

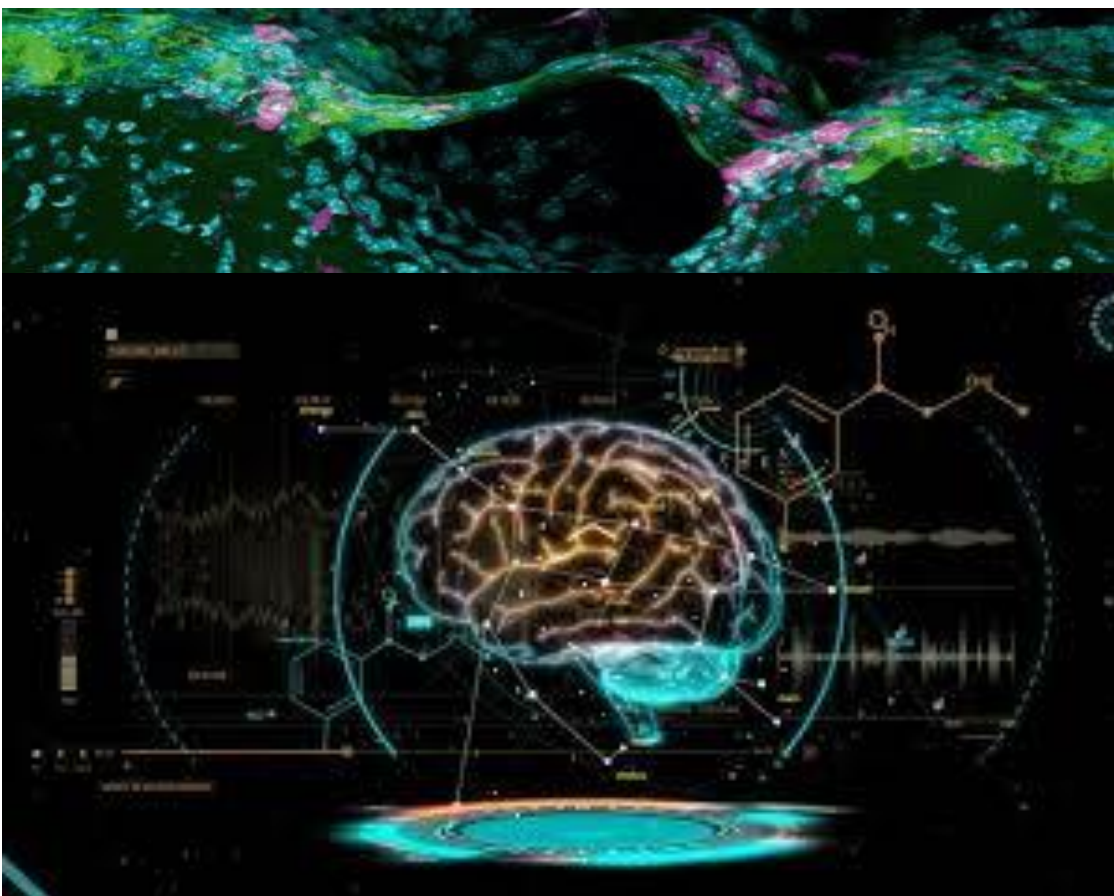
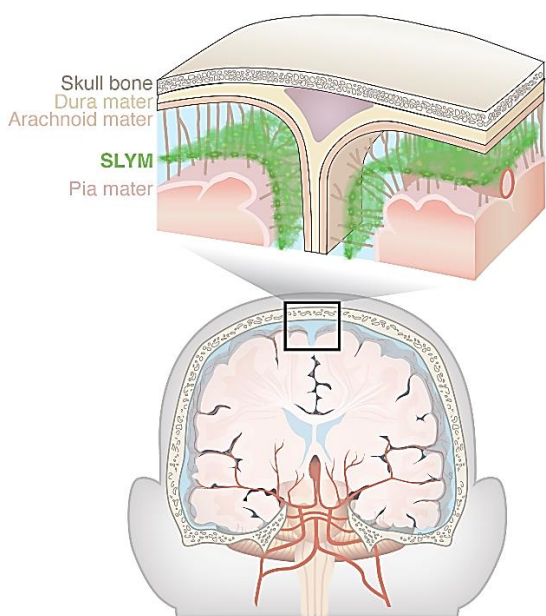
# Newly Discovered Anatomy of the Meninges that Shields and Monitors Brain Function

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From the complexity of neural networks to basic biological functions and structures, the human brain only reluctantly reveals its secrets. Advances in neuro-imaging and molecular biology have only recently enabled scientists to study the living brain at a level of detail not previously achievable, unlocking many of its mysteries. The latest discovery, described today in the journal *Science*, is a previously unknown component of brain anatomy that acts as both a protective barrier and platform from which immune cells monitor the brain for infection and inflammation.

The new study comes from the labs of Maiken Nedergaard, co-director of the Center for Translational Neuromedicine at University of Rochester and the University of Copenhagen and Kjeld Møllgård, M.D., a professor of neuroanatomy at the University of Copenhagen. Nedergaard and her colleagues have transformed our understanding of the fundamental mechanics of the human brain and made significant findings in the field of neuroscience, including detailing the many critical functions of previously overlooked



## SLYM Shields and Monitors Brain Function

cells in the brain called glia and the brain's unique process of waste removal, which the lab named the glymphatic system.

**"The discovery of a new anatomic structure that segregates and helps control the flow of cerebrospinal fluid (CSF) in and around the brain now provides us much greater appreciation of the sophisticated role that CSF plays not only in transporting and removing waste from the brain, but also in supporting its immune defenses," said Nedergaard.**

The study focuses on the series of membranes that encase the brain, creating a barrier from the rest of the body and keeping the brain bathed in CSF. The traditional understanding of what is collectively called the meningeal layer identifies the three individual layers as dura, arachnoid, and pia matter.

**Newly discovered membrane in the brain called SLYM is a thin but tight barrier that appears to separate "clean" and "dirty" CSF and harbors immune cells.**

The new layer discovered by the U.S. and Denmark-based research team further divides the space between the arachnoid and pia layers, the subarachnoid space, into two compartments, separated by the newly described layer, which the researchers name **SLYM**, an abbreviation of **Subarachnoidal Lymphatic-like Membrane**. While much of the research in the paper describes the function of SLYM in mice, they also report its presence in the adult human brain as well.

**SLYM is a type of membrane that lines other organs in the body, including the lungs and heart, called mesothelium. These membranes typically surround and protect organs, and harbor immune cells.** The idea that a similar membrane might exist in the central nervous system was a question first posed by Møllgård, the first author of the study, whose research focuses on developmental neurobiology, and on the systems of barriers that protect the brain.

**"The cerebro-spinal fluid is one of the highest known elements that are contained in the body, and unless the brain furnishes this fluid in abundance, a disabled condition of the body will remain. He who is able to reason will see that this great river of life must be tapped, and the withering field irrigated at once, or the harvest of health be forever lost."**  
-Dr. Andrew Taylor Still, M.D.

**Sources:**  
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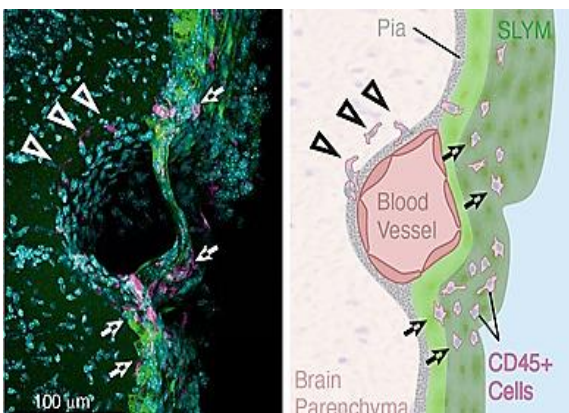
**"The lymphatics are closely and universally connected with the spinal cord and all other nerves, and all drink from the waters of the brain."**  
- Sutherland Cranial Teaching Foundation  
**"I believe we will see the day that participation in the Biodynamic Craniosacral process will be an essential element of everyone's healing process and optimal growth and development of each child."**  
-Joanne M. Gallagher, RCST®



# The Meningeal Lymphatic System: A New Player in Neurophysiology

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The new membrane is very thin and delicate, consisting of only a few cells in thickness. Yet SLYM is a tight barrier, allowing only very small molecules to transit and it also seems to separate “clean” and “dirty” CSF. This last observation hints at the likely role played by SLYM in the glymphatic system, which requires a controlled flow and exchange of CSF, allowing the influx of fresh CSF while flushing the toxic proteins associated with Alzheimer’s and other neurological diseases from the central nervous system. This discovery will help researchers more precisely understand the mechanics of the glymphatic system, which was the subject of a recent \$13 million grant from the National Institutes of Health’s BRAIN Initiative to the Center for Translational Neuromedicine at the University of Rochester.



Central nervous system immune cells (indicated here expressing CD45) use SLYM as a platform close to the brain's surface to monitor cerebrospinal fluid for signs of infection and inflammation.

The SLYM also appears important to the brain’s defenses. The central nervous system maintains its own native population of immune cells, and the membrane’s integrity prevents outside immune cells from entering. In addition, the membrane appears to host its own population of central nervous system immune cells that use SLYM as an observation point close to the surface of the brain from which to scan passing CSF for signs of infection or inflammation.

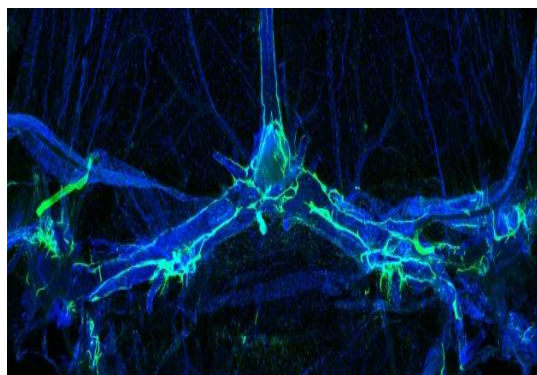
Discovery of the SLYM opens the door for further study of its role in brain disease. For example, the researchers note that larger and more diverse concentrations of immune cells congregate on the membrane during inflammation and aging. Furthermore, when the membrane was ruptured during traumatic brain injury, the resulting disruption in the flow of CSF impaired the glymphatic system and allowed non-central nervous system immune cells to enter the brain.

These and similar observations suggest that diseases as diverse as multiple sclerosis, central nervous system infections, and Alzheimer’s might be triggered or worsened by abnormalities

in SLYM function. They also suggest that the delivery of drugs and gene therapeutics to the brain may be impacted by SLYM, which will need to be considered as new generations of biologic therapies are being developed.

*Additional co-authors include Felix Beinlich, Peter Kusk, Leo Miyakoshi, Christine Delle, Virginia Pla, Natalie Hauglund, Tina Esmail, Martin Rasmussen, Ryszard Gomolka, and Yuki Mori with Center for Translational Neuromedicine at the University of Copenhagen. The study was supported with funding from the Lundbeck Foundation, Novo Nordisk Foundation, the National Institute of Neurological Disorders and Stroke, the U.S. Army Research Office, the Human Frontier Science Program, the Dr. Miriam and Sheldon G. Adelson Medical Research Foundation, and the Simons Foundation.*

*Mark Michaud – University of Rochester author*



## The Meningeal Lymphatic System: A New Player in Neurophysiology

The Mayo Clinic explains that:

A *bona fide* lymphatic vascular network is present in the meninges that wrap the brain and spinal cord of different mammalian species, including humans. The meningeal lymphatic system mediates the constant drainage of central nervous system fluids, molecules and immune cells into the cervical lymph nodes.

A published paper discusses the meningeal lymphatic system further:

The nature of fluid dynamics within the brain parenchyma is a focus of intensive research. Of particular relevance is its participation in diseases associated with protein accumulation and aggregation in the brain, such as Alzheimer’s disease (AD). The meningeal lymphatic vessels have recently been recognized as an important player in the complex circulation and exchange of soluble contents between the cerebrospinal fluid (CSF) and the interstitial fluid (ISF). In aging mammals, for example, impaired functioning of the meningeal lymphatic

vessels can lead to accelerated accumulation of toxic amyloid beta protein in the brain parenchyma, thus aggravating AD-related pathology. Given that meningeal lymphatic vessels are functionally linked to paravascular influx/efflux of the CSF/ISF, and in light of recent findings that certain cytokines, classically perceived as immune molecules, exert neuromodulatory effects, it is reasonable to suggest that the activity of meningeal lymphatics could alter the accessibility of CSF-borne immune neuromodulators to the brain parenchyma, thereby altering their effects on the brain. Accordingly, in this perspective we propose that the meningeal lymphatic system can be viewed as a novel player in neurophysiology.

## Consider What You Have Learned with Your Biodynamic Craniosacral Process...

- You have learned that your body has an inherent healing process designed to adapt and heal. The nerve system controls and adapts that process. The motility of the cerebrospinal fluid is very important to the function of the nerve system. Your fascial frame or body was designed to protect this motility. Traumas experienced in life can cause a restriction to fluid motion and can lead to compromise of function.
- The meninges are the core of your fascial body. Now science has “discovered” a fourth membrane of the meninges – the SLYM! It is for cleaning and immune function – more than before! And the meningeal lymphatic system can be viewed as a novel player in neurophysiology!
- This is additional validating scientific evidence that cerebrospinal fluid movement with glymphatic cleaning, hydraulic protection, oxygenation, nutrition, and hormonal and neurotransmitter transport is important to body function. It is vital to the optimal growth and development of our children.
- Participation in the Biodynamic Craniosacral session and balance is an important part of everyone’s life process – you and your family!

The existence of lymphatic vessels in the brain meninges was first mentioned toward the end of the 18<sup>th</sup> century by Paolo Mascagni, an Italian physician known for his unparalleled anatomical knowledge.