The Root of Thought

Unlocking Glia

The Brain Cell That Will Help Us Sharpen Our Wits, Heal Injury, and Treat Brain Disease

Andrew Koob

Vice President, Publisher: Tim Moore
Associate Publisher and Director of Marketing: Amy Neidlinger
Editorial Assistant: Pamela Boland
Operations Manager: Gina Kanouse
Digital Marketing Manager: Julie Phifer
Publicity Manager: Laura Czaja
Assistant Marketing Manager: Megan Colvin
Cover Designer: Stauber Design Studio
Managing Editor: Kristy Hart
Project Editor: Jovana San Nicolas-Shirley
Copy Editor: Deadline Driven Publishing
Proofreader: Water Crest Publishing
Indexer: Erika Millen
Compositor: Nonie Ratcliff
Manufacturing Buyer: Dan Uhrig

Publishing as FT Press
Upper Saddle River, New Jersey 07458

Printed in the United States of America

First Printing June 2009

ISBN-10: 0-13-715171-3
ISBN-13: 978-0-13-715171-4

Pearson Education LTD.
Pearson Education Australia PTY, Limited.
Pearson Education Singapore, Pte. Ltd.
Pearson Education North Asia, Ltd.
Pearson Education Canada, Ltd.
Pearson Educación de Mexico, S.A. de C.V.
Pearson Education—Japan
Pearson Education Malaysia, Pte. Ltd.

Library of Congress Cataloging-in-Publication Data

Koob, Andrew, 1976-
The root of thought : unlocking gila— the brain cell that will help us sharpen our wits, heal injury, and treat brain disease / Andrew Koob.
p. cm.
ISBN 978-0-13-715171-4 (hardback : alk. paper) 1. Neuroglia—Popular works. I. Title.
QP363.2.K66 2009
612.8’2—dc22

2008055452

1

Cities and highways

Back in the 1960s, it was discovered that glial cells are 90 percent of the brain. Neurons make up 10 percent. One would think that as a result of this revelation, the conclusion reached would have been that glial cells function as a main component of the nervous system. But it wasn't. The conclusion was that we use only 10 percent of our brain.

From an early age, we are taught that the major cell in the brain is the neuron. We are also taught that neurons hold all the information in the brain. Even through graduate-level studies, the central tenant of neuronal importance is the basis of the study of neuroscience. But the Neuron Doctrine has become more religion than scientific truth, explaining away even the most blatant facts with assertions such as, "We use only 10 percent of our brain."

However, no sustainable argument or discovery has been made to give insight to where our thoughts come from, where our imagination resides, our dreams ignite, and how creativity burgeons. These are mysteries that have been explained with ideas such as "random neuronal firing" or "interconnectibility." But the truth is that the neuron is the least likely cell in the brain for the root of thought.

Until recently, glia have been considered the structural elements to the active neurons, like void space with no purpose except to hold the brain together—the nuts, bolts, and the frame of the engine of our minds.

The importance of the neuron is being aggressively challenged in the field. The recovery from brain injury, the cause of degenerative diseases of the brain, the treatments for psychiatric disorders, and an understanding of human intelligence can be fully realized only through the study of glia.

The surge in glial interest is due to three main reasons. First, glia signal to each other in a manner conducive to storage of information. Second, glia have long been known to be the cellular makeup of most brain tumors. Third, researchers now know glia are the adult stem cells in the brain.

It was once thought that our brains develop in the womb and during early childhood, and then remained in this state until we died. It is now known that we regenerate cells throughout adulthood. The stem cells of the brain are glia, which can reproduce themselves and neurons if needed.

Glia can also regenerate locally in order to store more information. One of the most fascinating studies in the last 30 years was the analysis of Albert Einstein's brain. When markers for different types of cells were analyzed, Einstein's brain was discovered to contain significantly more glia than normal brains in the left angular gyrus, an area thought to be responsible for mathematical processing and language.

If glia are the libraries for information storage in the brain, and assuming humans have the highest intelligence, then lower life forms should have less glia. One of the most striking research events has been the discovery of a single glial cell for every 30 neurons in the leech. This single glial cell receives neuronal sensory input and controls neuronal firing to the body. As we move up the evolutionary ladder, in a widely researched worm, *Caenorhabditis elegans*, glia are 16 percent of the nervous system. The fruit fly's brain has about 20 percent glia. In rodents such as mice and rats, glia make up 60 percent of the nervous system. The nervous system of the chimpanzee has 80 percent glia, with the human at 90 percent. The ratio of glia to neurons increases with our definition of intelligence.

Not only does the ratio of glia to neurons increase through evolution, but so does the size of the glia. Astroglial cells in the human have a volume 27 times greater than the same cells in the mouse's brain.

The folded cortex of humans is not noticed in other animals until you reach higher-level species such as cats, dolphins, and other primates. Humans have 35 percent more glia in its cortex than the chimpanzee.

This excess glia in our brains might explain the fact that humans are more susceptible than other animals to develop degenerative diseases of the brain such as Alzheimer's and Parkinson's, which disrupt thought. In fact, in all degenerative diseases of the brain, loss of sense of smell is the first sign before the onset of symptoms. The olfactory bulb is known to have the highest turnover of cells in the brain because of the nature of smell. It is ever changing, and our olfactory bulb has to adjust as such. Glia are the stem cells necessary for this turnover.

The study of degenerative diseases of the brain in most labs today focuses on proteins that aggregate in neurons, the byproduct of the disease. This is like thinking a pothole is the reason a road is falling apart.

When a mechanism for glial proliferation is overactive, glia turn cancerous. Almost all tumors of the brain are gliomas, which are comprised of glia. Is it possible that glial regeneration is a normal process of the brain that needs to remain at a constant level depending on the amount of information learned and integrated? Is it possible that when it is lacking, degenerative disease occurs, and when it is aggressive, a tumor grows?

Our brains were also always thought to lose neurons as we grow older. Upon further review, it has been shown that neuronal numbers remain the same, whereas increases and disruptions are seen in glia. And just recently, it has been revealed that glia communicate to themselves in electrical waves through extensive nets involving calcium ion influx. These influxes of calcium can spread locally through glial networks. It has also been shown that glia express the receptors necessary to receive basic input from neurons, as well as signal to neurons themselves.

Neurons communicate down long processes called axons. Neurons either fire or they don't. This is called the "all-or-nothing" phenomenon. Glia are much more complex. Their wavelike communication may be more conducive to fluid information processing.

What are neurons if glia process and store information? Since researchers know that glia signal to neurons, it would seem neurons are simply static cells that fire at the beck and call of glia to other glial areas, which need to be ignited to produce related thoughts.

For instance, if you, like the author, think about pizza, and then you think about mozzarella, which leads you to think about Italy, you are igniting three glial centers in your brain. To get from one center to the next, if they are a significant distance, you must connect through a neuron. When the glial center for mozzarella receives strong neural firing from the center for pizza, then it ignites and thinks about everything related to mozzarella in that glial center.

For a century, scientists have barely questioned the idea of the dominance of the neuron. Even today, it's not a stretch to say that 99 percent of the laboratories studying the brain around the world focus on neuronal research.

But, as will be seen, this is the equivalent of aliens landing on earth in southern California and arriving at the conclusion that the freeway between San Diego and Los Angeles is more important to explore than the cities themselves.

References

Diamond, M.C., A.B. Scheibel, G.M. Murphy, and T. Harvey. "On the Brain of a Scientist: Albert Einstein." *Experimental Neurology*, 88: 198–204, 1985.

Hatton, G.I. and V. Parpura. *Glial—Neuronal Signaling*. Boston, MA: Kluwer Academic Publishers, 2004.

Kettenmann, H. and B.R. Ransom. *Neuroglia*, Second Edition. New York: Oxford University Press, 2005.

Laming, P.R., E. Syková, A. Reichenbach, G.I. Hatton, and H. Bauer. *Glial Cells: Their Role in Behavior*. New York: Cambridge University Press, 1998.

Murphy, S. *Astrocytes: Pharmacology and Function*. San Diego, CA: Academic Press, Inc., 1993.

Verkhratsky, A. and A. Butt. *Glial Neurobiology*. Chichester, West Sussex: John Wiley & Sons Ltd., 2007.

Volterra, A., P. Magistretti, and P. Haydon, *The Tripartite Synapse: Glia in Synaptic Transmission*. New York: Oxford University Press, 2002.

Index

B

H

I

J-K

L

M

N

O

P

Q-R

S

T

V

W-X-Y-Z