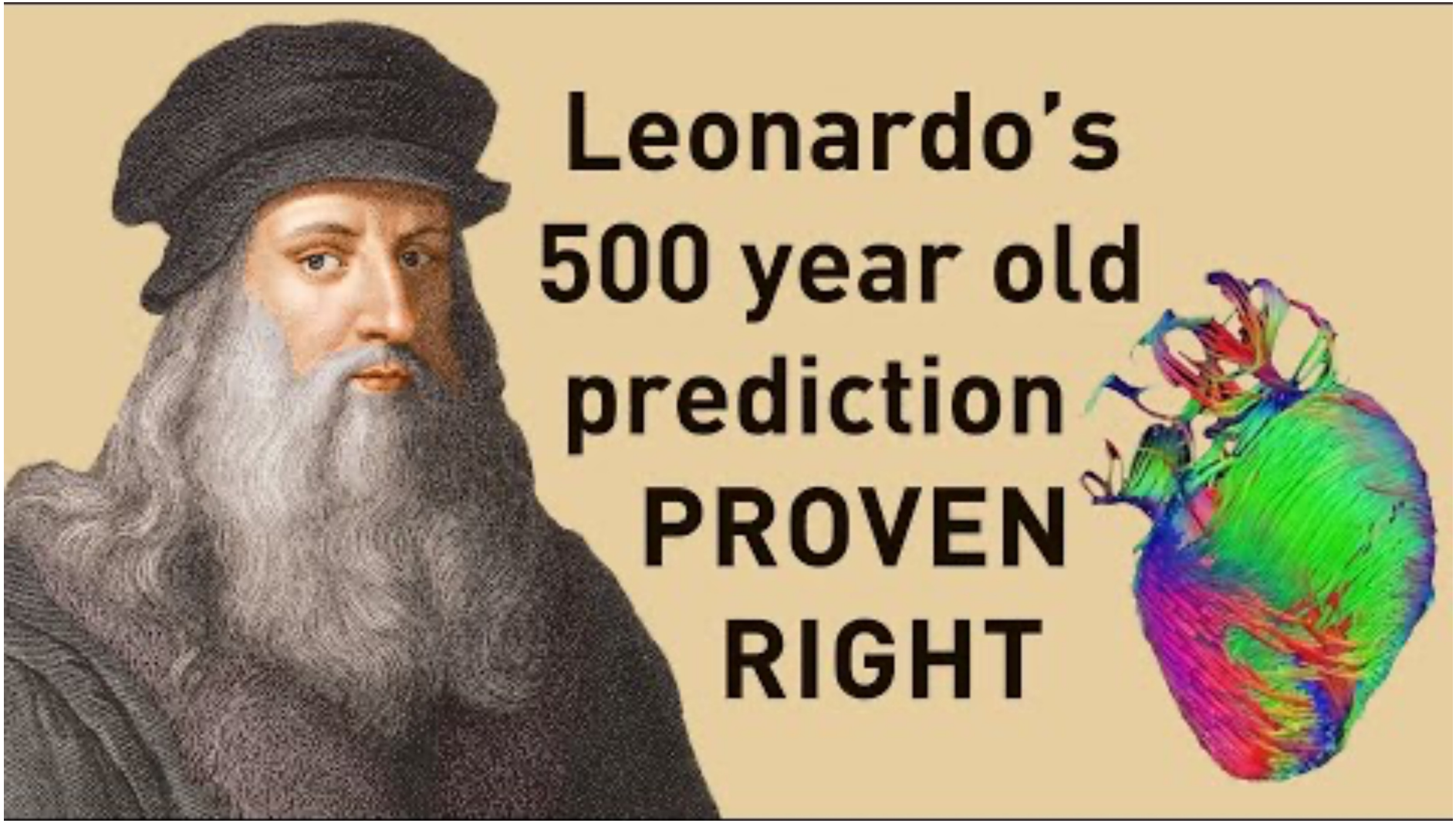


Fig. 14.3 **The double-spiral longitudinal vortex**

A longitudinal vortex showing the development of toroidal counter-vortices. These occur due to the interaction with the pipe-walls and have an effect similar to ball-bearings, enhancing the forward movement. Their interior rotation follows the direction of rotation and forward motion of the central vortex, whereas the direction of their exterior rotation and translatory motion are reversed. These toroidal vortices act to transfer oxygen, bacteria and other impurities to the periphery of the pipe, where, due to the accumulation of excessive oxygen, the inferior, pathogenic bacteria are destroyed and the water rendered bacteria-free.

Callum Coats, July 1992


Leonardo's
500 year old
prediction
PROVEN
RIGHT

Gerald Pollack- University of Washington (*The Fourth Phase of Water*)

•**Key Concept**: Pollack discovered a liquid-crystalline phase of water called Exclusion Zone (EZ) water, which forms next to hydrophilic surfaces.

•**How it works**:

- EZ water excludes solutes and is structured differently than regular water.
- This structured water forms naturally in the body, especially along blood vessel walls, which can support fluid motion without relying entirely on heart-generated pressure.

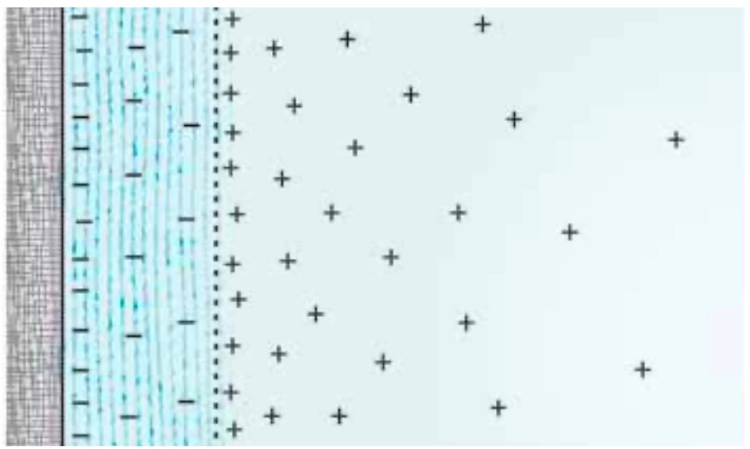


Figure 1. Diagrammatic representation of EZ water, negatively charged, and the positively charged bulk water beyond. Hydrophilic surface at left.

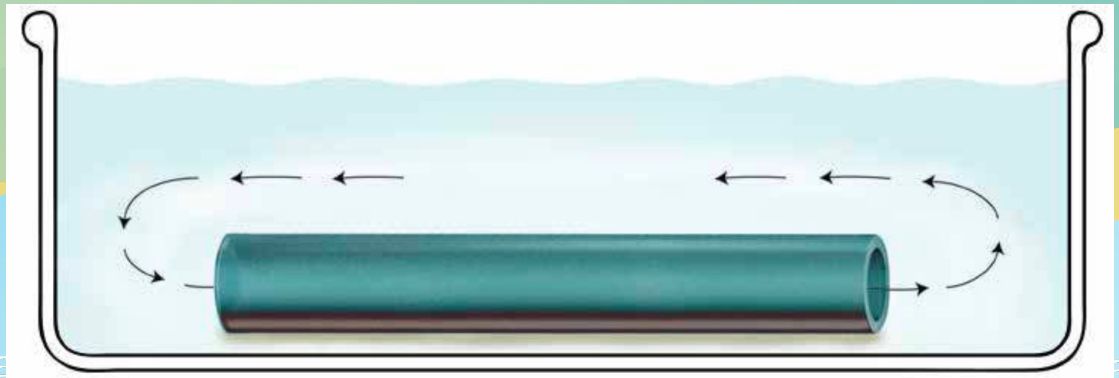


Figure 2. Practically incessant flow occurs through hydrophilic tubes immersed in water.

•**IR-Driven Blood Flow**: Infrared (IR) energy transforms ordinary water into EZ water, promoting blood circulation even without heart contraction.

•**Experimental Evidence**: Postmortem studies in chick embryos showed blood flow could continue for 50 minutes after the heart stopped beating, driven by IR energy.

•**Surface-Induced Flow**: This flow is suggested to be driven by surface activity in blood vessels. The study proposes that tubular surfaces, such as those in capillaries, create chemical concentration gradients, which propel blood. IR energy enhances this process, acting as a "fuel" for blood flow.

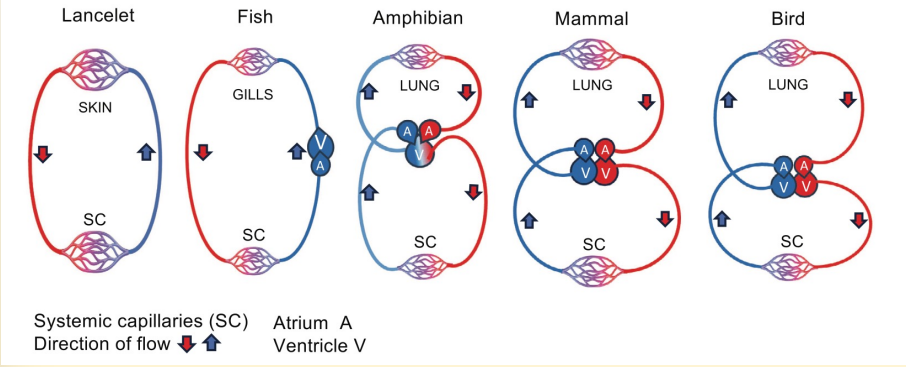
•**Solvent vs Solute:** EZ water forms next to the vessel walls and excludes red blood cells, potentially contributing to blood flow without the need for heart-generated pressure.

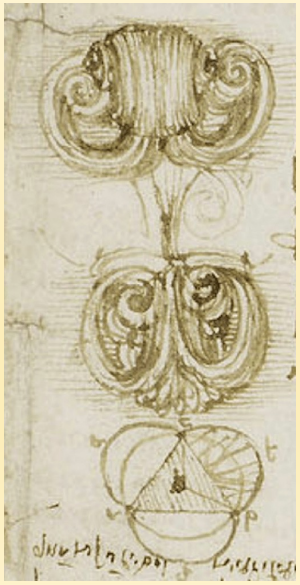
Implications for Circulatory Physiology: Blood vessels themselves, particularly in the capillaries, may actively drive blood flow in addition to the heart's pumping action. The findings open the door for reconsidering the heart's role as the sole driver of circulation and have potential implications for cardiovascular health and disease management.

•**Implication**: Blood circulation is not solely dependent on the heart's pumping function;
Energy can drive flow independently (GET YOUR SUNSHINE!)

Abstract

Circulation of the blood is a fundamental physiological function traditionally ascribed to the pressure-generating function of the heart. However, over the past century the 'cardiocentric' view has been challenged by August Krogh, Ernst Starling, Arthur Guyton and others, based on haemodynamic data obtained from isolated heart preparations and organ perfusion. Their research brought forth experimental evidence and phenomenological observations supporting the concept that cardiac output occurs primarily in response to the metabolic demands of the tissues. The basic tenets of Guyton's venous return model are presented and juxtaposed with their critiques. Developmental biology of the cardiovascular system shows that the blood circulates before the heart has achieved functional integrity and that its movement is intricately connected with the metabolic demands of the tissues. Long discovered, but as yet overlooked, negative interstitial pressure may play a role in assisting the flow returning to the heart. Based on these phenomena, an alternative circulation model has been proposed in which the heart functions like a hydraulic ram and maintains a dynamic equilibrium between the arterial (centrifugal) and venous (centripetal) forces which define the blood's circular movement. In this focused review we introduce some of the salient arguments in support of the proposed circulation model. Finally, we present evidence that exercising muscle blood flow is subject to local metabolic control which upholds optimal perfusion in the face of a substantive rise in muscle vascular conductance, thus lending further support to the permissive role of the heart in the overall control of blood circulation.





Research by Benno Furst (*The Heart: A Secondary Organ in the Control of Blood Circulation*)

- **Peripheral Control**: Furst argues that circulation is largely controlled by peripheral mechanisms, driven by metabolic needs, rather than the heart's pumping function.
- **Guyton's Venous Return Theory**: Cardiac output is primarily dictated by venous return, meaning the heart adjusts its activity based on the body's demand for oxygen and nutrients rather than driving the process.
- **Reevaluation of the Heart's Role**: Instead of being the primary force behind blood movement, the heart may act more as a passive responder to peripheral circulation.

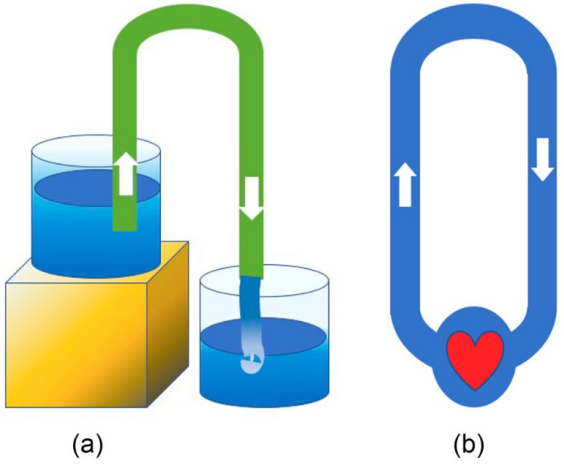
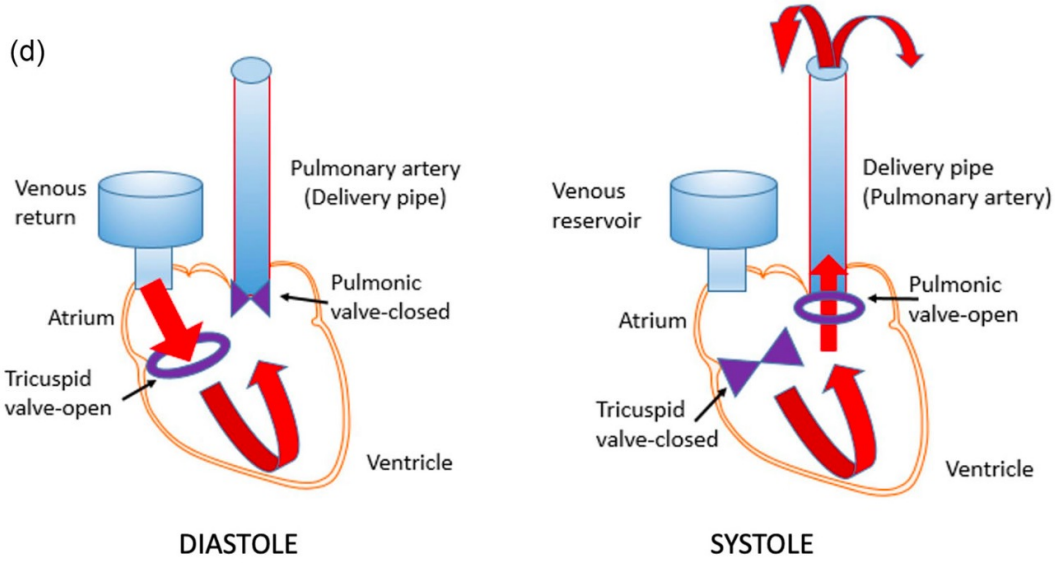


FIGURE 4 The siphon principle. (a) An open siphon is an inverted U-shaped tube used to deliver a flow of liquid above the surface of the reservoir without a pump, powered by the combination of gravitational pressure and suction created within the tube. The principle of operation is based on Bernoulli's energy conservation law where, in an ideal liquid (at steady flow and without viscous losses) the sum of hydrostatic pressure, gravitational potential energy and kinetic energy remains constant. Once primed, the uphill flow of liquid in the shorter tube of the siphon is maintained by suction and is independent of the height of the loop. (b) Closed loop siphon. The circulatory system consists of numerous such loops *above* and *below* the level of the heart (inverted siphon). Counterbalance of forces in the ascending (arteries) and descending limbs (veins) eliminates the need for additional energy on the part of the heart to overcome gravity. (Reproduced from Furst (2020), used by permission of Springer-Nature.)

The Heart as a Facilitator, Not the Driver



- **The Hydraulic Ram Model**: The heart's function is compared to a hydraulic ram, where it responds to incoming blood rather than actively pushing it throughout the body.

- **Exercise and Blood Flow**: Blood flow during exercise is controlled more by **local tissue demands** and vascular factors than by heart rate or function.

FIGURE 3 Components and working cycle of a hydraulic ram (a, b). (a) Water from the reservoir (A) accelerates by gravity along the drive pipe (B) and escapes from the open spill valve (S). (b) Drag from the accelerating water closes the spill valve (S), creating a back surge (water-hammer effect) and an increase in pressure, forcing water to flow up the delivery pipe (C). A drop in pressure in the drive pipe (B) opens the spill valve (S) and the cycle repeats. (c) Automatic operation of a ram requires an additional valve (S2) and a pressure vessel ('Windkessel') (D). A build-up of pressure (air cushion) in the pressure vessel (D) forces water to exit the delivery pipe (C). (d) Schematic representation of the heart as a hydraulic ram (right heart cycle). During diastole, blood flows from the atrium (reservoir) and fills the ventricle (analogous with (B) in the upper panel). In systole, flow reversal and build-up of pressure in the ventricle close the tricuspid valve (analogous with spill valve (S)) and eject the blood into the pulmonary artery (delivery pipe (C)). (Adapted from Furst (2020a), used by permission of Springer-Nature.)


GP
super
ALKALINE

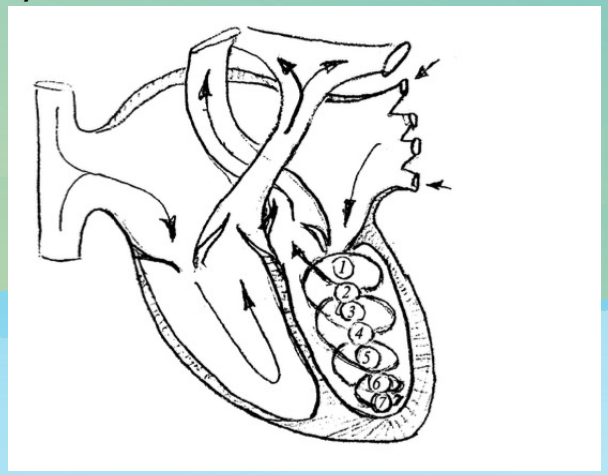
FUNCTION DRIVES FORM

METABOLISM DRIVES FUNCTION

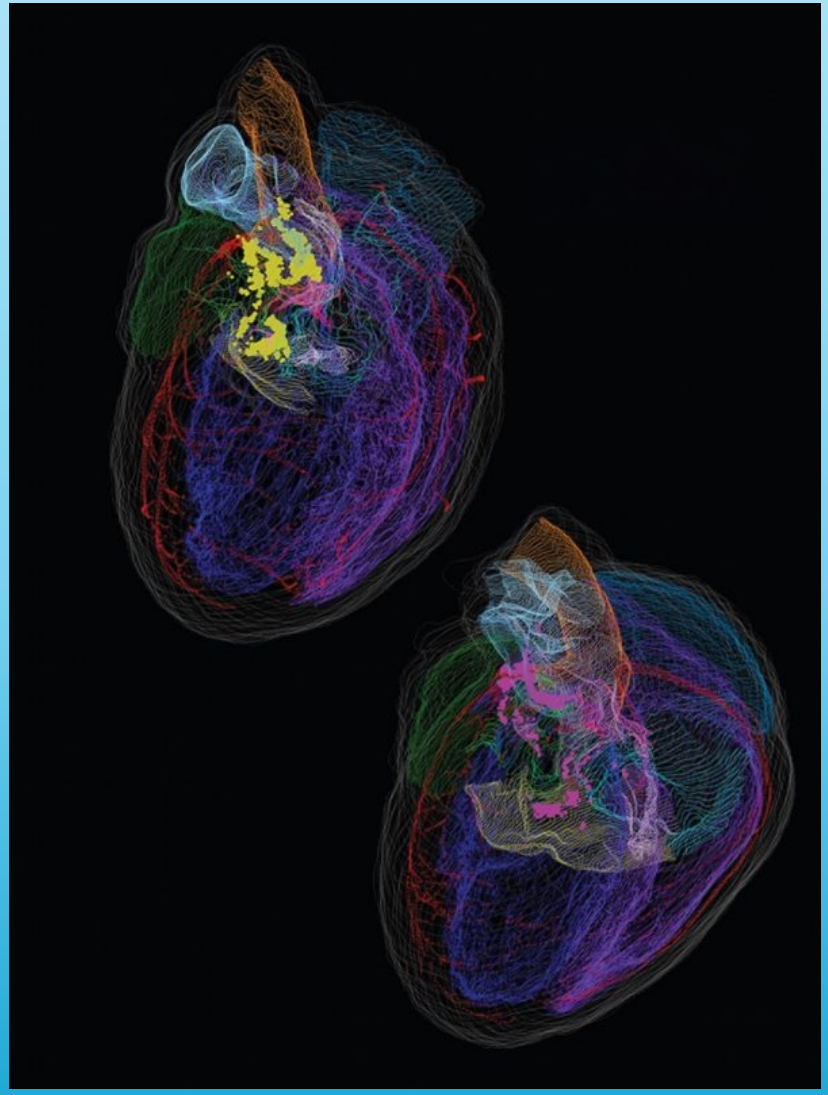
The Heart and Consciousness

Research by A.I. Goncharenko (*Heartspace as the Basis of Superconsciousness*)

•**Minihearts and Targeted Blood Flow**: Goncharenko describes "minihearts" within the ventricles that direct specific blood portions to individual organs, implying that the heart plays a more complex role in circulation.
•**Heart as a Conscious System**: The heart is proposed to be a "conscious" organ, capable of processing information and distributing blood with precision based on the needs of different parts of the body.



"But does the heart's heart have its own heart, and does it have its own consciousness?"



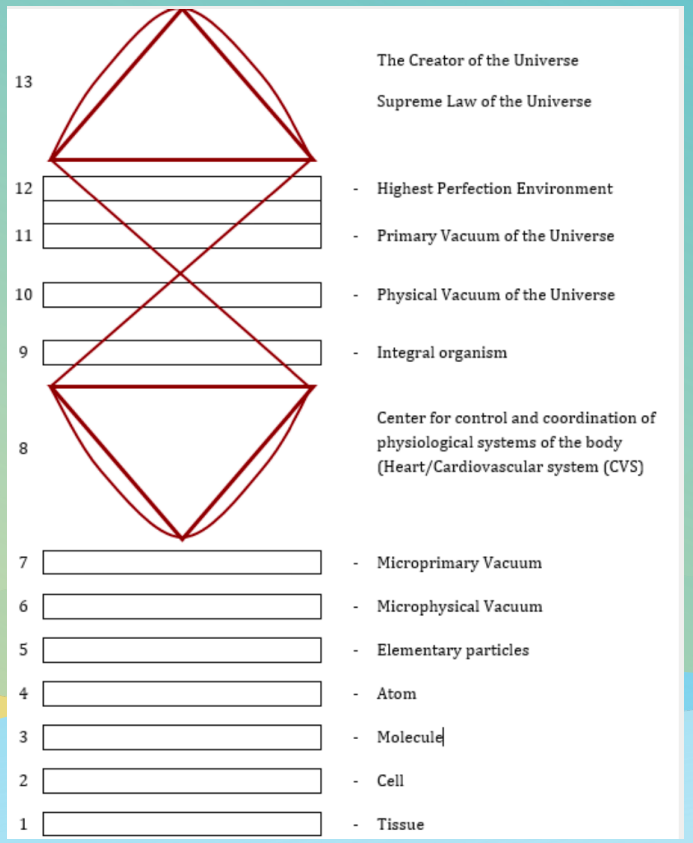
Autonomous Heart Function: The heart can function independently of the nervous system, regulating blood flow to specific organs even when neurological input is disabled.

The Heart Brain- Mapping, modeling and tagging is showing ganglia and their connections through the organs. Notice Male heart (Yellow) and Female heart (pink)

Implications for Health: This perspective opens up new possibilities for understanding cardiovascular diseases, especially regarding how stress or physical trauma impacts the heart

https://research.jefferson.edu/2022-magazine/the-hearts-little-brain.html

Thought Formation in the Heart



Research by Vladimir Dodtievich (*Modern View on The Mechanism of Thought Formation and its Implementation Program*)

- **Heart as a Thought Generator**: Dodtievich's research suggests that thought is generated at a supramolecular level in the heart, particularly in the left ventricle.
- **Biosphere and Noosphere Interaction**: The heart mediates information between the body and its environment, transmitting bioenergetic signals that help form thoughts. The brain acts as a processor, but not the originator of thought.
- **Heart-Brain Interaction**: The heart's function is not just mechanical but bioenergetic, influencing both physical and cognitive functions.
- **Superconsciousness**: The heart's ability to process bioinformation might play a critical role in how humans interact with their environment and even in the development of consciousness.

VORTEX FLOW OF THE HEART IS FOR ENERGY EFFICIENCY

Furst's vortex flow theory (2023) shows that blood flow in the ventricles forms **vortex patterns**, optimizing energy distribution and aligning with Still's view of the heart as a **dynamic force** in the body.

Key Insight:

•Vortex flow patterns allow the heart to direct blood based on **peripheral demand**, supporting Still's idea that the heart **modulates** flow.

•Vortex flow helps conserve energy, allowing the heart to direct blood to tissues that need it most. This aligns with Still's idea of the heart as the **central distributor of life energy**. Aortic changes promote the vortex.

Reference:

Furst, B., & González-Alonso, J. (2023). *The heart as a secondary organ in blood circulation*. *Experimental Physiology*. PubMed ID: 37689540.

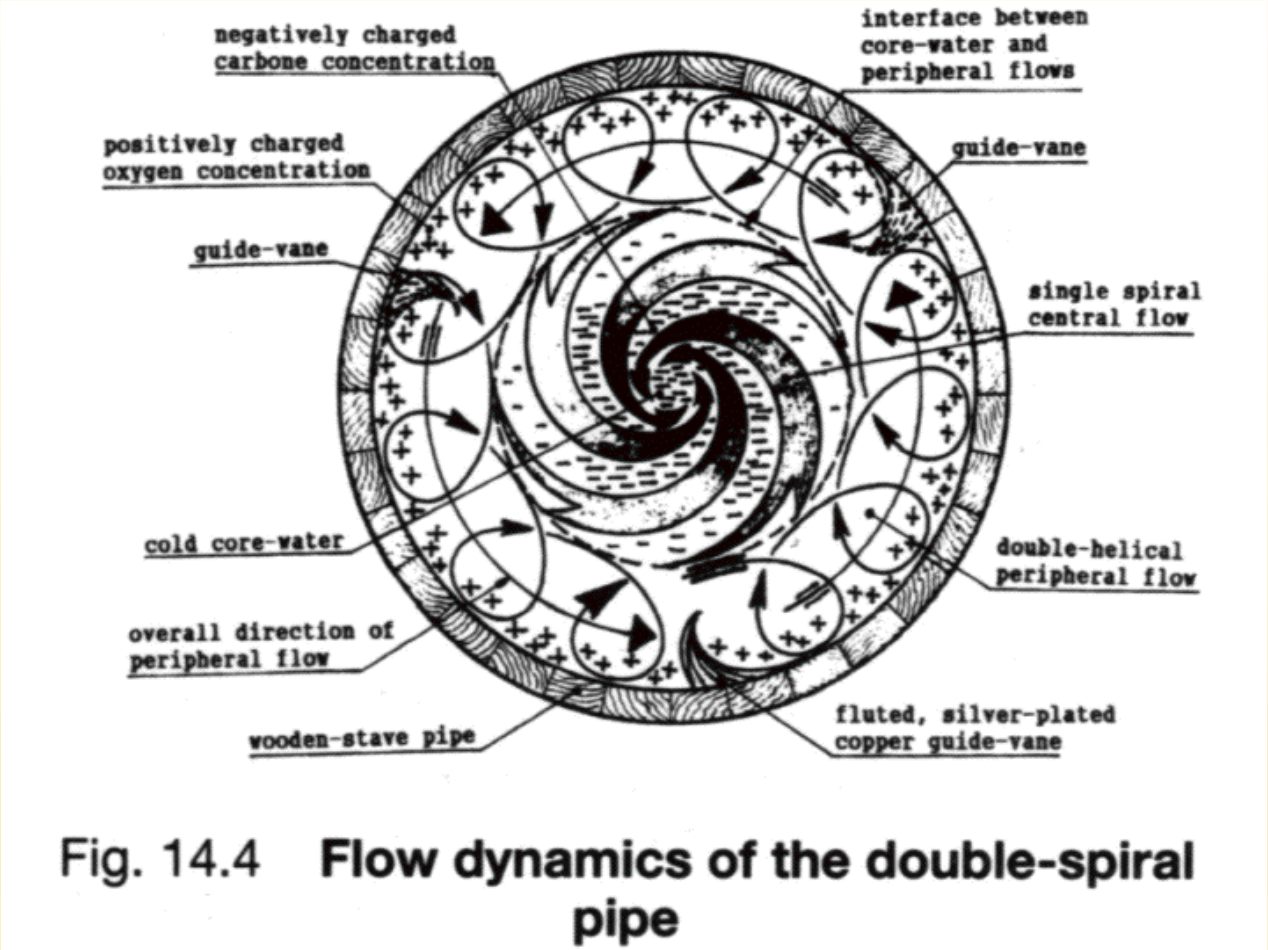


Fig. 14.4 **Flow dynamics of the double-spiral pipe**

Coates J Living Energies Gateway Books 1996

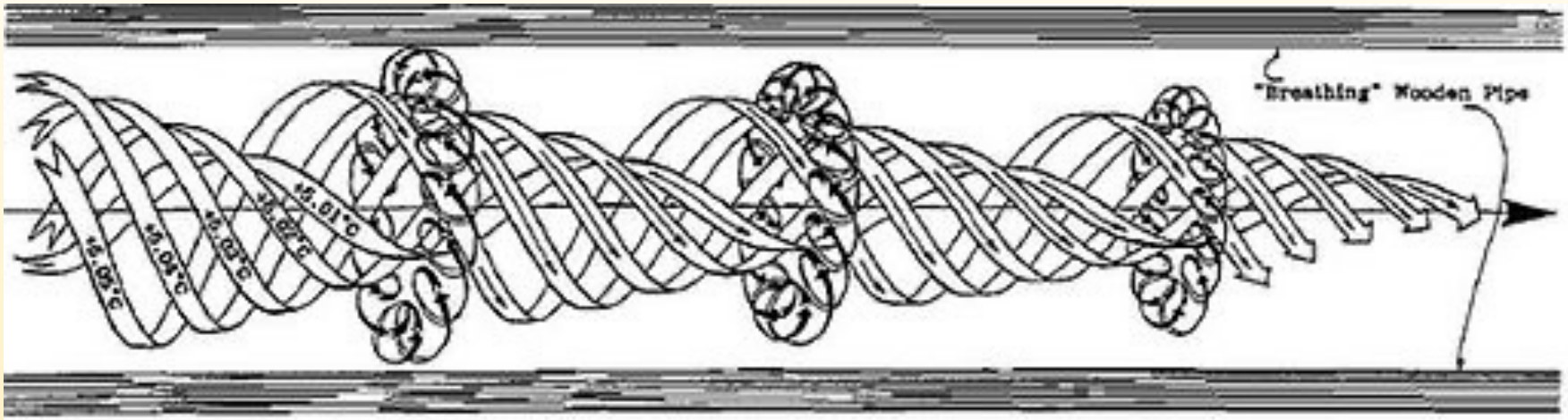
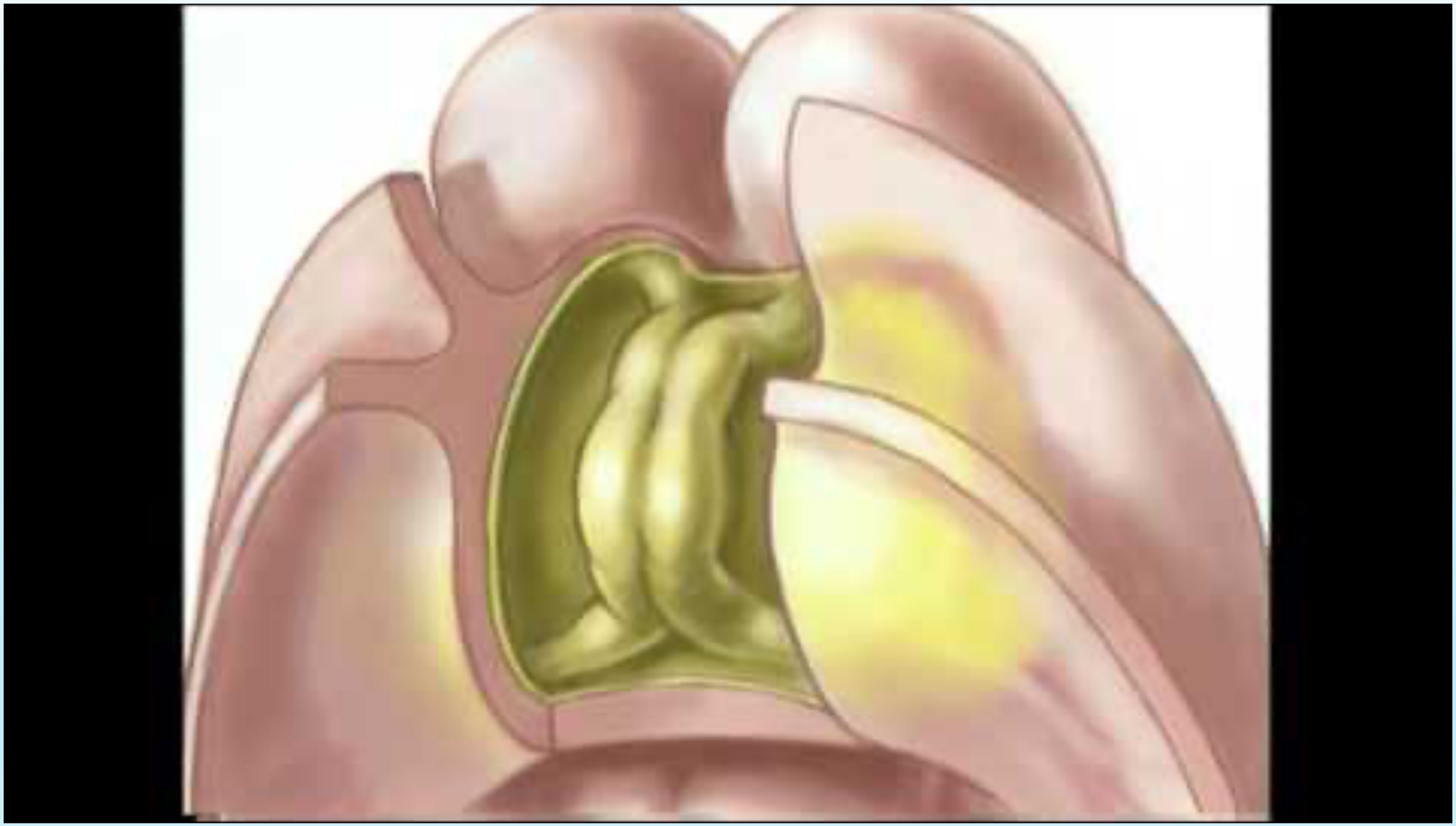


Fig. 14.3 **The double-spiral longitudinal vortex**

A longitudinal vortex showing the development of toroidal counter-vortices. These occur due to the interaction with the pipe-walls and have an effect similar to ball-bearings, enhancing the forward movement. Their interior rotation follows the direction of rotation and forward motion of the central vortex, whereas the direction of their exterior rotation and translatory motion are reversed. These toroidal vortices act to transfer oxygen, bacteria and other impurities to the periphery of the pipe, where, due to the accumulation of excessive oxygen, the inferior, pathogenic bacteria are destroyed and the water rendered bacteria-free.

Callum Coats, July 1992

“The Helical Heart” from David Geffen School of Medicine



The Heart's Electromagnetic Field

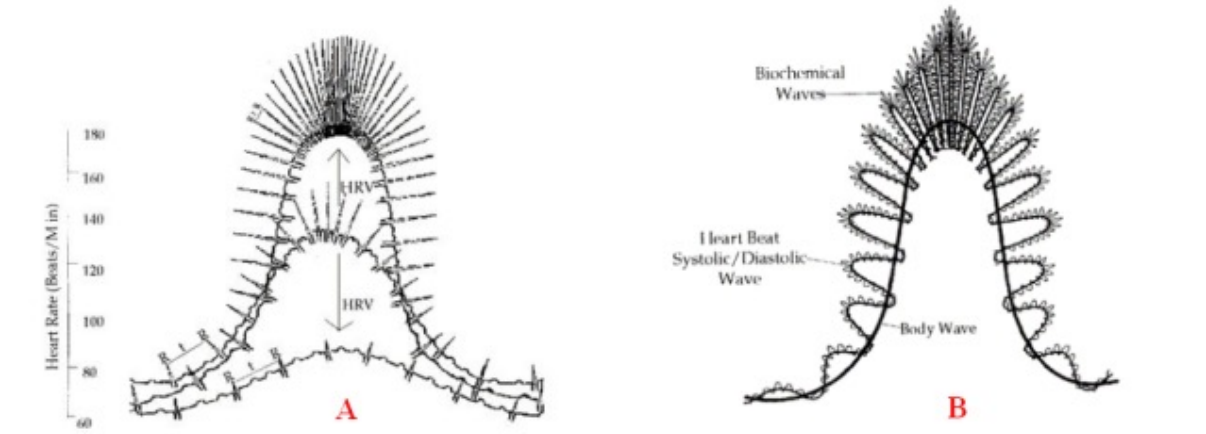
The heart generates the strongest **electromagnetic field** in the body, which can be detected several feet away. Its magnetic field is **5000 times stronger** than the brain's, and its electrical field is **60 times** stronger than brain waves.

Key Insight:

•The heart's biomagnetic field coordinates **cell communication** and acts as a **global synchronizer** for the body.

Reference:

The Energetic Heart: Biomagnetic Communication Within and Between People. In *Bioelectromagnetic Medicine*, CRC Press, 2004
PubMed ID: 15190863.



Listening To Your Heart

(A) The higher your peak heart rate wave range gets, the more it increases your HRV capacity. (B) The Heart Wave imprints on the overall body wave of exertion and recovery and our biochemical waves that govern our cellular growth and repair processes

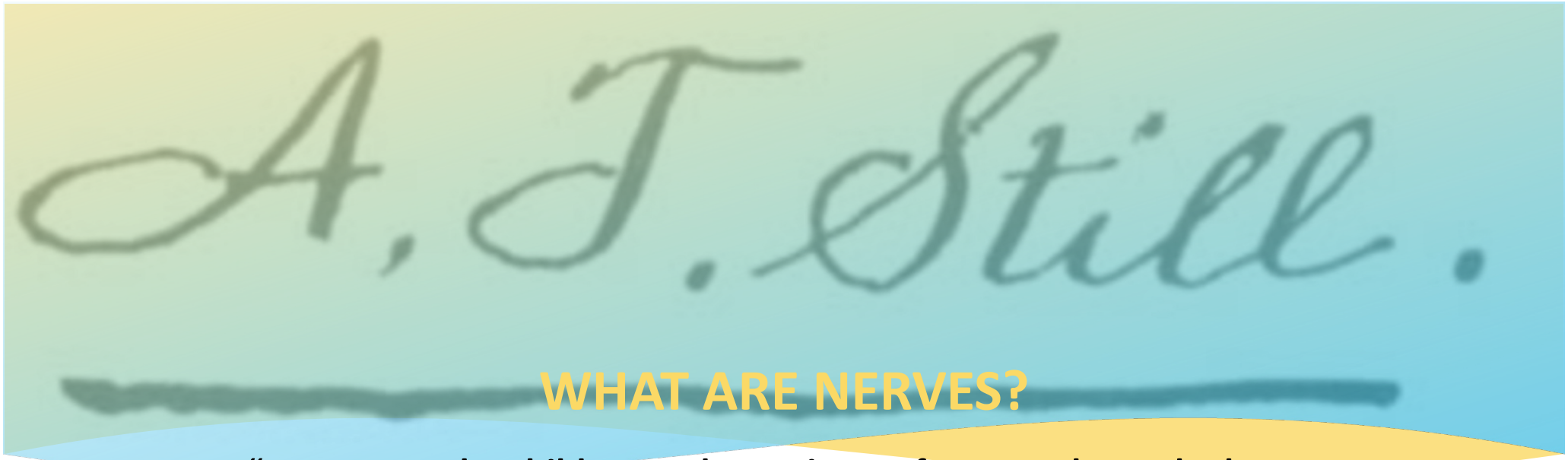
Conclusion: The Heart's Multifaceted Role

•**Beyond a Pump**: Current research points to the heart's expanded roles in:

- Regulating thought formation and consciousness.
- Acting as a bioenergetic and informational mediator with the environment.
- Supporting circulation through non-mechanical processes like radiant energy.

•**A Call for Rethinking**: The heart is more than just a pump; it is a complex, multifunctional organ that plays a key role in both physiology and cognition.

Practical 3: Palpating Arterial, Venous, And Lymphatic Fluid & the Heart



WHAT ARE NERVES?

“Nerves are the children and associates of one mother—the heart.

She, the heart, is the **wise form-giving power of life.** She is life centralized for the use of each and all animals. All beings are simply constructed through the wisdom in the vital energy contained in this mother’s power. She plans and builds according to the forms necessary to execute the orders of her dictators. **She is the mother, nerve, and soul of all nerves pertaining to this body. She orders, constructs, and repairs, and continues in constructing her work to absolute completeness.** She is a graduate from the school of the Infinite, and her works are expected to show perfection in forethought, and are to be inspected, passed upon, received, or rejected by the scrutinizing mind of the Infinite, whose orders are very positive, always holding before her mind the penalty of torture and death for failing to do all her work to the fullest degree of physical perfection.

What are Nerves? p.47-49 The Philosophy and Mechanical Principles of Osteopathy www.interlinea.org Andrew Taylor Still

The first command of the Infinite is for her to be at her post, to keep the picture of the plans forever before her eye. Before she makes a motion to construct a fiber of flesh to cover her nakedness, she must open both eyes, and scrutinize and inspect carefully every fiber that enters into the material house known as the physical heart. **First is formed the material heart, in which the spiritual establishes an office in which to dwell and oversee and enforce the requirements of the specifications for constructing the human body** or that of any animal, fish, reptile, or bird. Having established the office of life in which the plans and specifications stand in bold relief, she receives from her superior officer an order to prepare a laboratory in which the necessary material is prepared to enter Into the construction of this divinely formed being. She runs or constructs a branch road of transportation to and from that manufactory, which is located at the proper distance from her office to give it plenty of room to carry on the business of manufacturing. She calls this, when done, the abdominal work -shop. In order not to be disturbed, she sends out her foreman with instructions to build a fence or wall around herself, and calls that wall the pericardium. Outside of that are other separating walls, with attachments.

A. T. Still.

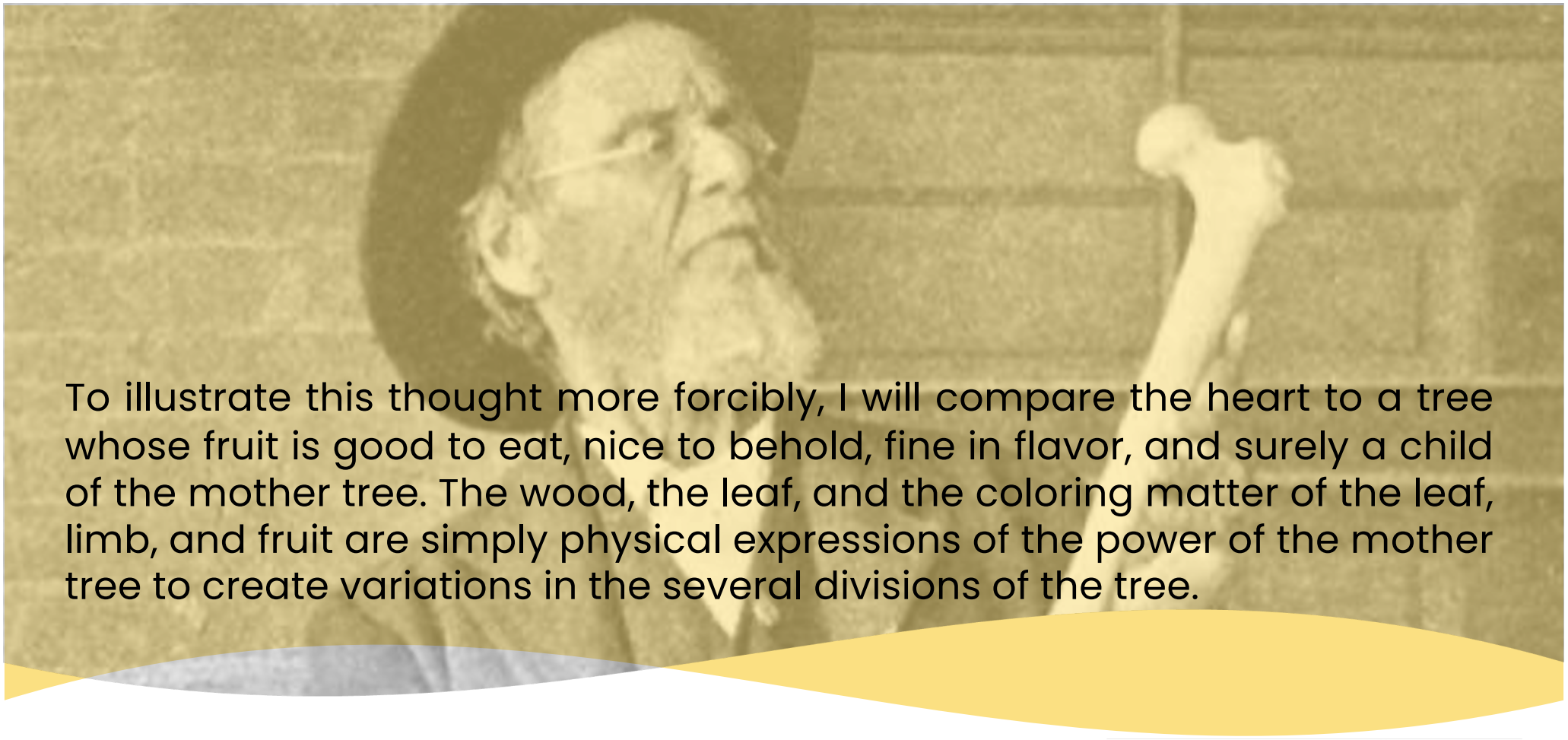
At this important moment she reads in the specifications that she is expected to run out the necessary tracks for the construction of **a storage battery, the brain, with the grand trunk line, the spinal cord, and connect that battery with her office, the grand central, with wires, the nerves.** As she advances with the plans and specifications, she makes other connections and constructs lungs, liver, spleen, pancreas, kidneys, bladder, genital organs, limbs of locomotion, the framework and the finished house, the thorax and abdomen. **She patiently continues the performance of making all conveniences necessary for the comfort of the indweller, the spiritual being.**

A. T. Still.

Thus we find the heart to be the mother of all the nerves of the human body, of all its parts and principles known in vital action. From her vital chamber she delivers vitality to all forms, fibers, and functioning substances of life and motion. All parts of the body are wholly dependent on this vital center, and it can move and act without the assistance of any machine or part of the machine to which she has given form and life. She charges one set of fibers with vitality, and we call them nerves of sensation; she charges another set we call nerves of nutrition, and another set of wires we call nerves of motion.

A. T. Still.

They have no motion, no sensation, no nutriment; they are simply roads for the convenience of executing the orders as found in the plans and specifications of life. My object in the foregoing description of the heart is to draw the attention of the reader to another thought that I will present as well as I can. We can all comprehend that the heart is the engine of blood-force and supply. With this statement I will ask the question, Would the severing of a nerve produce paralysis of a limb or any division of the body, or would it be the tearing up of the road between the limb and the heart? It is true enough that the brachial nerve reaches the brain from the arm. If that nerve has been severed and motion destroyed, has it not separated the limb from the storage battery, the brain, from whence it was supplied?



To illustrate this thought more forcibly, I will compare the heart to a tree whose fruit is good to eat, nice to behold, fine in flavor, and surely a child of the mother tree. The wood, the leaf, and the coloring matter of the leaf, limb, and fruit are simply physical expressions of the power of the mother tree to create variations in the several divisions of the tree.

A. T. Still.

What are Nerves? p.47-49 The Philosophy and Mechanical Principles of Osteopathy www.interlinea.org Andrew Taylor Still

What are Nerves? (p.47-49 The Philosophy and Mechanical Principles of Osteopathy www.interlinea.org Andrew Taylor Still)

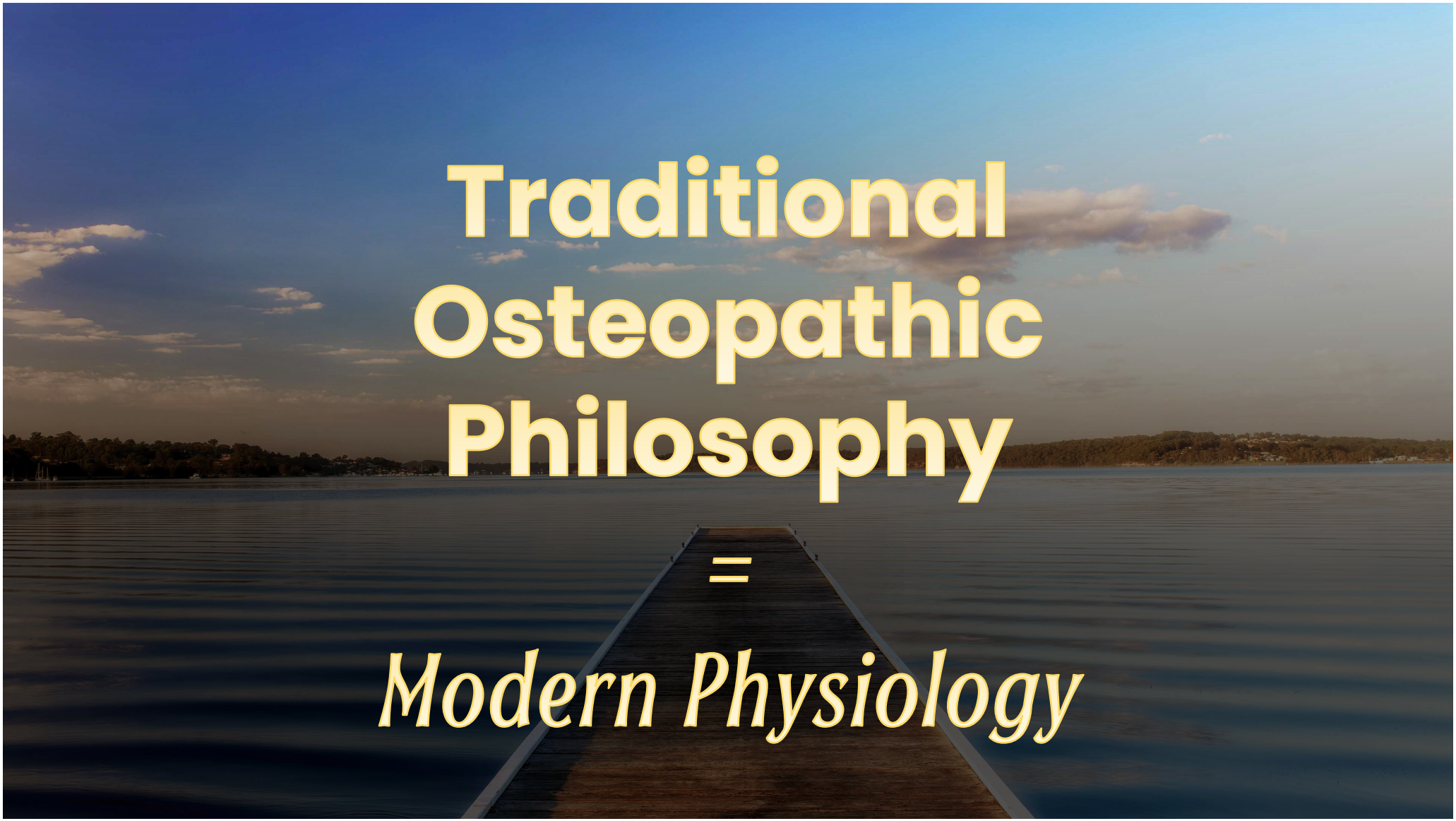
What evidence have we, that is absolute and undebatable, that all physical forces of the body are not conceived, developed, and issued from the heart? We speak of sensory nerves, nutrient nerves, motor nerves, voluntary and involuntary nerves, and to some degree we have described their special locations. By the knife and microscope we have found that all systems of nerves have one universal connection. We have found nothing that would warrant us in saying that the brain has any power to create nerve-fluid or force. We can talk about the brain of the head, the abdominal brain, the brain of liver, and go on with such speculative divisions and find a new brain in every ganglion of the body, but we have only found storage batteries from the heart that are new to our observation

A. T. Still.

What are Nerves? p.47-49 The Philosophy and Mechanical Principles of Osteopathy www.interlinea.org Andrew Taylor Still

We find one cluster in the lungs, one in the brain, one in the stomach and bowels, one at the kidneys, uterus, bladder, spine, and limbs, ***but all sing "Sweet Home" to Mother Heart*** when peace and harmony prevail, and cry with anguish when she fails to communicate the glad tidings of health, peace, plenty, and harmony. **Thus joy is perpetual when the watchman cries, "All is well."**

A. T. Still.


Traditional
Osteopathic
Philosophy
=
Modern Physiology

Summary of Evidence (1/4)

- CSF in the subarachnoid space has an outflow pathway from cerebrum, along the cribriform plate to lymphatic vessels adjacent to the olfactory bulbs to lymphatics within the nasal submucosa (in mice) [ref 1: Spera et al]
- Combining physiological studies with examination of the anatomical pathways for lymphatic drainage of the brain and CSF is essential for understanding lymphatic clearance in health and disease as it is important for volume regulation and for removal of waste products. [ref 2: Bakker, et al]
- Nasopharyngeal lymphatic plexus is a major hub for CSF outflow to deep cervical nodes. The plexus has unusual valves and short lymphangions but no smooth-muscle coverage. The plexus atrophies with ageing, but deep cervical lymphatics do not, although CSF outflow can still be increased by adrenergic or nitric oxide signaling, which may be useful in some age-related neurological conditions. [ref 3: Yoon, et al]
- Infrared (IR) energy can propel a flow-driving mechanism in blood vessels that can operate without imposed pressure, allowing the heart of a 3-day-old chick-embryo whose heart was stopped to continue to have blood flow for 50 minutes, albeit at a lower velocity. Each capillary may be viewed as a flow generator that runs on IR energy sending blood back to the heart. Infrared energy has a wavelength and may drive blood circulation. [ref4: Li and Pollack]
- Endothelial and mural cells stabilize blood vessels. Pericytes are a subtype of mural cells found in the microvasculature that extend their processes to wrap around the endothelial monolayer. They are recruited during vessel growth through the excretion of soluble factors from endothelial cells where they stabilize angiogenic sprouts and induce maturation of the resident cells. Alteration in function of the endothelial and mural cells causes numerous diseases. [ref 5: Warren and Gerecht]
- Alternative circulation model: Cardiac output occurs primarily in response to the metabolic demands of tissues. Blood circulated before the heart is functionally integrated. Negative interstitial pressure may play a role in assisting the flow of blood back into the heart. The heart functions like a hydraulic ram and maintains a dynamic equilibrium between the arterial (centrifugal) and venous (centripetal) forces which define the blood's circular movement. Exercising muscle blood flow is subject to local metabolic control so that perfusion is optimal when muscle vascular conductance rises. [ref 6: Furst and Gonzalez-Alonso]
- The paravascular (or glymphatic) pathway, according to the paravascular model, clears waste in the brain by CSF entering paravascular spaces surrounding penetrating arteries of the brain, mixing with the interstitial fluid and solutes in the parenchyma, and drains metabolic waste products and solutes, e.g. amyloid-beta, into paravascular spaces of draining veins. There is also a perivascular pathway waste clearance in a direction opposite to paravascular flow, but evidence for paravascular pathway clearance is not very solid at this time. [ref 7: Bacyinski, et al}

Summary of Evidence (2/4)

•Heartspace as the Basis of Superconsciouness:

•The heart has numerous minihearts along the inner surface of the ventricles which form spindle-shaped “packs” of erythrocytes in ventricular cavities. The cavities direct these “packs” to an associated organ at systole. At the moment of heart stroke compression, a magnetic impulse launches contractile function, and the brain contained in each miniheart joins in a trajectory of information and energy packs of erythrocytes move through blood vessels, each miniheart sending out a wave-guide haemodynamic link that controls the trajectory of information and energy packs of erythrocytes to send only to the organ associated with it. The organ receives a vortex driven “pack” with exactly the quantity of blood needed, sending the necessary oxygenation and nutrition needed for that cell to function.

•Stress can cause blood clots along the vortex pathway, which may lead to arterial dysfunction or myocardial infarction, specifically located in the distribution of the vortex pathway of the miniheart involved.

•The heart can control electromagnetic fields.

•The nervous system is not involved in the regional blood flow. Nor is chemical regulation or rotary pumping.

•Minihearts must have matching frequency resonance. Embryonic development of the heart involves minihearts taking part in the formation of associated tissues. The miniheart muscles form smooth muscle fibres of the vessels in the organs, entering the organs and splitting in capillaries. They conduct the high-frequency radiation that the heart uses to track the structure, information, and energy distribution of blood flow. DNA and RNA is very uniform in all structures that the miniheart forms.

•Several thousandths of a second between the magnetic impulse originating in the centre of the ventricular cavity causes electrical currents in the heart. The magnetic impulse is generated by deformation of the blood, launches the heart’s electrical system, and then produces an electromagnetic link beyond the heart, moving along vessels and creating movement of direct currents.

•It takes six to twenty seconds for blood to travel from heart to organs during which time the aorta and large vessels accept a portion of blood intended for the other organs, which allows the heart’s tracking system to save 5-6 times the amount of blood required by the body.

•The heart forms our brain during embryonic period, putting the consciousness of the heart system above our consciousness (which is why the body can survive for many years without a cerebrum functioning).

Summary of Evidence (3/4)

- Capillaries receive information for the heart, forming the border for interaction with the internal and external world. Moving erythrocyte structures make it possible for capillaries to absorb all information from the universe and accumulate the information in blood circulation. The information materializes with the venous system as the present, the lymphatic system as the past and the arterial system as the future. The brain, through nerve fibers, dischdrges mitochondria and lysosomes into the lymphatic system to form the matrix of switches of the past (memory).
- The heart's brain is located above the right auricle at the point of entrance of the superior vena cava, laterally, and it is exposed at the entrance to the atrium where it controls the inflow of blood elements and forms them into vortical packs. Information from the heart reaches the brain several seconds later. The heart adds images, feelings and events to the memory. Our mind thinks that this is the present, but for the heart's brain, it is the past. The time interval is the most vulnerable point for foreign intervention, if it is not protected spiritually. [Ref 8, Goncharenko]
- Far Infrared can improve wound healing, blood circulation, reverse peripheral sensory neuropathy, increase skin microcirculation, improve peritoneal membrane function for dialysis patients, and improve chronic heart failure. [Ref 9, Li and Pollack]
- CSF drainage in the human brain is now shown to have a CSF canalicular system with channels on either side of the sagittal sinus vein that communicate with the subarachnoid cerebrospinal fluid via Virchow-Robin spaces. This flow is independent of the venous system and from the cranidl base the flow channels into the neck to the subclavian vein. [Ref 10, Pessa]
- A 4th meningeal layer, the Subarachnoid Lymphatic-like Membrane or SLYM (mice) covers the entire brain and brain stem, forming a roof to shield the subarachnoid CSF-filled cisterna and the pia-adjacent vasculature. It facilitates periarterial influx of freshly produced CSF, supporting unidirectional glymphatic CSF transport. It also subdivides the subarachnoid space into to compartments. [Ref 11, Pla, et al.]
- The PRIMO VASCULAR SYSTEM
  - Present in many central and peripheral nervous system structures, on the surface of most viscera, in lymph and blood vessels, and in adipose tissue; more recently found in bovine heart, brain ventricles, and central canal of spinal cords plus abdominal adipose tissues.
  - High concentration of nucleic acids and adult small embryonic-like stem cells and also hormones in secretory granules
  - Circulatory properties, endocrine functions, support of anti-inflammatory processes, and possible role in cancer physiopathology and treatment

Summary of Evidence (4/4)

- PVS formally discovered by bong-Han Kim in the 1960's as he studied why acupuncture meridian system worked. He described bundles of tubular structures clearly distinguishable from nervous, blood vessels, and lymph systems in histological and experimental-biological characters with tubular structures ranging from 20 to 50 microns. He did not describe the dye that he used or the methods and protocols, so his work was not scientifically verifiable. His work has now been verified and is being used to regenerate injured tissues and heal wounds and heal other illness.
- May reshape Osteopathic treatment in time. [Ref12, Chikly, et al.]
- Cerebrospinal fluid circulation in human nerves gaining evidence.
- CNS flow in nerve sheaths, including pia meninges, epineurial channels, perineurium, and myelin sheaths (neurolemma) suggested by studies. Also direct ventricle-to-pia meninges CSF pathways found.
- CSF flow is an open circulatory system that occurs via channels, intracellular flow, and cell-to-cell transport associated with glial cells. Neural sheaths may participate in glucose and solute transport to axons. [Ref 13, Pessa].

Closing Practical:
Heart Field Palpation

THANK YOU! Dig ON!

Works Cited (in slide order)

Cerritelli, F., Chiacchiaretta, P., Gambi, F., Saggini, R., Perrucci, M. G., & Ferretti, A. (2021). Osteopathy modulates brain-heart interaction in chronic pain patients: An ASL study. *Scientific Reports, 11*, 4769. https://doi.org/10.1038/s41598-021-83893-8

Cerritelli, F., & Esteves, J. E. (2022). An enactive-ecological model to guide patient-centered osteopathic care. *Healthcare (Basel), 10*(6), 1092. https://doi.org/10.3390/healthcare10061092

Rasmussen, M. K., Mestre, H., & Nedergaard, M. (2018). The glymphatic pathway in neurological disorders. *The Lancet Neurology, 17*(11), 1016–1024. https://doi.org/10.1016/S1474-4422(18)30318-1

Expert Reviews in Molecular Medicine. (2003). *The blood-brain barrier: Effects of amyloid beta peptide on neurovascular cells* [Figure]. Scientific Figure on ResearchGate. https://www.researchgate.net/figure/The-Blood-Brain-Barrier-Adapted-from-Expert-Reviews-in-Molecular-Medicine-2003_fig1_274671770 (accessed May 9, 2025)

Louveau, A., Smirnov, I., Keyes, T. J., Eccles, J. D., Rouhani, S. J., Peske, J. D., Derecki, N. C., Castle, D., Mandell, J. W., Lee, K. S., Harris, T. H., & Kipnis, J. (2015). Structural and functional features of central nervous system lymphatic vessels. *Nature, 523*, 337–341. https://doi.org/10.1038/nature14432

UR Medicine. (2013, August 15). *The glymphatic system: Scientists discover previously unknown cleaning system in brain* [Video]. YouTube. https://youtu.be/ci5NMscKJws

Møllgård, K., Beinlich, F., Kusk, P., et al. (2023). A mesothelium divides the subarachnoid space into functional compartments. *Science, 379*(6627), 84–88. https://doi.org/10.1126/science.adc8810

Pessa, J. E. (2023). Identification of a novel path for cerebrospinal fluid (CSF) drainage of the human brain. *PLOS ONE, 18*(5), e0285269. https://doi.org/10.1371/journal.pone.0285269

Absinta, M., Ha, S.-K., Nair, G., Sati, P., Luciano, N. J., Palisoc, M., Louveau, A., Zaghloul, K. A., Pittaluga, S., Kipnis, J., & Reich, D. S. (2017). Human and nonhuman primate meninges harbor lymphatic vessels that can be visualized noninvasively by MRI. *eLife, 6*, e29738. https://doi.org/10.7554/eLife.29738

Hauglund, N. L., Andersen, M., Tokarska, K., Radovanovic, T., Kjaerby, C., Sørensen, F. L., Bojarowska, Z., Untiet, V., Ballestero, S. B., Kolmos, M. G., Weikop, P., Hirase, H., & Nedergaard, M. (2025). Norepinephrine-mediated slow vasomotion drives glymphatic clearance during sleep. *Cell, 188*(3), 606–622.e17. https://doi.org/10.1016/j.cell.2024.11.027

Yamamoto, E. A., Bagley, J. H., Geltzeiler, M., Sanusi, O. R., Dogan, A., Liu, J. J., & Piantino, J. (2024). The perivascular space is a conduit for cerebrospinal fluid flow in humans: A proof-of-principle report. *Proceedings of the National Academy of Sciences, 121*(42), e2407246121. https://doi.org/10.1073/pnas.2407246121

Coats, C. (1995). *Living energies: An exposition of concepts related to the theories of Viktor Schauberger*. Gateway Books.

Medlife Crisis. (2017, October 3). *Leonardo da Vinci's theory about the heart was right* [Video]. YouTube. https://www.youtube.com/watch?v=faVlZRGyBDs

Pollack, G. H. (2019). Water isn't what you think it is: The fourth phase of water. *Compendium of Scientific and Practical Findings Supporting Eco-Restoration to Address Global Warming, 2*(2), 43–47. https://bio4climate.org/wp-content/uploads/Compendium-Release-Vol-2-No-2-January-2019-r.1.pdf

Furst, B., & González-Alonso, J. (2025). The heart, a secondary organ in the control of blood circulation. *Experimental Physiology, 110*(5), 649–665. https://doi.org/10.1113/EP091387

Meda, K. (2022, April 19). *The heart's "little brain"*. Jefferson Research Magazine. https://research.jefferson.edu/2022-magazine/the-hearts-little-brain.html

Dodtievich, V. (2019). Modern view on the mechanism of “thought” formation and its implementation “program” at the supramolecular level. *International Journal of Cell Science & Molecular Biology, 6*(3). https://doi.org/10.19080/IJCSMB.2019.06.555688

Furst, B., & González-Alonso, J. (2025). The heart, a secondary organ in the control of blood circulation. *Experimental Physiology, 110*(5), 649–665. https://doi.org/10.1113/EP091387

Buckberg, G. D. (2015). *The Helical Heart* [Video]. David Geffen School of Medicine at UCLA. https://www.youtube.com/watch?v=v75tpamodY4

McCraty, R. (2003). The energetic heart: Bioelectromagnetic interactions within and between people. *The Neuropsychotherapist, 6*(1), 22–43. https://doi.org/10.12744/tnpt(6)022-043

Still, A. T. (1899). What are nerves? (pp. 47–49). In *The philosophy and mechanical principles of osteopathy*. Kansas City, MO: Hudson-Kimberly Publishing Co. Retrieved from https://www.interlinea.org