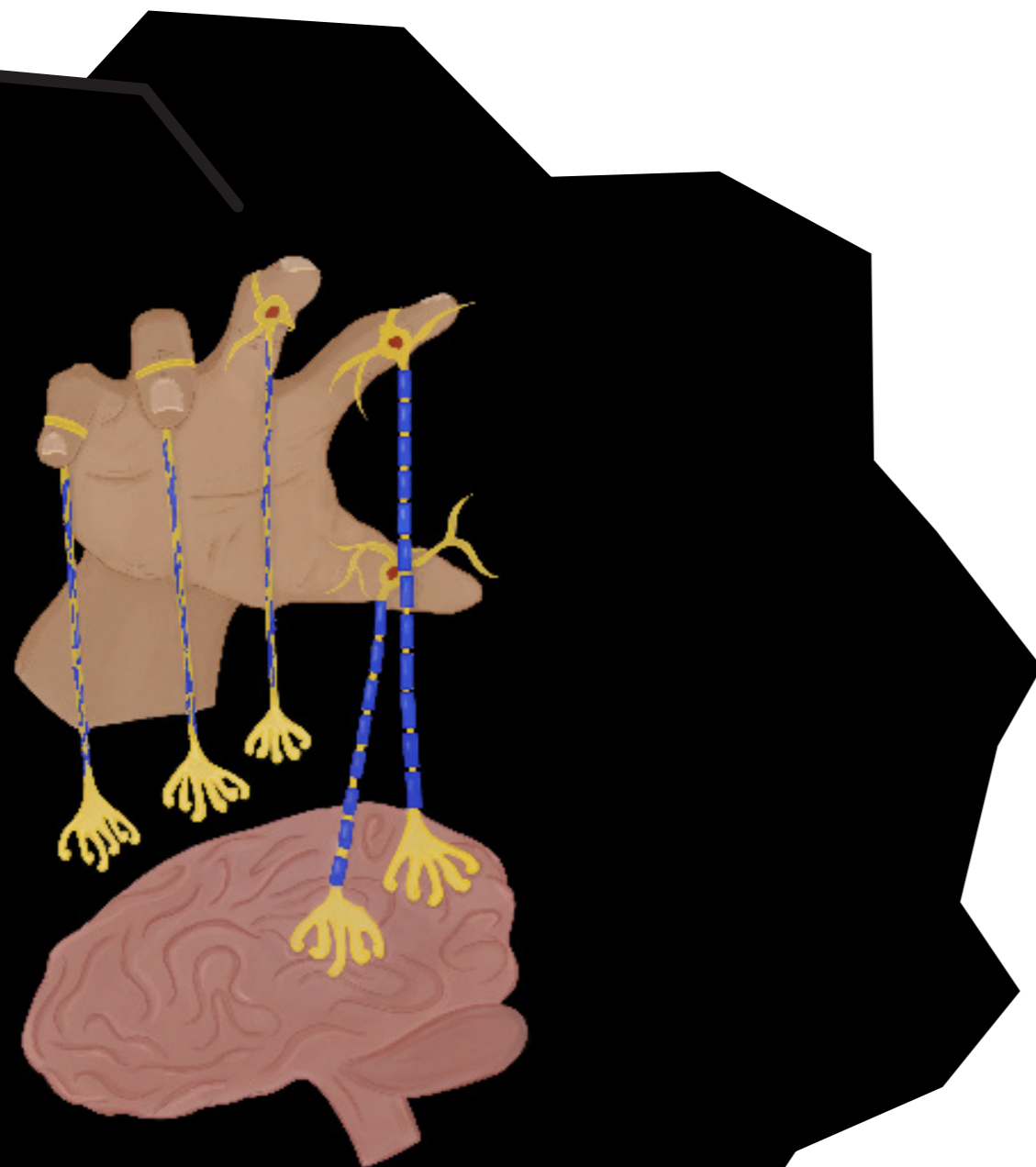


# BEYOND THE

## Myelination's Role in Disorder and Disease



# NEURON:

BY: MATTHEW CALDERONE  
ART BY: GAURI KUMAR

**A**lthough neurons receive a majority of the attention in widespread neuroscience literature, there are many cell types in the brain that have crucial roles in regulating brain function. One of these cell types, glial cells, account for 33% of all brain tumors and 50% of all cells in the brain [1, 2]. Glial cells, also referred to as glia, play a role in pathogenesis of diseases and disorders of the central nervous system, which consists of both the brain and spinal cord. Glia come in three subsets: microglia, astrocytes, and oligodendrocytes. Microglia, named as such for their small size, are major players in the brain's immune system. Astrocytes (which means star [astro] cell [cyte]) are responsible for transportation of nutrients [3]. The third glial cell type, Oligodendrocytes, are unique because they have complex, specific interactions with neurons. To illustrate these interactions, imagine you are driving a car down a straight dirt path in the countryside, with occasional potholes and pebbles that are getting kicked up while you are driving. Now compare this to driving on a newly constructed, freshly paved stretch of highway on the Pennsylvania turnpike. What can you assume about safe speeds of the cars in these two situations? What about the duration of the trip? This

example highlights two key features applicable within the brain. The average speed of your car is proportional to the condition of the road, meaning that if the road is smooth and paved, your car can drive faster, and the duration of your trip is inversely proportional to these road conditions, meaning that if the road is rough and unpaved, your trip is longer. In this sense, neurons are like roads; they can be "paved" or myelinated, a term used to describe when oligodendrocytes coat or wrap around a portion of the neuron to create a covering called the myelin sheath [4].

Essentially, myelination converts the communication space between neurons into a super-highway. Before it can send its own signal, a neuron must receive information through its dendrites. Dendrites are branchlike extensions from the neuron's cell body and relay the signal all the way to its end, the axon. Once the axon receives this signal, it is able to produce an electrical current that causes a cascade of cellular processes within the neuron. This cascade results in the release of signaling molecules from the axon into the synaptic cleft, the space between one neuron's axon and the dendrite of the receiving neuron. Myelination increases the efficiency of a neuron's axon, making

General Editor: Margaret Silva | Graduate reviewer: Rachel Podgorski Lay  
Reviewer: Yanna O'Boyle | Scientific Reviewer: Nakiyah Shoemake



the process of transmitting signals easier and faster. This is why we are able to respond quickly to our environment, and why you're able to focus your eyes on the words you're reading now. Myelination plays a key role in ensuring proper functioning of the brain's circuits and pathways, and when this system doesn't function properly it can lead to disastrous effects.

As myelination occurs many times throughout many regions of the central nervous system; this means there are many opportunities for errors to occur. Two examples of this are demyelination and dysmyelination. Demyelination is a process by which the myelin sheath degrades, while the axon is left mostly intact [5]. Dysmyelination is a process in which neurons are not properly myelinated. The distinction between demyelination and dysmyelination is that demyelination occurs in neurons that were originally myelinated, whereas in dysmyelination, neurons never had proper myelination to begin with.

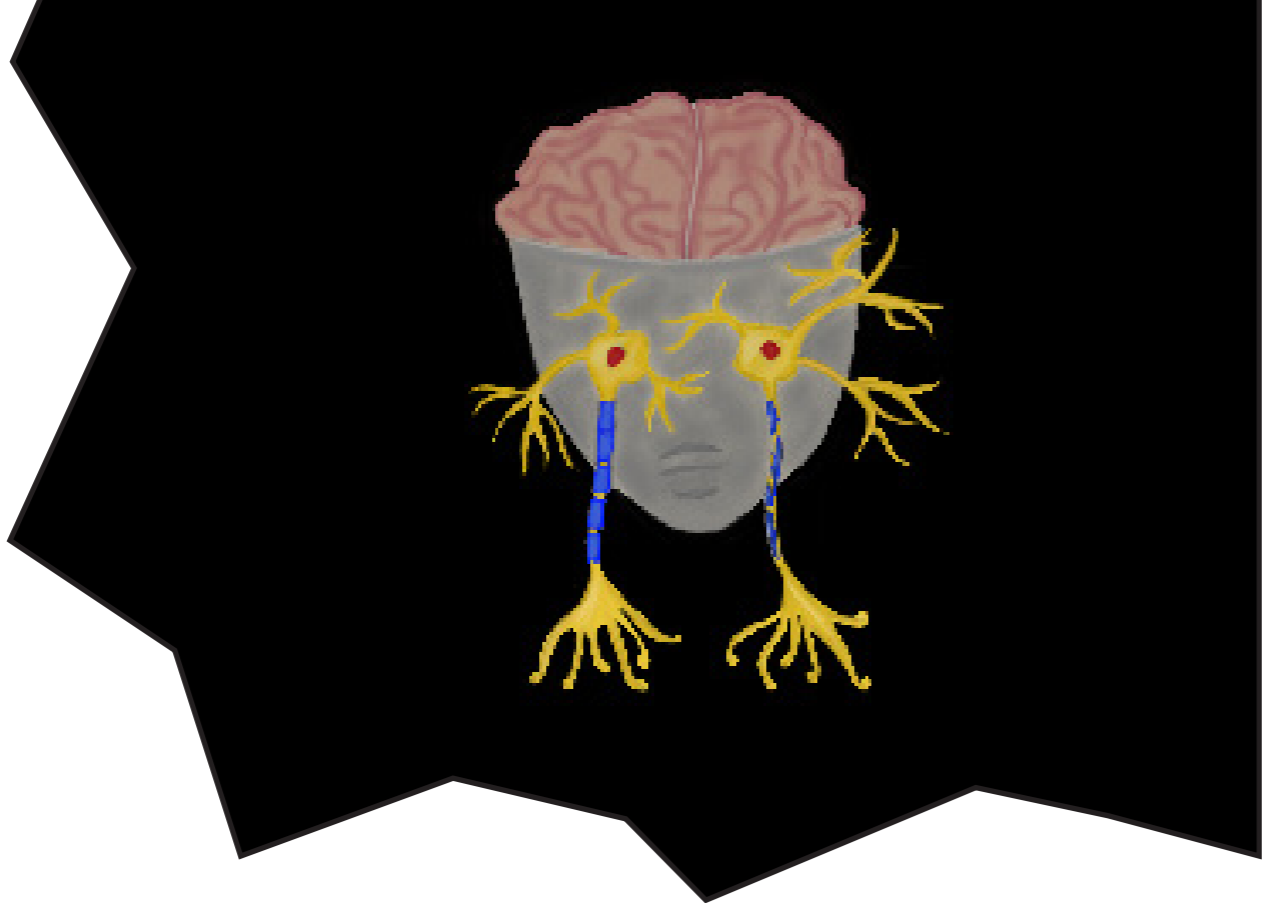
Multiple sclerosis (MS) is a disorder that causes the immune system to attack and degrade myelin of the central nervous system, and is a prime example of demyelination resulting from a disorder [6]. MS mainly affects young adults, primarily those between the ages of 20 and 40 years of age, and presents in two forms; relapsing remitting MS (RRMS), and less commonly, secondary progressive multiple sclerosis [7]. Typically, the first stage of MS is RRMS, where a patient may have episodes of MS symptoms consisting of: tingling of the extremities, visual impairments, fatigue, spasticity, urinary dysfunction, and learning and memory impairments [7,8]. These symptoms develop over hours to days and eventually hit a plateau where they will persist for several weeks then eventually desist [7]. Recovery from these episodes comes with a rebound of symptoms, but magnetic resonance imaging (MRI), a non-invasive technique used to build 3D images of organs, reveals asymptomatic lesions not only in the brain, but also within the spinal cord [9, 10]. These lesions,

regions of damaged cells, contribute to continued neurodegeneration and worsening of symptoms to the point of secondary progressive MS, a disease state where the progression of the disease is no longer halted by remitted periods of symptoms [9].

Another disorder that causes demyelination is acute disseminated encephalomyelitis (ADEM) which is characterized by a rapid, short-lasting inflammation that destroys myelin. While the reason for this attack is not completely known, current theories link the inflammation to environmental stress in genetically vulnerable people [11]. ADEM can be mistaken for an MS episode but comes with its own differentiating properties. ADEM is most common in children under the age of 10, and typically presents as a single widespread attack on the myelin sheath. In contrast, MS is characterized by persistent attacks on the sheath spanning over the course of a few weeks or months and occurs as a result of viral or bacterial infections [11, 12]. These two disorders are classic examples and give important insight into disorders associated with improper myelination.

Interestingly, there are emerging theories about myelin's potential role in previously unlinked disorders. Some of these theories look at the role of myelin in attention-deficit/hyperactivity disorder (ADHD), autism spectrum disorder (ASD), obsessive-compulsive disorder (OCD), and post-traumatic stress disorder (PTSD). ADHD is a neurodevelopmental disorder, meaning it arises during the early stages of brain development, and is characterized by a dysregulation of the reward system within the brain [13]. Behaviorally, ADHD is seen as inattention, hyperactivity, and a lack of executive functioning skills for the patient's age [14]. Genome-wide association meta-analyses have recently been employed to scan the genetic library of individuals with ADHD in an attempt to find its genetic components [15, 16]. These analyses have found mutations in a gene that encodes for the beta-galactoside-alpha-2,3-sialyltransferase-III membrane protein (ST3GAL3). Silencing of this protein in mice, by knockout of two exons (the coding region of DNA) within the gene's coding sequence, has been linked to a cognitively impaired behavioral phenotype caused by dysmyelination [17].

**MYELINATION PLAYS A KEY ROLE IN ENSURING PROPER FUNCTIONING OF THE BRAIN'S CIRCUITS AND PATHWAYS, AND WHEN THIS SYSTEM DOESN'T FUNCTION PROPERLY IT CAN LEAD TO DISASTROUS EFFECTS**



ASD is another neurodevelopmental disorder characterized by difficulties in communication, restricted interests, repetitive behaviors, and other symptoms that impair a person's social integration [18]. While there is a genetic component to ASD, the precise localization of the causes of the disorder are not well characterized. Phan et al. performed an analysis of differentially expressed genes (DEGs) and linked ASD pathology to genes dysregulating oligodendrocytes, or in our terms, dysmyelination [19]. This dysregulation of myelination can be seen in human post-mortem brain tissue as well as in ASD mouse models, and opens the door for further research.

In contrast, OCD is a chronic, long-lasting disorder which consists of uncontrollable obsessive thoughts and compulsive behaviors [20]. An MRI study investigating the brain composition of OCD patients found that while there was no difference in total brain volume or gray matter volumes (neurons), as compared to control brains, the brains of OCD patients were found to have higher total white matter volumes (glia) [21]. This increase of myelin could be quickening the connection between compulsive behavior and obsessive thought modulating portions of the brain.

Similarly, Chao et al., performed MRI analyses in veterans suffering from PTSD, in comparison to matched trauma-controlled veterans not suffering from PTSD. These analyses found significantly more myelination of the hippocampus, the memory center of the brain [22]. OCD and PTSD highlight an interesting break from the previously mentioned component of demyelination in MS, and ADEM, as well as the dysmyelination seen in ADHD and ASD. That is the problem of over-myelination, an issue which can be thought of as reinforcing a negative pathway through the brain, meaning to create a quicker reaction to negative stimuli; this results in stress, obsessions, and compulsions.

Overall, myelin's role within the brain is to streamline neuronal signals. Issues in this process by demyelination or dysmyelination can lead to problematic transduction of these signals. Two disorders that characterize demyelination are MS and ADEM, the distinction being repeated attacks in MS, and a single attack in ADEM. ADHD and ASD are neurodevelopmental disorders with genetic components linked to dysmyelination by way of insufficient myelination. PTSD, and OCD are less genetically associated disorders that relate to dysmyelination through increased levels of myelination; mechanistically this could be through quicker response to negative stimuli. Myelination is a process that is crucial for the proper functioning of neuronal pathways throughout the brain, and alterations to this delicate process can lead to devastating effects. 🧠

## FOOTNOTES

### FLORENCE SYNDROME: BEAUTIFUL MADNESS

1. *tabula rasa*, (Latin: "scraped tablet"—i.e., "clean slate") in theory of knowledge and psychology, a supposed condition that empiricists have attributed to the human mind before ideas have been imprinted on it by the reaction of the senses to the external world of objects [1]
2. A type of disorder in which psychological factors are believed to play a significant role in the origin and/or course of disorder [5]
3. Psychosis is an "abnormal mental state involving significant problems with reality testing" (APA, 2022). Psychosis is characterized by serious impairments or disruptions in perception, cognitive processing, emotions and affect and is manifested in behavioral phenomena, such as delusions, hallucinations, and disorganized speech [6]
4. Hallucination is a "false sensory perception that has a compelling sense of reality despite the absence of an external stimulus" (APA, 2022). The most common hallucinations are auditory hallucinations and visual hallucinations. Hallucinations usually signify a presence of a psychotic disorder, but also may result from substance use and neurological abnormalities [7]
5. Delusion is a "highly personal idea or belief system, not endorsed by one's culture or subculture, that is maintained with conviction in spite of irrationality or evidence to the contrary" Delusions range from transient and fragmentary to systematized and elaborate. Common delusions include delusional jealousy, delusions of being controlled, delusions of grandeur, delusions of persecution, delusions of ordinary events having a special meaning for an individual, delusions of being dead, and somatic delusions. Delusions are derived from emotions rather than logical errors [8].
6. DSM-5 (Diagnostic and Statistical Manual of Mental Disorders) is the primary psychology diagnostic manual used in the United States that was published in 2013 [10].
7. BMJ Case Reports is one of the world's most influential and respected general medicine journals that delivers a focused, peer-reviewed, valuable collection of cases in all health-related disciplines [11]
8. The awe-inspiring stimulus is experienced as "vast" and difficult to comprehend. Awe experiences can be overwhelming and can motivate wonderment [13].
9. Persecutory delusion is an erroneous belief that others are conspiring against one or threatening one in any way [14]
10. Culture shock is a state of loneliness, anxiety, and confusion experienced by an individual or group that suddenly experiences a radical cultural change. For example, a Filipino student studying at an American university may experience culture shock, as may a businessperson traveling abroad [17]
11. Functional Magnetic Resonance Imaging (fMRI) is a form of magnetic resonance imaging used to localize areas of cognitive activation, based on the correlation between brain activity and blood property changes linked to local changes in blood flow to the brain. During periods of cognitive activation, blood flow is always increased to a greater extent than oxygen extraction. In consequence, the proportion of oxygenated hemoglobin in the red blood cells transiently increases in an active region, leading to a local increase in the signal detected by fMRI [20]
12. Positron Emission Tomography (PET) scan is an imaging technique using radiolabeled tracers that emit positively charged particles (positrons) as they are metabolized. Used to evaluate cerebral metabolism and blood flow as well as the binding and transport of neurotransmitter systems in the brain. PET enables documentation of functional changes that occur during the performance of mental activities [21]
13. Insular cortex is an area of the brain located deep within the lateral sulcus of the brain. Insular cortex is responsible for emotional feelings, including maternal and romantic love, anger, fear, sadness, happiness, sexual arousal, disgust, aversion, unfairness, inequity, indignation, uncertainty, disbelief, social exclusion, trust, empathy, sculptural beauty, a 'state of union with God', and hallucinogenic states [22; 23]
14. Neuroaesthetics are "the study of the neural processes underlying the psychological processes that are evoked in the creator or the viewer of the object in the course of interacting with it. The psychological processes may involve perceptual, sensory, cognitive, emotional, evaluative, and social aspects, all of which are presumed to have biological-neural-basis" [15].
15. Default Mode Network is an anatomically defined brain system that is activated when the person is engaged in internally focused tasks, including autobiographical memory retrieval, envisioning the future, and conceiving the perspectives of others. It consists of the medial prefrontal cortex, posterior cingulate cortex, angular gyrus, precuneus, and middle frontal gyrus. Some researchers believe that constant unconstrained self-reflective thought might be the natural state of human mind (APA, 2022).
16. Mentalization is the ability to understand one's own and others' mental states, and so, to understand one's own and others' intentions and affects [25]
17. Apperception is the process of becoming conscious of a perception, so that perception is recognized and understood [26]
18. Megalomania is a delusion of grandeur; a highly inflated perception of one's personal importance, power and capabilities that can be often seen in individuals with mania and paranoid schizophrenia. Megalomania might be accompanied or preceded by delusions of persecution [30].
19. Erotomania is a compulsive sexual activity; an erroneous belief that one has a romantic relationship with a public figure [31]
20. Mysticism is the idea that there are credible sources of knowledge and truth that can be acquired by means outside of senses, logic and empirical methods. It is believed that mystical knowledge can be gained through inspiration, revelation and other mystical experiences. Mysticism also describes the belief that the wisdom and unity with the divine can be achieved through personal religious experience [32].
21. Anorexia is an absence or loss of appetite for food. It may be primarily a psychological disorder, as in anorexia nervosa. It may also have physiological causes [33].
22. Cosmopolitan ("citizen of the world") is derived from the idea of cosmopolitanism. Cosmopolitanism describes a philosophical approach that regards all humanity as a single community [35].

## REFERENCES

- most-americans-have-traveled-abroad
- American Psychological Association. (n.d.). Megalomania. In APA dictionary of psychology. <https://dictionary.apa.org/megalomania>
  - American Psychological Association. (n.d.). Erotomania. In APA dictionary of psychology. <https://dictionary.apa.org/erotomania>
  - American Psychological Association. (n.d.). Mysticism. In APA dictionary of psychology. <https://dictionary.apa.org/mysticism>
  - American Psychological Association. (n.d.). Anorexia. In APA dictionary of psychology. <https://dictionary.apa.org/anorexia>
  - Bar-El, Y., Durst, R., Katz, G., Zislin, J., Strauss, Z., & Knobler, H. (2000). Jerusalem syndrome. *British Journal of Psychiatry*, 176(1), 86-90. doi:10.1192/bjp.176.1.86
  - The Stanford Encyclopedia of Philosophy. (2019). Cosmopolitanism. The Stanford Encyclopedia of Philosophy. <https://plato.stanford.edu/entries/cosmopolitanism/>
  - American Psychological Association. (n.d.). Paranoid psychosis. In APA dictionary of psychology. <https://dictionary.apa.org/paranoid-psychosis>
  - American Psychological Association. (n.d.). Mirror neuron. In APA dictionary of psychology. <https://dictionary.apa.org/mirror-neuron>
  - Wilson SA. Pathological Laughing and Crying. *Proc R Soc Med*. 1923;16(Sect Psych):39-40
  - Campellone, J. (2022). Anatomy of the brain. *Anatomy of the Brain - Health Encyclopedia - University of Rochester Medical Center*. Retrieved November 28, 2022, from <https://www.urmc.rochester.edu/encyclopedia/content.aspx?ContentTypeID=85&ContentID=P00773>
  - Floeter MK, Katipally R, Kim MP, Schanz O, Stephen M, Danielian L, Wu T, Huey ED, Meoded A. Impaired corticopontocerebellar tracts underlie pseudobulbar affect in motor neuron disorders. *Neurology*. 2014 Aug 12;83(7):620-7. doi:10.1212/WNL.0000000000000693
  - Parvizi J, Anderson SW, Martin CO, Damasio H, Damasio AR. Pathological laughter and crying: a link to the cerebellum. *Brain*. 2001 Sep;124(Pt 9):1708-19
  - Zhu Y, Gao H, Tong L, Li Z, Wang L, Zhang C, Yang Q, Yan B. Emotion Regulation of Hippocampus Using Real-Time fMRI Neurofeedback in Healthy Human. *Front Hum Neurosci*. 2019 Jul 16;13:242. doi: 10.3389/fnhum.2019.00242
  - Sankar A, Purves K, Colic L, Cox Lippard ET, Millard H, Fan S, Spencer L, Wang F, Pittman B, Constable RT, Gross JJ, Blumberg HP. Altered frontal cortex functioning in emotion regulation and hopelessness in bipolar disorder. *Bipolar Disord*. 2021 Mar;23(2):152-164. doi: 10.1111/bdi.12954
  - Bratec Mulej S, Xie X, Wang Y, Schilbach L, Zimmer C, Wohlschläger AM, Riedl V, Sorg C. Cognitive emotion regulation modulates the balance of competing influences on ventral striatal aversive prediction error signals. *Neuroimage*. 2017 Feb 15;147:650-657. doi: 10.1016/j.neuroimage.2016.12.078
  - Rosen HJ, Cummings J. A real reason for patients with pseudobulbar affect to smile. *Ann Neurol*. 2007 Feb;61(2):92-6
  - Kekere V, Qureshi D, Thanju A, Fourn P, Olupona T. Pseudobulbar Affect Mimicking Depression: A Case Report. *Cureus*. 2022 Jun 23;14(6):e26235. doi:10.7759/cureus.26235
  - Cook CE, Décarý S. Higher order thinking about differential diagnosis. *Braz J Phys Ther*. 2020 Jan - Feb;24(1):1-7. doi: 10.1016/j.bjpt.2019.01.010
  - Hammond FM, Sauve W, Ledon F, Davis C, Formella AE. Safety, Tolerability, and Effectiveness of Dextromethorphan/Quinidine for Pseudobulbar Affect Among Study Participants With Traumatic Brain Injury: Results From the PRISM-II Open Label Study. *PM R*. 2018 Oct;10(10):993-1003. doi: 10.1016/j.pmrj.2018.02.010
  - Young FG, Nguyen D. Treatment of pseudobulbar affect (PBA) in a patient with a history of traumatic brain injury, partial brain resection, and brainstem stroke: a case report. *J Med Case Rep*. 2020 Dec 4;14(1):235. doi:10.1186/s13256-020-02525-3
  - NCI Dictionary of Cancer terms. National Cancer Institute. (2022). Retrieved November 28, 2022, from <https://www.cancer.gov/publications/dictionaries/cancer-terms/def/antagonist>
  - Sauvé WM. Recognizing and treating pseudobulbar affect. *CNS Spectr*. 2016 Dec;21(S1):34-44. doi: 10.1017/S1092852916000791
  - NCI Dictionary of Cancer terms. National Cancer Institute. (2022). Retrieved November 28, 2022, from <https://www.cancer.gov/publications/dictionaries/cancer-terms/def/selective-serotonin-reuptake-inhibitor>
  - Colamonico J, Formella A, Bradley W. Pseudobulbar affect: burden of illness in the USA. *Adv Ther*. 2012 Sep;29(9):775-98. doi: 10.1007/s12325-012-0043-7
  - onlinelibrary.wiley.com/doi/abs/10.1111/ene.13819
  - Ghasemi, N., Razavi, S., & Nikzad, E. (2017). Multiple sclerosis: Pathogenesis, symptoms, diagnoses and cell-based therapy. *Cell journal*. Retrieved November 11, 2022, from <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5241505/>
  - Thompson, A., Banwell, B. L., Barkhof, F., Carroll, W. M., Coetzee, T., Comi, G., Correale, J., Fazekas, F., Filippi, M., Freedman, M. S., Fujihara, K., Galetta, S. L., Hartung, H. P., Kappos, L., Lublin, F. D., Marrie, R. A., Miller, A. E., Miller, D. H., Montalban, X., ... Cohen, J. A. (2017, December). Diagnosis of multiple sclerosis: 2017 revisions of the McDonald Criteria. *The Lancet. Neurology*. Retrieved November 29, 2022, from <https://pubmed.ncbi.nlm.nih.gov/29275977/>
  - U.S. Department of Health and Human Services. (n.d.). Magnetic Resonance Imaging (MRI). National Institute of Biomedical Imaging and Bioengineering. Retrieved November 29, 2022, from <https://www.nibib.nih.gov/science-education/science-topics/magnetic-resonance-imaging-mri>
  - Anilkumar, A. C., Tadi, P., & Foris, L. A. (2022, January). Acute Disseminated Encephalomyelitis. National Library of Medicine. Retrieved November 12, 2022, from <https://www.ncbi.nlm.nih.gov/books/NBK430934/>
  - U.S. Department of Health and Human Services. (n.d.). Acute disseminated encephalomyelitis. National Institute of Neurological Disorders and Stroke. Retrieved September 28, 2022, from <https://www.ninds.nih.gov/health-information/disorders/acute-disseminated-encephalomyelitis>
  - Stark, R., Bauer, E., Merz, C. J., Zimmermann, M., Reuter, M., Plichta, M. M., Kirsch, P., Lesch, K. P., Fallgatter, A. J., Vaitl, D., & Herrmann, M. J. (2011). ADHD related behaviors are associated with brain activation in the reward system. *Neuropsychologia*, 49(3), 426-434. <https://doi.org/10.1016/j.neuropsychologia.2010.12.012>
  - Centers for Disease Control and Prevention. (2022, August 9). What is ADHD? Centers for Disease Control and Prevention. Retrieved November 12, 2022, from <https://www.cdc.gov/ncbddd/adhd/facts.html#:~:text=ADHD%20is%20one%20of%20the,%2C%20or%20be%20overly%20active.>
  - Demontis, D., Walters, R. K., Martin, J., Mattheisen, M., Als, T. D., Agerbo, E., Baldursson, G., Belliveau, R., Bybjerg-Grauholm, J., Bækvad-Hansen, M., Cerrato, F., Chambert, K., Churchhouse, C., Dumont, A., Eriksson, N., Gandal, M., Goldstein, J. I., Grasby, K. L., Grove, J., ... Neale, B. M. (2018, November 26). Discovery of the first genome-wide

### BEYOND THE NEURON: MYELINATION'S ROLE IN DISORDER AND DISEASE

- Gliomas. Johns Hopkins Medicine. (2022, February 11). Retrieved September 16, 2022, from <https://www.hopkins-medicine.org/health/conditions-and-diseases/gliomas>
- von Bartheld, C. S., Bahney, J., & Suzana Herculano-Houzel. (2016, May 17). The search for true numbers of neurons and glial cells in the human brain: A review of 150 years of cell counting. *Wiley Online Library*. Retrieved September 16, 2022, from <https://onlinelibrary.wiley.com/doi/10.1002/cne.24040>
- Jäkel, S., & Dimou, L. (2017). Glial cells and their function in the Adult Brain: A journey through the history of their ablation. *Frontiers in Cellular Neuroscience*. <https://doi.org/10.3389/fncel.2017.00024>
- Bradl, M., & Lassmann, H. (2009). Oligodendrocytes: Biology and pathology. *Acta Neuropathologica*, 119(1), 37-53. <https://doi.org/10.1007/s00401-009-0601-5>
- Love, S. (2006). Demyelinating diseases. *Journal of Clinical Pathology*, 59(11), 1151-1159. <https://doi.org/10.1136/jcp.2005.031195>
- Lemus, H. N., Warrington, A. E., & Rodriguez, M. (2018). Multiple sclerosis. *Neurologic Clinics*, 36(1), 1-11. <https://doi.org/10.1016/j.ncl.2017.08.002>
- Dobson, R., & Giovannoni, G. (2018, October). Multiple sclerosis – a review - Dobson - *Wiley Online Library*. *Wiley Online Library*. Retrieved September 29, 2022, from <https://>

## REFERENCES

- significant risk loci for attention deficit/hyperactivity disorder. *Nature News*. Retrieved November 11, 2022, from <https://www.nature.com/articles/s41588-018-0269-7>
16. Lesch, K.-P. (2019, February 20). Editorial: Can dysregulated myelination be linked to ADHD pathogenesis... Association for Children and Adolescent Mental Health. Retrieved October 7, 2022, from <https://acamh.onlinelibrary.wiley.com/doi/10.1111/jcpp.13031>
  17. Yoo, S. W., Motari, M. G., Susuki, K., Prendergast, J., Mountney, A., Hurtado, A., & Schnaar, R. L. (2015). Sialylation regulates brain structure and function. *The FASEB Journal*, 29(7), 3040–3053. <https://doi.org/10.1096/fj.15-270983>
  18. U.S. Department of Health and Human Services. (n.d.). Autism spectrum disorder. National Institute of Mental Health. Retrieved November 12, 2022, from <https://www.nimh.nih.gov/health/topics/autism-spectrum-disorders-asd>
  19. Phan, B. D. N., Bohlen, J. F., Davis, B. A., Ye, Z., Chen, H.-Y., Mayfield, B., Sripathy, S. R., Page, S. C., Campbell, M. N., Smith, H. L., Gallop, D., Kim, H., Thaxton, C. L., Simon, J. M., Burke, E. E., Shin, J. H., Kennedy, A. J., Sweatt, J. D., Philpot, B. D., ... Maher, B. J. (2020, February). A myelin-related transcriptomic profile is shared by Pitt-Hopkins Syndrome Models and human autism spectrum disorder. *Nature neuroscience*. Retrieved October 7, 2022, from <https://pubmed.ncbi.nlm.nih.gov/32015540/>
  20. U.S. Department of Health and Human Services. (n.d.). Obsessive-compulsive disorder: When unwanted thoughts or repetitive behaviors take over. National Institute of Mental Health. Retrieved November 12, 2022, from <https://www.nimh.nih.gov/health/publications/obsessive-compulsive-disorder-when-unwanted-thoughts-take-over>
  21. Atmaca, M., Onalan, E., Yildirim, H., Yuce, H., Koc, M., & Korkmaz, S. (2010). The Association of Myelin oligodendrocyte glycoprotein gene and white matter volume in obsessive-compulsive disorder. *Journal of Affective Disorders*, 124(3), 309–313. <https://doi.org/10.1016/j.jad.2010.03.027>
  22. Chao, L. L., Tosun, D., Woodward, S. H., Kaufer, D., & Neylan, T. C. (2015). Preliminary evidence of increased hippocampal myelin content in veterans with posttraumatic stress disorder. *Frontiers in Behavioral Neuroscience*, 9. <https://doi.org/10.3389/fnbeh.2015.00333>