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The Unsung Healers: Unlocking the regenerative potential of glial cells

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AUTHOR BIO

Rhea Govani is a high school student at high school in Illinois with a strong passion for neuroscience, biology, and healthcare. As a dedicated researcher, Rhea has explored the role of glial cells in neurological processes and has written a research paper on the human brain. She is actively involved in HOSA (Health Occupations Students of America), where she engages in medical competitions and deepens her understanding of healthcare professions. Additionally, Rhea is a violist in her school orchestra and a member of Tri-M honors music society, demonstrating a commitment to both science and the arts. With aspirations of pursuing a career in medicine and research, Rhea seeks to contribute to advancements in the medical field through scientific inquiry and innovation.

ABSTRACT

The role of glial cells within neurobiology has been constantly debated between scientists for decades, and in the past, has often been overshadowed by neurons in talks of neurocellular healing. However, in recent years, glial cells have been found to be promising sources of control and healing within the human body as a whole. The dynamic applications of glial cells have sent many neuroscientists on a journey to apply their skills of maintaining homeostasis to deadly diseases and conditions, such as Alzheimer's Disease, cancer, and even localized conditions such as Crohn's Disease. Glial cells are so foundational to biology, that they determine the efficiency and accuracy of almost every organ system in the body.

Keywords: *Alzheimer's, biology, glia, healing, homeostasis, neurobiology, neurodegeneration, neuroglia.*

INTRODUCTION

Traumatic brain injuries (TBIs) are among the most severe neurological emergencies, often requiring urgent surgical intervention. According to the Centers for Disease Control and Prevention (2022), approximately 223,000 TBI-related hospitalizations occurred in the United States in 2019 alone. In many such cases, the body initiates its healing response before medical intervention can begin. One critical component in this self-regulatory process is the activity of glial cells—non-neuronal cells that support, protect, and maintain the nervous system's environment. While neurons have traditionally dominated neurobiological discourse, glial cells have begun to emerge as central figures in both physical and cognitive healing. Their roles range from regulating inflammation and guiding cellular communication to participating in scar formation and tissue repair. As research deepens, glial cells are proving to be key players not only in neurological conditions but also in systemic disorders. This paper explores the wide-reaching implications of glial cells in healing, emphasizing their potential in revolutionizing modern approaches to neurobiology and medicine.

THE SIGNIFICANCE OF GLIAL CELLS ON THE HUMAN BRAIN

On a warm afternoon on a scenic coastal street, a young woman glided along the sidewalk on rollerblades—when a collision with a vehicle suddenly changed everything. She was rushed to the hospital, where she was diagnosed with a traumatic brain injury (TBI), prompting doctors to prepare for surgery to assess and contain the damage. Doctors decided to operate on the woman once her vitals were stable a few hours later. However, when these doctors examined the injury, they discovered something remarkable: scar tissue had already started to form around the area of injury, already confining the damage to the initial area of impact before surgeons even began the procedure.

The formation of this scar tissue is a skilled, instinctive response by the brain, and is an extraordinary example of the human body's determination to heal and maintain homeostasis—known in the organic sciences as the ability to maintain the biological equilibrium necessary to sustain life. The processes of healing and homeostasis are deeply intertwined with one another, and these actions which are essential to survival, are only made possible through the help of glial cells. It is for this reason that the exploration of the glial cells would be the most beneficial area of study for researchers, as these cells play a key role in many healing processes.

GLIAL CELLS AND CELLULAR COMMUNICATION

Glial cells are intrinsic to the process of cellular communication which is prerequisite for most types of healing, making them the best cell to research because of their broad applications to multiple types of cells. Glial cells, also known as neuroglia, serve as regulators for the brain, maintaining the brain's overall homeostasis by facilitating communication between various types of neuroglial cells. The widespread impact of neuroglial communication is observed in the research of CD (Crohn's Disease), a common gastrointestinal disease which creates extreme pain and inflammation within the stomach; Enteric glial cells are known to engage with various cell types in the gut, including the intestinal lining, immune system cells, blood vessel cells, and enteric neurons-all of which may contribute to the development of Crohn's disease (CD). Structural irregularities in these glial cells within the enteric nervous system (ENS) have been observed in individuals with CD. Additionally disruptions in the enteric goal network have been found in both affected and unaffected regions of the ileum and colon in CD patients (Mao et al., 2024). Glial cells play a vital role in various diseases and bodily functions, even those affecting systems far away from the brain. The way these cells aid such systems is by ensuring that communications between cells are precise and efficient, not only ensuring that systems receive these signals, but

that they are not corrupted by the time they receive them as well. Corrupted signals may cause cells to start multiplying at an alarming rate, leading to cancers and other harmful conditions and diseases caused by an imbalance of cell types (Mao et al., 2024). CD is the perfect example to encapsulate these concepts, as it displays the power that glial cells hold in maintaining homeostasis, both within and outside the confines of the brain and spine, simply through allowing an efficient route of communication.

The effects of well-mediated glial cell communication within the body are further expanded within new research on Alzheimer's (AD), a variant of dementia which affects memory and behavior. This research suggests that "blocking microglia or cytotoxic T cells prevents tau-mediated neurodegeneration. Taken together, these results suggest that microglia mediate inflammatory responses in late AD and promote AD progression" (Xie et al., 2024, p. 13). The prevention of neurodegeneration is a huge step in healing a multitude of neurological and mental health disorders. Neurodegeneration severely affects behavior and lifespan, and the fact that simply blocking one area of microglial communication can slow the progression of AD and prevent neurodegenerative diseases, proves that glial cells are interacting with structures that may be the primary cause of disease and death in many people. In further support of the significance of glial cells, also known as "the other brain," within the medical field, Douglass Fields, a well-known neurologist, states within his book, that, "Everything from drug abuse, hearing loss, critical periods for learning, aging, cancer, and many more health-related aspects of brain function involve the other brain. Glia are thus at the hub of brain health and disease" (Fields, 2010). Fields explores how developing research on the glia could contribute to a much more foundational understanding of entire neurological diseases and physical systems of the human body, thanks to their constant communication with various parts of the brain. Additionally, Fields advocates for further study on them through the reasoning that these cells play a foundational role in communication, and that a better understanding of the glial cell system will inevitably lead to increased understanding of many biological systems. He also highlights the complexity of the glial cell within the medical field, and that because of their broad applicability to many organ systems, they can be the answers for many medical mysteries.

NEURONS AND GLIAL CELLS

However, many researchers view the comprehensive nature of glial cells as imprecise, leading them to feel that focus should remain on neurons rather than exploring the glia for their more direct role in the neurotransmitters of the brain, and their easily observable structure. Neurons are directly responsible for delivering electrical signals between various areas of the brain, while glial cells are largely foundational within the process of electrical cellular communication, and are not directly responsible for it. Neurons are much easier to see under microscopes, meaning they have traditionally been easier to research. They are also far more unique in their electro- signaling characteristics. This is corroborated when researchers found possible solutions to the oxidation of neurological organs, which can lead to harmful conditions such as diabetic gastrointestinal disease (DGD). Their study found that redoxosome signaling is present during the oxidation-related damages within EGCs, which often takes place during the progression of DGD, resulting in a new potential target for researchers pursuing the treatment of DGD. (Jiang et al., p. 1). This study relied much more on neurons than glial cells, as the direct intercommunication between cells, rather than the conditions to allow communication, was the focal point of the study. This implies that neurons are of greater importance to understanding the brain overall because of their specific purpose of sharing communications between every area of the brain, allowing these messages to eventually radiate to the rest of the body. However, in reality, the lack of specificity glial cells have within their cellular interactions is what should make them so appealing to new researchers. Glial cells maintain the environment

necessary for neurons to survive and work properly. Their ability to handle inflammatory responses affects and moderates the entire body, not only the glial cells or communications aspects of the brain. Glial cells set up the foundation for the body to complete their jobs in the first place. They act as the land that a bridge, neurons, would be built on.

To expand further on the substantial role that glial cell-based communication plays in the body's overall regulation, research investigating the relationship between stomach conditions and glial cells then focused on a wider array of gastrointestinal diseases, including both Inflammatory Bowel Disease (IBD) and Crohn's Disease. Researchers within this study found that enteric glial cells play a role in metabolic processes and help support the structure of enteric neurons. Increasing research points between these glial cells and neurons in managing key functions of the digestive system. When this relationship is disrupted, it can interfere with gut balance and may contribute to the development of gastrointestinal conditions like inflammatory bowel disease (IBD). (Mao et al., 2024, p. 2). The role of glial cells in maintaining homeostasis is essential to understanding its complex balancing effects within the entire body, and how glial cells can open up more doors to researchers than neurons can. While neurons are responsible only for the electrical impulses and direct transfer of information within the brain, glial cells allow for the favorable conditions of many different aspects of the brain, such as immunity, and the balancing of chemicals all over the body.

Further supporting the significance of the glial cell foundation research on the effect of abnormal glial cells on exosomes, researchers found that the exchange of information executed by exosomes lead to neurons outgrowing, and in turn causes the survival of neurons through the transfer of micro-RNA. (Abdallah et al. 2024, p. 2). This relationship between neurons and glial cells underscores the heavy burden that glial cells carry by providing the conditions necessary for neurons to survive at a normal rate, not only allowing for neurons themselves to do their jobs, but to let the entire brain and body thrive by managing the unique balance needed in order for living beings to live comfortably.

GLIAL CELLS AND NEUROLOGICAL DISORDERS

Advancements in glial cell research will not only lead to breakthroughs in neurodegenerative disease treatment but also redefine how researchers approach and treat mental health disorders. Research studying the connections between the glia and neurological disease is most often focused on Alzheimer's, for its large demographic. Studies have found that during the progression of Alzheimer's, connections between brain cells die alongside the cells themselves, leading to the destruction of structures needed for memory. In a research journal studying the contributions of glial cells within Alzheimer's Disease, researchers found that microglia regulate the activity of other glial cells and also play a role in maintaining immunity, therefore participating in the pathological progression of AD (Xie et al., 2024, p. 14). By being environmental regulators within the brain and having a firm control of immunity, glial cells allow the brain to withstand a wider array of outside damages and conditions, leading to a more reliable neurological immune system. The ability to defend against unwanted sepsis and imbalances is crucial in the field of medical treatment, as in order to treat a disease, researchers must build off the body's natural defense techniques in order to create a truly seamless remedy and prevention. The glial cell's executive position in regulating immune responses makes it clear that research on glial cells will accomplish two tasks simultaneously: increasing scientific understanding of glial cells when transporting information, and streamlining the relationship between treatments and disease. By using their newfound familiarity with glial cells, scientists will now be able to better tailor medications and therapies to diseases, thus resulting in less invasive forms of treatment. Additionally, preventing the progression of neurological disorders leads to improved mental health, as many neurological disorders greatly impact emotions and behavior, such as those in

AD. In fact, scientists have also found in research of AD damages that "a new subcluster of microglia-disease-associated microglia (DAM) was discovered in a mouse model of AD [8]. DAM usually appears under conditions of accumulation of neuronal apoptotic bodies and myelin debris in AD [9]" (Xie et al., 2024, p. 2). Within this journal, the researchers focus on the connection between the brain's homeostasis and Alzheimer's. While this initially seems like a far leap between two very different subjects, Alzheimer's progresses by weakening and eventually breaking down neurocellular communication, which can be prevented with proper balancing of the chemicals present in the brain's environment. Improper balancing of chemicals within the brain can also lead to many mental health issues, such as depression and bipolar disorder, each of which can negatively impact peoples' lives. Researchers finding the conditions under which harmful cell clusters such as DAM along with finding more specific effects of neurological diseases such as AD allow researchers a more complete understanding of mental health and its relationship to disease as a whole.

CONCLUSION

With the progress scientists have made in understanding the connection between the mind and body, researchers should focus on using this knowledge to improve an essential universal process—the process of healing. The incredible adaptability of the glial cell means that researchers can mold its power over the immune system to better protect the brain, and result in a better healed mind and body. An emphasis on neuroglia will allow researchers to simultaneously learn more about an under-researched cell type, and find better ways to tailor medicines and treatments to disorders, allowing for a happier and healthier global population. By unlocking the full potential of glial cells, researchers may not only revolutionize the scientific understanding of cognition and mental health as a whole, but reshape our treatments of mental health disorders and neurodegeneration as a whole.

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