LYME BRAIN

WHAT TO DO WHEN YOU'RE GOING CRAZY

DR. KEVIN CONNERS

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Section 2

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Chapter Two

How your brain WORKS

Brain Development

Oh, the sheer excitement of the above title. My neurology professor (30 years ago) was a terrible teacher and I never learned a thing about the brain. It would be decades later that I was introduced to Professor Carrick and life changed. I discovered that human behavior, though governed by choice, is shaped largely by the intricate function of a few pounds of fatty tissue encased in relatively thin bone. It's amazing really; humans who build skyscrapers that touch the clouds, engineer moon landings, cage giant animals ten times their size, and rule the world have not enough bodily hair to keep from freezing to death on a cold night, no claws

sufficient for gathering enough food for the day, teeth too small to rip through an animal should carrion be found nor skin thick enough to able to defend even an attack from a large group of mice. No, we were created to use our brains.

> *"I consider that a man's brain originally is like a little empty attic, and you have to stock it with such furniture as you choose. A fool takes in all the lumber of every sort that he comes across, so that the knowledge which might be useful to him gets crowded out, or at best is jumbled up with a lot of other things, so that he has a difficulty in laying his hands upon it. Now the skillful workman is very careful indeed as to what he takes into his brain-attic. He will have nothing but the tools which may help him in doing his work, but of these he has a large assortment, and all in the most perfect order. It is a mistake to think that that little room has elastic walls and can distend to any extent. Depend upon it there comes a time when for every addition of knowledge you forget something that you knew before. It is of the highest importance, therefore, not to have useless facts elbowing out the useful ones."*
> — *Arthur Conan Doyle, A Study in Scarlet*

Most neurological texts would dive into evolutionary theories on how fish brains lack a neocortex and as we evolved from slime we simply decided to grow neuronal hemispheres capable of reason. It takes at least as much faith to believe that as it does to believe there is a grand weaver who has a sovereign plan. If you want to get technical about it, thousands of years ago, humans had bigger brains. That conclusion was reached after researchers showed that ancient human skulls from Europe, the Middle East and Asia had an average brain capacity of 1500 cubic centimeters, compared to today's 1359 cc.

The old skulls tested were almost certainly post-Flood, hence at most a few thousand years old by biblical reckoning, and 'only' tens of thousands of years old in evolutionary belief. If the result had shown that today's brains are bigger, evolutionists would no doubt have interpreted this as humans evolving more 'smarts'. But this outcome has caused a quiet surprise—not just for being contrary to evolutionary expectations, but because of the extent and speed of change. John Hawks of the University of Michigan called it "a major downsize in an evolutionary eye-blink". That said, I will do my best to make this section readable and keep you from falling asleep because even though the facts may be 'dry', understanding them explains much about problem behavior.

Over the centuries scientists have argued two dominate views on human development. They proposed that children either came into the world genetically pre-programmed (“nature”) or that they were a “blank slate” on which their environment shaped their development (“nurture”). Lately, the debate over nature vs. nurture is fading as scientists now are investigating the complex ways in which genes and environment interact in part due to the completion of the human genome project that exposed the failure of the ‘genetically preconditioned’ camp. It turns out that we have fewer genes than expected – far fewer! If it is ‘genetics’ that we can blame all our problems on, it’s ‘epigenetics’ (what our environment does to affect the genes). Current brain science understands that both nature and nurture shape brain development, and that each set of influences is dominant to varying degrees at various points in time.

Before birth, nature is the primary actor in brain development. We certainly cannot dismiss the effect of environment as any parent of a Fetal Alcohol Syndrome/Fetal Drug child would attest, but the pre-programmed genetic map runs the show at this stage. According to Dr. Pasco Rakic, a professor of neuroscience at Yale University, “The number of neurons and the way that they are organized is determined by heredity.” We know that during the third week of pregnancy, a thin layer of cells in the developing embryo folds inward to create a fluid-filled cylinder called the neural tube. (Berk, 1994, p. 99). It is in the neural tube where the production of neurons, the brain cells that store and transmit information, begins at the rate of 250,000 per minute (Nash, 1997, p. 52). Here is where environmental toxicity may interrupt genetic processes.

By the end of the second trimester, the process of producing neurons is essentially completed. It was once believed that no more neurons would ever be produced again in an individual’s lifetime – a topic now hotly debated. Some neurons are programmed for specific functions such as breathing, controlling the heartbeat, regulating body temperatures, or producing reflexes – all depending on the pathways on which they are created. But, for the most part, neurons are not designated to perform specific tasks, and thus brain development is not complete at this point. Think of neurons as highways on which communication travels.

Brain development is "stimulus-dependent," meaning that the electrical activity in every circuit—sensory, motor, emotional, and cognitive--shapes the way that circuit gets wired. Similar to computer circuits, neural circuits

process information through the flow of energy (electricity). Unlike computer circuits, however, the circuits in our brains are not fixed structures and don't solely use electricity but utilize chemistry as well.

Packages of chemistry called neurotransmitters created and degraded through enzymes made by specific genes govern the flow of electricity across miles of neuronal highways. Every experience--whether it is seeing one's first rainbow, riding a bicycle, reading a book, sharing a joke--excites certain neural circuits and leaves others inactive. Those that are consistently turned on over time will be strengthened, while those that are rarely excited may be dropped away, pruned to conserve valuable real estate. This is neuroplasticity and it is both good and bad. If my first experience with the world was an inattentive parent who neglected me, I may experience adult behavioral issues with getting needs met. We neurologically tie connections to feelings, experiences, events, object identification, color, sound, and every conceivable stimulus.

Functional neurologists say, "Cells that fire together, wire together," meaning connections are created, not pre-wired. The elimination of unused neural circuits, also referred to as "pruning," may sound harsh, but it is generally a good thing. It streamlines children's neural processing; making the remaining circuits work more quickly and efficiently. Without synaptic pruning, children wouldn't be able to walk, talk, or even see properly. But it goes both ways. If a two-year-old is never taught social behavior skills, pathways of 'normal' behavior far outreach cultural acceptance. Also, abused or neglected children create pathways of worthlessness that become superhighways easily traveled throughout life. This is the neural connection to "sins of the father carrying out to the third and fourth generation." The cycle must be broken but it takes work – or should we say, neural exercise.

At any stage of development, other environmental toxins including maternal malnutrition, substance abuse (including alcohol, smoking, illegal drugs, and use of prescription and over-the-counter medications), exposure to chemicals or radiation, vaccinations, pathogens (like Lyme and other bacteria) and viral infections (such as measles) can lead to adverse effects on the developing brain. It goes without saying then that even the most loving parents; living in the fallen world which is inescapable with its chemical, EMFs, and destroyed food supplies (GMOs, additives,

pesticides, herbicides…) can have children with brain issues. It's NOT about blame; it's about recognition and correction!

While newborns are born with a full set of neurons, the most important part of brain development begins after birth - the wiring phase. Following birth, each of the brain's 100 billion neurons creates links to thousands of others. This process is accomplished as neurons produce a web of wire-like fibers called axons (which transmit signals) and dendrites (which receive signals). Once axons make their first connections, the nerves begin to fire. It is at this point that the environment begins to take over in the process of brain development. Scientists often describe this stage as the equivalent of creating telephone trunk lines between the right neighborhoods in the right cities. At this point in development, the brain has to sort out which wires belong to which house. It is with these maps that learning will take place (Nash, 1997, p. 53, Carnegie, 1994).

The most important factor in this process of developing connections is stimulation, or repeated experience. Scientists now know that in the months after birth the number of synapses increases from 50 trillion to 1,000 trillion (Carnegie, 1994). Neurons that are stimulated by input from the surrounding environment continue to establish new synapses. Those that are seldom stimulated soon die off.

It's like a highway system. Roads with the most traffic get widened. The ones that are rarely used fall into disrepair.

It's not black and white, it's GREY and WHITE

The nervous system is divided into components based on location: the central nervous system and the peripheral nervous system; as well as function: the volitional system and the autonomic system. Then there are other divisions; the autonomic is divided into the sympathetic and parasympathetic based on opposing functions. The central nervous system is composed of the brain and the spinal cord. The brain is then divided wholly into grey and white matter. Scientists are very left-brained and enjoy memorizing systems and names and big words that make you sound really smart.

Grey matter is the part of the brain that is made up of nerve cell bodies and the majority of the true dendrites (numerous, short, branching filaments that

carry impulses towards the cell body). Grey matter has no myelin blanket; it is simply the collection of cell bodies.

The real processing is conducted in the grey matter. It was given the name gray because, wait for it – it's grey. Neurons create networks, in which nerve signals travel and though we speak of connections, they do not make contact with each other when conveying messages, but do so through sending chemicals across a gap called a synapse. The chemicals called neurotransmitters serve as the medium to connect one neuron to another neuron. The senses of the body (speech, hearing, feelings, seeing and memory) and control of the muscles are part of the grey matter's function.

The white matter, also known as substantia alba (no, not Jessica Alba's daughter though that would have been my first pick), is a neuron that is made up of extending, myelinated nerve fibers, or axons. It composes the structures at the center of the brain, like the thalamus and the hypothalamus. It is found between the brainstem and the cerebellum, between the neocortex (newer brain centers) and lower brain. It is the white matter that allows communication to and from grey matter (nerve cell) areas. It functions by transmitting the information from the different parts of the body towards the cerebral cortex; the white matter is the axons. It also controls the functions that the body is unaware of, like temperature, blood pressure and the heart rate. Dispensing of hormones and the control of food, as well as the intake of water and the exposition of emotions, are additional functions of the white matter. Communication along these fibers reaches a speed of 2-300 miles per hour (remember this for the quiz).

Because of the evidence emerging on synaptic development, scientists believe that appropriate stimulation of the child's brain is critically important during periods in which the formation of synapses is at its peak (Berk, 1994). It is during these critical periods, or windows of opportunity that exist for different brain functions, when a child's experiences can make the most difference. And, for some areas, if the connections between neurons are not developed during these critical periods, they will never develop at all.

Nutrition is so important in every stage but crucial in the early years. The average Western diet has changed dramatically such that humans today consume a much higher proportion of omega-6 fatty acids relative to omega-3 fatty acids than ever before. The importance of omega-3 fatty acids in human development has been well established in fetal and neonatal development, with brain and retinal tissues highly dependent on omega-3 fatty acids, specifically docosahexaenoic acid (DHA) for membrane fluidity and signal transduction. In childhood, omega-3s have been shown to contribute to ongoing cognitive development so supplementation with DHA is highly recommended. (Carlson, 2013)

> *"But when you're in front of an audience and you make them laugh at a new idea, you're guiding the whole being for the moment. No one is ever more him/herself than when they really laugh. Their defenses are down. It's very Zen-like, that moment. They are completely open, completely themselves when that message hits the brain and the laugh begins. That's when new ideas can be implanted. If a new idea slips in at that moment, it has a chance to grow."*
> *— George Carlin, Last Words*

This is why I've always said that a fat-free diet is the most dangerous diet known to man. Did you know that there is a phenomenon known as rabbit starvation? Yes, it is described by observing settlers that ate nothing more than rabbits, which were in abundance, and filled their bellies, yet died of starvation. The lack of fat in rabbit meat (tastes like chicken) was the killer. You NEED fat; pregnant mothers and children need fat even more (eat coconut oil). There, now you can't say that you didn't learn a thing from this book!

How does all of this apply to Lyme brain? Anything that causes a decrease in firing of cortical centers leads to dysfunction! This includes developmental delays due to everything from nutrition to lack of love or infections (like Lyme) that ramp-up inflammation in the brain. Every second of your life your brain requires stimulation; if you don't use it, you lose it. Period; exclamation point. Poor use of grammar I know, but I want you to get his point.

Lyme Brain and the Prefrontal Cortex

In order to explain this important part of your brain that sits directly in back of your forehead I need to tell you about the Disney movie UP, Adolph Hitler, a Roman General, and my dog Lady. For those of you who have not seen Pixar's UP, you now have some homework because the humorous observation of the dogs in this animated blockbuster give real insight into the prefrontal cortex.

In the story, balloon salesman Carl Fredricksen and his energetic wife Ellie live a wonderful life with dreams of adventure that always seems beyond financial reach. After Ellie's death, Carl grows quiet and confined until meeting 8-year-old Wilderness Explorer Russell who is eager to get his "helping the elderly" pin. Without retelling the entire story, this unlikely duo travel to a faraway land and meet the antagonist as well as new friends like Dug, a dog with a special collar that allows him to speak, and Kevin, a rare 13-foot tall flightless bird (but a very nice bird, as all Kevin's are).

Before you start thinking that I have ulterior motives for having children, there is a great lesson in the story's antagonist (famed explorer/inventor Charles Muntz) and his dogs. Fitted with their talking collars, the dogs pursue the pair to capture their new friend, the exotic bird Kevin. In doing so we see the truth about dogs – they have a very small prefrontal cortex, as I'm sure you were thinking as well when you watched the movie.

Once, when capture seemed inevitable and the adventure seemed doomed to failure as the talking dogs were at the verge of victory, Russell ingeniously distracted the animals from their goal by shouting, "Squirrel!" A large and healthy prefrontal cortex is what necessary to stay on task, remain focused on intention and block out distractive issues. Humans should have no problem with focus, dogs do. No matter how obedient to their evil master the dogs desired to be, dog are dogs and dogs chase squirrels.

Your prefrontal cortex allows attention on intention; it is the schoolmaster keeping the rest of the brain on task and without it there would be chaos directly proportional to the lesion. It is primarily responsible for regulating behavior, mediating conflicting thoughts, making choices between right and wrong, and predicting the probable outcomes of actions or events. It governs social control, such as suppressing emotional or sexual urges.

Since the prefrontal cortex is the brain center responsible for receiving data from the world and deciding on actions, it is most strongly implicated in human qualities like consciousness, general intelligence, and personality. It is what makes us unique as humans – the size of our prefrontal cortex.

If you bring to understand the function of the prefrontal cortex you can see why disruption from the inflammation in Lyme can lead to an array of symptoms.

> *"Every man can, if he so desires, become the sculptor of his own brain"*
> *— Santiago Ramón y Cajal*

World War II

It was the summer of 1941, the plan was simple, but Hitler was alone in his thinking that it would be simple to perform. Given the size of Russia, the German army would be divided into 3 groups. Army Group North would advance through the Baltic States towards Leningrad, Army Group South would move into the Ukraine and then the Caucasus to take the wheat and oil fields of Russia, and Army Group Center would advance through White Russia towards Moscow.

Germany had already conquered most of Europe and the Fuhrer's success following his planned Blitzkrieg was unprecedented. He thought Germany was unbeatable and he trusted his track record over wise counsel. This obstinacy became the cause of many heated debates between Hitler and his Generals and proved disastrous for "Operation Barbarossa," the attack on Russia. When a country goes to war, it is only sensible that the Government and the Military have already determined the enemy's "Center of Gravity", and have already planned on how to neutralize it. The enemy's "Center of Gravity" can be their armed forces, their capital, a powerful ally, etc.

Hitler and his Generals disagreed from the start about what Russia's "Center of Gravity" was. The Generals thought it was Moscow, while Hitler thought it was Ukraine and the Oil fields of the Caucasus. Hitler's reasoning, if it can be called that, was based on history. Napoleon had taken Moscow, but the Russians had not given in, and in the end Napoleon had to retreat, with disastrous results for his Empire. Hitler was determined not to repeat that mistake; he was going to head south, take the Ukraine and the Oil fields, and deny the Russians the resources he felt they needed to continue the war.

His Generals could not have disagreed more. They argued that Russia was so vast, and capable of replacing whole armies, that only the capture of Moscow would destroy the Soviet Regime. They argued that Moscow was the political and logistical hub of European Russia, and if it was taken, the Russians would not be able to continue the war west of the Urals. A simple glance at any world atlas will indeed show that in Western Russia, "all roads lead to Moscow."

The General's reasoning was that since most of Russia's population, resources and industry were located west of the Urals, even if the Russians elected to fight on, it would be a lost cause. Finally, they argued that Stalin was so feared and despised, (nearly a million citizens took up arms against Russia's military) that if the Red Army was destroyed, and Moscow taken, the people would overthrow him and welcome Germany's rule.

Hitler was a ruthless dictator, and therefore had the last word; in this case he was absolutely wrong. The attempt to seize of Ukraine in 1941 was blind optimism, born out of pride in the heart of a deranged tyrant. Even if the Germans had taken Ukraine and all of the oilfields, the Soviet Regime would still be intact and worse, given the still considerable Russian armies to the north and the long lines of communications the Germans would have in the south, the Russians could have possibly cut off the German army in southern Russia as they actually did in late 1942.

What does this have to do with the prefrontal cortex? Recent research on why we do what we do has concentrated on decision-making. There appears to be a dichotomy in cognitive neuroscience between reflective versus reflexive decision-making. Reflective, goal-oriented, or what has been termed model-based thinking is now been shown to be a right prefrontal function. This means if I have greater left-brain dominance, I will be more prone to habitual, less reasoned, or what is known as model-free decisions.

Right-brain dominant people base decisions more on perspective thought, weighing consequences, and seeing possible outcomes. Left-brain dominant individuals make choices more on what was done in the past, patterns that are common, and "the way I've always done it." It goes without saying that evil dictators have brain problems but I think most have

two severe (very severe) lesions: right dorsolateral and right anterior cingulate damage.

A study published in Neuron in October, 2013 showed that disrupting the right dorsolateral prefrontal cortex impaired flexible model-based choices, driving behavior toward simpler, model-free (habitual) control. Blind pride may have more of a neurobiological cause than previously believed. Damage to prefrontal brain structures has been documented in psychopathic criminals as well.

These studies show that human choice behavior often reflects a competition between inflexible computationally efficient control (from the left brain) and a slower more flexible system based on weighing factors and consequences (the right brain) on the other. One can see that BOTH are necessary for optimal performance in a complex world. A commander of armed forces, a CEO of a major company and a parent of small children need healthy functioning frontal lobes to both make quick decisions based on past experience and slower, more carefully thought out choices based upon reason.

There are times we all need reflexive, non-emotional decision-making that will be efficient and give us a good chance that the outcome will be similar to past outcomes based on similar circumstances and there are other times where being able to imagine all sides of either ruling will guide us to the best selection. Imbalance is not healthy.

Would World War II have had a different outcome had Hitler had a more balanced brain? Well, yes, it wouldn't ever have started had Hitler had a healthy prefrontal cortex. We could write an entire book on his traumatic childhood, his mother's death of cancer, and his brain problems and conditioning but it suffices to say that one could explain all ill-behavior, no matter if demonic or innocent as having at least part of its origin in the prefrontal cortex.

Mirror Neurons

“What is human memory?" Manning asked. He gazed at the air as he spoke, as if lecturing an invisible audience - as perhaps he was. "It certainly is not a passive recording mechanism, like a digital disc or a tape. It is more like a story-telling machine. Sensory information is broken down into shards of perception, which are broken down again to be stored as memory fragments. And at night, as the body rests, these fragments are brought out from storage, reassembled and replayed. Each run-through etches them deeper into the brain's neural structure. And each time a memory is rehearsed or recalled it is elaborated. We may add a little, lose a little, tinker with the logic, fill in sections that have faded, perhaps even conflate disparate events.

"In extreme cases, we refer to this as confabulation. The brain creates and recreates the past, producing, in the end, a version of events that may bear little resemblance to what actually occurred. To first order, I believe it's true to say that everything I remember is false.”
— Arthur C. Clarke

My dog Lady is a great friend. She’s obedient (for the most part) and since she’s aged a few years, she’s just the level of mellow that I like in a pet. She drives me crazy though when I’m busy doing something like carrying groceries from the car or running to the barn to get the power drill. Wanting my immediate attention, I find myself frustrated with her uncanny ability to position herself exactly in the direction I’m moving. “Look out Lady,” I cry, as she moves again precisely where I was planning to step. She has absolutely no sense of self! She has no idea that she’s ‘in the way’ because she doesn’t even know that she is she. She cannot possibly see my point of view, cannot place herself in my situation, and cannot understand my intention because she has no sense of being.

What makes humans human? We are born completely dependent on mom and take years to develop; but Lady was wrestling with her brothers just minutes after her birth. Brett, my first grandson, took months to roll over, longer to sit up on his own and nearly a year before he walked and finally blurt out what was deep inside him since birth, “Grandpa is my favorite.” Lady on the other hand seemed to possess near her current intelligence weeks after birth and though her fondness for stealing shoes has diminished, she’s been Lady as I know her now since she was a pup.

Humans are different. We are more neurologically advanced yet it takes years, even decades, to mature through stages that lower species seem to

conquer in days or weeks. Why? It seems rather counterintuitive. Shouldn't higher-level species have evolved a quicker defense against predators and be able to progress more rapidly to higher consciousness? Let's talk about a special class of brain cells called mirror neurons.

We humans learn much of what we know by imitation. As neurons myelinate, our sense of self becomes keen and soon we are able to do something lower species cannot – we can adopt another's point of view. The ability to see the world from another's point of view is a complex function that my dog will never possess. Her frontal lobe is too small! I might embarrassingly add that often my frontal lobe acts as if it is equally small when I fail to see things from her point of view and blurt out expletives that I later regret.

The ability to create a mental model of another's complex thoughts, called theory of mind, is unique to humans. Though Disney makes movies where animals reason and plan and argue and contemplate and set goals and give advice, Lady and her fellow non-homosapiens, no matter how many times I may say, "Can't you SEE I'm carrying groceries," will never understand. It's tied to our ability to converse; our language to convey to another what we think about, how we feel, and even how we feel they feel about us. I can understand a complex dramatic plot and enjoy watching The Notebook because I possess mirror neurons (I've never actually watched The Notebook). I know what you're thinking – I've finally solved the age-old quandary and can now explain it to men everywhere: women have more mirror neurons! This may actually be true, but we'll discuss this another time.

Mirror neurons enable you to simply watch someone do something and fire the same brain circuit as if you did the same thing. They enable you to imagine doing something and fire the same circuit as if you actually did it. This is why I get an unpleasant sensation course my body when I watch Funniest Home Videos and see a skateboarder miss a rail and why I get a chill up my spine when I hear a patient explain how they missed the last step before tumbling to the tile. I have mirror neurons. Watch someone get pricked with a needle and you'll fire pain pathways that can be measured on EEG scans.

The ability to wonder

It's amazing really. We have the unique ability to empathize intimately with another's misfortunes. We have the exclusive skill to learn, strategize, and contemplate what others may be contemplating. Humans can wonder. Mirror neurons give us the capability to blur the boundary between self and others.

I've asked patients, "If I stepped on your foot, where would you feel the pain?" They, of course answer, "my foot." "Really," I play. "The receptors for pain may be in your foot but you actually experience the pain in your parietal lobe, on the opposite side. It is the neuronal cell body in the primary sensory cortex in the parietal lobe that feels the pain and that then sends messages to the frontal lobe to make decisions about and react to such a stimulus." This is exactly why Lyme patients, with inflammation in the parietal lobe, feel pain in the associated body part!

The ability to even contemplate the above paragraph required receptors in your auditory cortex to send messages to the frontal lobe and so on. Why am I boring you with this mental yoga? Because it's extremely important when we are talking about problems that people have that would possess them to read a book like this. Mirror neurons are in the brain and problems in the brain cause problems with mirror neurons.

Depression, in part, can be explained as the inability to inhibit the mirror neuron pathway perseverating on impending doom; anxiety is the inability to inhibit fight or flight centers. Autism and Asperger's is an obvious fracture of mirror neurons revealing countless symptoms of one's inability to see anything beyond the narrow tunnel of immediate gratification. They are chained, like Lady, to whatever degree of inability to see beyond their current point of view.

A healthy 'free will' is only possessed by those with healthy, cortical, mirror neurons. We can consciously inhibit most motor functions and 'override' mimicking another's behavior but autonomic function still prevails. If I tell my daughter there is a spider on her back, she'll scream, sweat, panic, jump and throw her hands up in that girl-ish way girls do even before proving my assertion with hard evidence. That was her 'learned' response (I never taught her that, it must have been her mother). She fired real pathways.

As we will see in later chapters, the ability to control these pathways is health. Phobias are over-firing learned circuits; OCD, tics, PTSD, and panic attacks are the same – inability to control mirror neuron circuits. The same is true for someone stuck in self-pity, narcissistic personalities, and violent criminals with no hesitation to harm another. Healthy individuals can inhibit circuits that less healthy people can't and the fact that inhibitory pathways can be strengthened is the very reason we wrote this book and gives hope to civilization!

Again, how does all this have to do with Lyme brain? Lyme causes inflammation that BLOCKS these pathways!

The Limbic System

Limbic is an odd, Latin term meaning the edge or border. It's where we get the word "limbo". It's an intermediate state between two important places. Early anatomists saw this area of the brain, that which is between the important neocortex and the midbrain as the 'in-between area', or limbic lobe. The limbic system includes one of the following on each side: the hippocampus, amygdala, and other named structures in the temporal lobes that we won't be discussing. (Some experts would also include parts of the hypothalamus, thalamus, midbrain reticular formation, and olfactory areas in the limbic system.)

> *"The neural processes underlying that which we call creativity have nothing to do with rationality. That is to say, if we look at how the brain generates creativity, we will see that it is not a rational process at all; creativity is not born out of reasoning."*
> *— Rodolfo R. Llinás, I of the Vortex: From Neurons to Self*

Are you bored yet? Hang in there as you may spot some relevance as we discuss symptoms when these structures aren't working well. The Limbic System houses several important structures to anyone with behavioral or emotional issues.

First let's discuss the hippocampus because it has such a groovy name. Historically, the earliest hypothesis was that the hippocampus was involved in the sense of smell. Now we know that it is more tied to memories of different smells and how a particular smell of let's say German potato salad instantly connects us to Grandma's house on Thanksgiving when you were

5. Over the years, anatomists have whittled down several main ideas of hippocampal function: inhibition, memory, special order, and circadian rhythm.

The behavioral inhibition theory (caricatured by O'Keefe and Nadel as "slam on the brakes!") was very popular up to the 1960s. It derived much of its justification from two observations: first, that animals with hippocampal damage tend to be hyperactive; second, that animals with hippocampal damage often have difficulty learning to inhibit responses that they have previously been taught.

The second major theory relates the hippocampus to memory. This idea stems from a famous report by Scoville and Brenda Milner describing the results of surgical destruction of the hippocampus (in an attempt to relieve epileptic seizures), in a patient named Henry Gustav Molaison, known until his death in 2008 as H.M. The unexpected outcome of H.M.'s surgery was a specific type of amnesia: H.M. was unable to form new memories after his surgery and could not remember any events that occurred just before his surgery. He retained memories for things that happened years earlier, such as his childhood. This case produced such enormous interest that H.M. reportedly became the most intensively studied medical subject in neurological history.

There were then other patients with similar levels of hippocampal damage and amnesia (caused by accident or disease) who have been studied as well. There is now almost universal agreement that the hippocampus plays some sort of important role in memory and most agree its role is more similar to the part of the brain that the original anatomists placed it than they could ever imagine because it is a 'check station' for working memory (things happening now) to pass through to long-term storage (in the temporal lobe).

What does this mean to you? Well, if you've ever walked into a room and asked yourself that stupid question, "What did I come in here to get?" then you've experienced a "blip" in your hippocampus. Working memory, or current thoughts and plans, needs to shunt back from the planning centers in the prefrontal cortex, through the hippocampus to the temporal lobe where they are stored for future use. "Honey, will you get me the scissors in the kitchen," spoken when I'm in the middle of writing a section on the limbic system ends up with me standing in the kitchen with absolutely NO

idea of why I was there. In this case, brain chatter caused incomplete processing of frontal lobe commands (or maybe it's just because I'm a man).

Is it just age that brings about a greater incidence of "senior moments"? If so, then somebody tell me why my teenager can't seem to follow simple instructions even if I tattooed them on her arm. Yes, chatter, disinterest, and not really paying attention will cause working memory issues but abnormal attention problems and continually forgetting where you placed your keys or having to depend more on lists than ever before are all signs of hippocampal damage, most commonly caused by inflammation. We'll talk more about causes in a later chapter but right now, let's just admit we may have a problem.

The third important theory of hippocampal function relates the hippocampus to space. A very influential book, The Hippocampus as a Cognitive Map, championed the spatial theory. As with the memory theory, there is now almost universal agreement that spatial coding plays an important role in hippocampal function. A cognitive map is a type of mental representation (you could say your 'mind's eye') which serves an individual to acquire, sort, store, recall, and decode information about the relative locations (where) and attributes (what) of phenomena in their everyday spatial environment.

> *Some people feel guilty about their anxieties and regard them as a defect of faith but they are afflictions, not sins.*
> *-CS Lewis*

You could say that the hippocampus works to sort experiences into respective files and then recover them for future use like a file clerk carefully labeling those little plastic tabs that go on the green hanging files and systematically placing all the important papers in the perfect alphabetical order. Boy, am I dating myself! Maybe a better example would be how I acted just like a hippocampus this morning when I sorted all my Word documents into neat files on my desktop so I wouldn't have to spend 45 minutes trying to find a handout on liver/gallbladder flush to give to a patient (like I did yesterday).

Some researchers view the hippocampus as part of a larger medial temporal lobe memory system responsible for general declarative memory (memories that can be explicitly verbalized—these would include, for

example, memory for facts in addition to episodic memory). Damage to the hippocampus does not affect some types of memory, such as the ability to learn new motor or cognitive skills (playing a musical instrument, or solving certain types of puzzles, for example). This fact suggests that such abilities depend on different types of memory (procedural memory) and different brain regions.

Finally we'll discuss the hippocampus' role in circadian rhythm, you know, that smooth Jazz band that your Uncle Larry listens to. No, the circadian rhythm is the cyclical output of hormone release. This timekeeping system, or biological "clock," allows us to anticipate and prepare for the changes in the physical environment that are associated with day and night, energy needs of the body and brain, and sleep patterns thereby ensuring we will "do the right thing" at the right time of the day.

When I hear patients say things like, "I can't fall asleep", or "I fall asleep fine but then wake and can't get back to sleep," I think, "They have a screwed-up hippocampus" (or sometimes I think, "I'd really like a peanut butter sandwich" – but let's not confuse things here).

Cutting through all my ridiculous attempts to bring my really stupid humor to a rather boring topic, let's review some things about the hippocampus before moving on:

- It may be important in behavioral inhibition along with the prefrontal cortex
- It is very important in shunting working memory to long-term storage
- It is important in sorting and retrieving memories
- It may tie memories of special senses (smell) to events, people, or places
- It helps with hormone output as it connects to the hypothalamus and pituitary gland
- It may help tie emotional memories to the amygdala as we shall soon see
- And, it's a fun word to say

So again, inflammation in the brain from Lyme can cause issues in the above functions!

Lyme brain and the Amygdala

Next we'll discuss the amygdala. It sits at the end of the hippocampus, on both sides of the brain and I think it sounds like the name of a French, cream-filled pastry (I must be hungry). Its central nucleus produces autonomic (non-conscious) components of emotion (e.g., changes in heart rate, blood pressure, and respiration) as well as conscious perception of emotion primarily through the prefrontal cortex (anterior cingulate cortex, orbitofrontal cortex, and dorsolateral prefrontal cortex). Important to note is that these pathways go both ways, which controls emotional behavior, fears, and anxiety.

The amygdalae perform primary roles in the formation and storage of memories associated with emotional events. Research indicates that, during fear conditioning, sensory stimuli reach the amygdalae, particularly the lateral nuclei, where they form associations with memories of the stimuli, especially if there is a strong emotional connection. Memories of emotional experiences imprinted in reactions of synapses in the amygdala elicit fear behavior. Fear behavior may be described as what you'd experience if a grizzly bear tore your tent door off. Think of that for a bit and then I don't need to describe the loss of digestive control, raw emotions surfacing, sweating, lump-in-stomach, loss of sexual desire, etc.

This technically happens through connections with a grouping of neurons in what's called the central nucleus of the amygdalae and the bed nuclei of the stria terminalis (BNST). The central nuclei are involved in the genesis of many fear responses, including freezing (immobility), tachycardia (rapid heartbeat), increased respiration, and stress-hormone release. This is because it fires directly into the sympathetic nervous system (the flight, fight, or freeze system). So, stimulation of the amygdala causes intense emotion, such as aggression or fear.

An example of a strong stimulation of the amygdala would be a panic attack. Panic attacks are brief spontaneously recurrent episodes of terror that generate a sense of impending disaster without a clearly identifiable cause. PET scans have shown an increase in blood flow to the hippocampus, beginning with the right hippocampus (think right brain – more emotional) and then to the amygdala. Similar but attenuated blood flow increases occur during anxiety attacks and prolonged stress.

Any lesions of the amygdala or from the prefrontal cortex connections to the amygdala were shown to be primarily responsible for 'flatness of affect'. This work eventually led to the psychosurgical technique of prefrontal lobotomies (my aunt had this done in the 1930's and lived as a personality-less 'vegetable' for another 60 years). Remember the movie with Jack Nicholson, "One Flew over the Cuckoo's Nest?" The prefrontal cortex sends inputs into the amygdala and severing this input obliterates the conscious connections to emotions, social behavior, and interaction leaving a flatness of affect directly proportional to the size of the lesion.

Likewise, the opposite is true with excitation – lack of inhibition, excessive motive, OCD-like behavior, excessively emotional, etc. Lesions may increase or decrease function of any particular area or its connections to or from such lobe. Remember, by 'lesion' we mean any interference, stimulation or abnormal function.

The amygdala combines many different somatosensory and visceral inputs—this is where you get your "gut reaction". The link between prefrontal cortex (conscious awareness and decision-making), hypothalamus (hormonal response), and amygdala (emotional memory), likely gives us our gut feelings, those subjective yet protective feelings about what is good and what is bad.

One intriguing observation in ASD is the apparent enlargement of the amygdala. The concept of "allostatic overload" (McEwen 2004, and McEwen & Lasley, 2003) was coined hypothesizing a possible biological defect causing an overgrowth. The enlargement of the amygdala would explain an increased activity of amygdalar function in many individuals – a heightened level of fear and anxiety, chronic stress of an 'overly sympathetic' (by sympathetic I am referring to the sympathetic nervous system controlling fight or flight responses) state, and generalized avoidance of social situations.

Are you beginning to see any Lyme Brain symptoms that you may be having? I am sharing all this technical, and probably boring information to prove to you that you are not crazy, that inflammation in the brain form Lyme can cause literally EVERY symptom you can imagine and that ultimately, through ridding the cause (Lyme) and rebuilding the pathways, you CAN get your life back.

Remarks

Regardless of what you choose about healthcare, I pray that you make wise, rational decisions based on facts (though often hidden) and not fear. You need to take responsibility and not hand it over to any practitioner, conventional or alternative. Get advice from many, weigh it all against their biases, and pray for peace about your decisions.

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