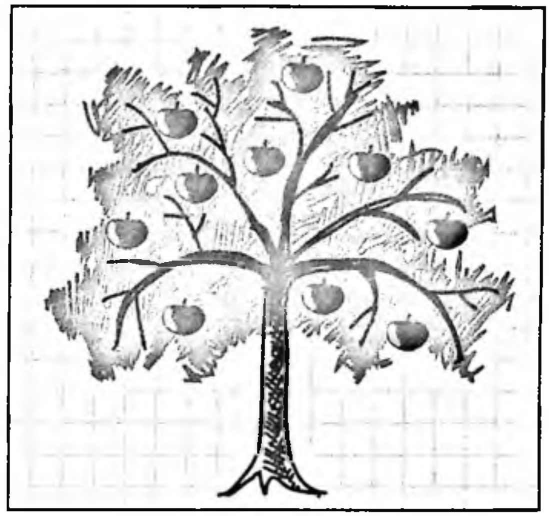
chapter 1

Let's Study the Brain

INTRODUCTION

Yes, all roads lead to the brain. However, it is important to also review the corresponding paths to get there. Let's think about the anatomy of the human nervous system. Please note that this information is not meant to replace or supplement a thorough review of neuroanatomy. In this chapter, we show the various neurological systems and the brain in a basic manner. We will start with the anatomy of trees. Yes, trees. While this may seem *disconnected* from the premise of this book, it will all make sense.



ANATOMY OF A TREE: OUR NERVOUS SYSTEM

Have you ever marveled at the wonder and beauty of trees? Trees go through various stages within their lives, as well as between seasons. My grandfather loved to practice gardening. One of his huge successes was an apple tree. I was not aware that he had planted seeds for an apple tree until one time when I came for a visit. It was simply amazing how out of nowhere, there was a yard full of plentiful, delicious apples.

The area in which my grandfather planted the tree was not the best location, in my opinion. There were apparent obstacles that would seem to halt the growth of the roots. Yet, the tree flourished, allowing my children to taste the fruits of my grandfather's labor.

Now, why are we talking about trees? Perhaps you have already made some conclusions. Our bodies need food and water, as well as other external input. We are like trees in that we take in information from the environment through our limbs as well as our eyes, ears, and our skin. There are several internal processes that result in sensation in the form of information navigating through the "trunks" and various "branches" of our nerves before reaching our brains. In order for us to grow and develop, we must participate in this process. Passive interaction will not result in one's growth and will hamper development.

When working with our children, we must think of them as we do of the trees. We do not view trees as stagnant. We do not look at them as lacking potential. We know trees are transformative. Their growth is sometimes

> **Brain Nugget**
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> **Photosynthesis is the process that nourishes trees. In our nervous system, our brain's ability to change and make new connections is called neuroplasticity.**

unpredictable like that of my grandfather's apple tree. While we only see the external parts of the trunk and branches, there is a strong connection made between the tree and its foundation through the many roots that have developed over time.

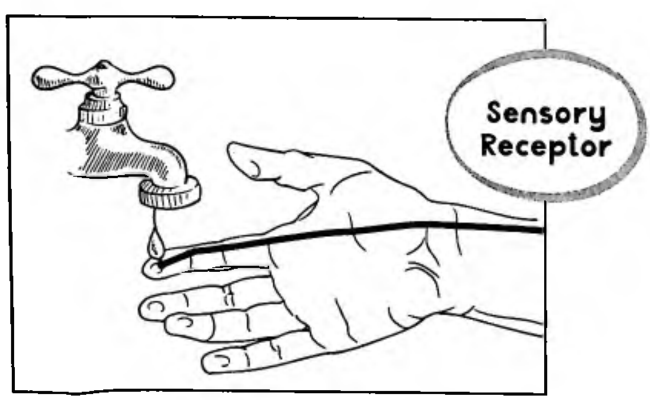
This concept can be correlated to our nervous system: Like a tree, our nervous system is not static. Like roots, new connections are made and strengthened based on our relationship with the surrounding environment. Change and growth is always possible. Our nerves are like roots that can grow and make new pathways. What connections are made depends on the environment to which one is exposed and the context in which one exists. My grandfather's tree only grew because it was exposed to what it needed. He cared for it despite its less then optimal quarters.

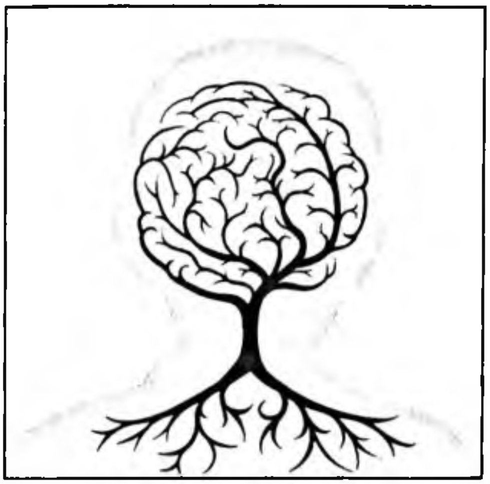
Our nervous system is powered through communication with the various happenings around us. Sensory information, or rather, stimuli from our environment, is the source of it all! Think of sensory stimulation as the detection of changes in the environment and inside of the body. If the context remained the same, stimulation would not occur. But things do change, causing arousal in our bodies. The light, temperature, sound, and demands on our bodies are constantly changing, causing us to frequently adapt. Similar to the trees adjusting between seasons, our adapting to sensory stimulation is part of our survival. For us to be successful, the various aspects of the nervous system must work together.

Let's think about our nervous system as bifold, use the tree as our model. The tree's underground anatomy—the roots and the root hairs—is the tree's first point of contact with the environment before nourishment is delivered to the other parts. For humans, our sensory receptors are the first point of contact, and nerves send messages through our bodies.

Like the tree's roots and root hairs, our receptors detect changes in the environment and determine if the nerve should receive the information or not. The detected change must be substantial enough for the sensory receptor to respond. A sensory receptor reaches a **threshold** as the result of a *strong enough* or *long enough* change in stimulation to evoke a response. This change occurs through touch, taste, sight, smell, sound, movement, or alterations in our internal organs; sensory receptor stimulation initiates the sensory process.

The **process of sensory information** is as follows:





- The body detects a change, and the sensory receptors react.
- Information is then sent through nerve pathways.
- Messages regarding changes in touch or within our joints and muscles travel through the spinal cord.
- Hearing, taste, smell, and sight sensory stimuli enter through sensory receptors from various body parts, such as eyes, ears, and taste buds.
- Internal sensation from organs such as the stomach, lungs, and heart occur through receptors and nerves from those specific internal organs.
- Messages are then sent to the brain's various structures.

Like in the tree, the systems in the human body all must work together. Whereas anatomy courses teach us about the various subsystems in the body, the body as a whole, must work in synchrony. One subsystem cannot overpower another. When one does, dysfunction arises.

An image of a tree depicts a combination of the tree and the nervous system. The brain is infused with nerve branches and is connected with the body through its nerves. It communicates with the environment through the sensory receptors. A tree illustrates the subsystems as a working unit processing the information in the environment. If too little stimulation is presented, the sensory receptors will not react and will neglect to send the message. In such situations, information is not relayed to the brain.

Brain Nugget

Because the sensory receptors in our nervous system are located outside of the brain and spinal cord, this system is identified as the peripheral nervous system (PNS). The second component consists of the brain and the spinal cord. It is called the central nervous system (CNS).

A lack of sensory stimulation will negatively affect appropriate engagement. Under-water a tree, and the tree will not flourish. A person deprived of the necessary sensory stimulation, desired by their body, may lack appropriate interaction and engagement with others. Their maladaptive behavior may be an attempt to acquire what is deficient. The opposite occurs in the presence of too much stimulation—our sensory systems may become over-aroused.

A tree receiving too much water wilts and lacks vigor. A person receiving too much stimulation may also lack appropriate participation with others and their environment. Instead, their attention is focused on attempting to block out or avoid overstimulation. For humans, input to our bodies must be **"just right."**

Just as the various trees and plants in our environment each require different levels of input to flourish, we, too, vary in our needs. What each person needs is highly unique and dependent on the individual.

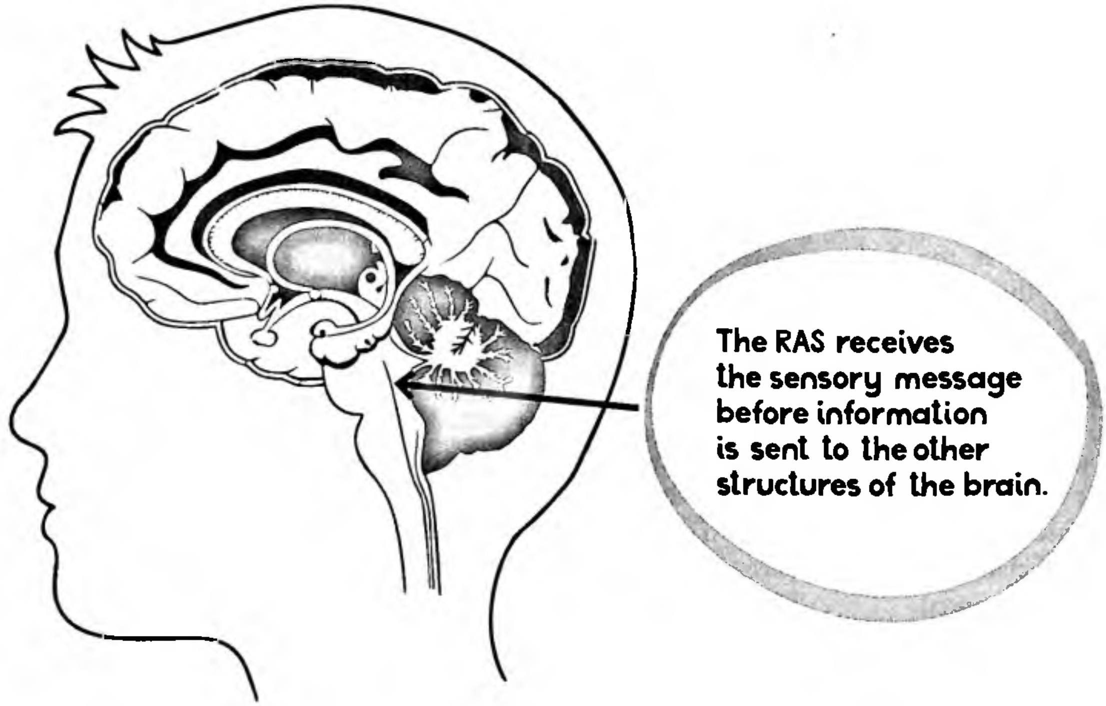
SO, WHAT HAPPENS FIRST? A TRIP THROUGH THE AIRPORT!

Sensation occurs first, then our bodies react to the sensory stimuli entering through the receptors. We have an extraordinary ability to attend to or block out stimuli. This helps us to prioritize what is important. The sensation has to catch our attention for us to feel and react. Have you ever found yourself saying "Did you hear that?" or "Did you see that?" only for the other person to respond "No?" For you, that stimulus was important, but the sound or sight that caught your attention was not powerful enough to catch the other person's attention. They were most likely focused on something else of importance to them. The system that controls this process is called the **Reticular Activating System (RAS).**

The RAS is like a gatekeeper. Its role is similar to the function of an airport security gate: It helps to filter out unwanted or unneeded sensory stimulation. The RAS acts as follows:

- **The RAS will allow in the information that is important to YOU!**
- All sensory information passes through the RAS, with the exception of smell.
- What information enters the RAS and how much depends on the person, place, or event.
- **Your arousal is affected by sensory input.** Depending on how much of the sensation and what stimulation enters, you will experience varying levels of alertness or rest.
- The RAS has output to the entire brain, spinal cord, and other important structures of our nervous system.
- The RAS is crucial for attention and decreasing distraction.

So, where is the RAS? It is located in the brainstem area.



Let us further explore the RAS. Think about going through airport security. Many people travel through the airport each day, some hours are busier than others. The morning brings a lot of people, while the late night sees just a few. Our consciousness operates similarly: We are wired to let in varying levels of stimulation depending on the time, event, or place. High facilitation when there is a lot of sensory information, moderate facilitation allowing for alertness and function.

Inhibition of stimulation allowing for rest and sleep RAS functions include the following:

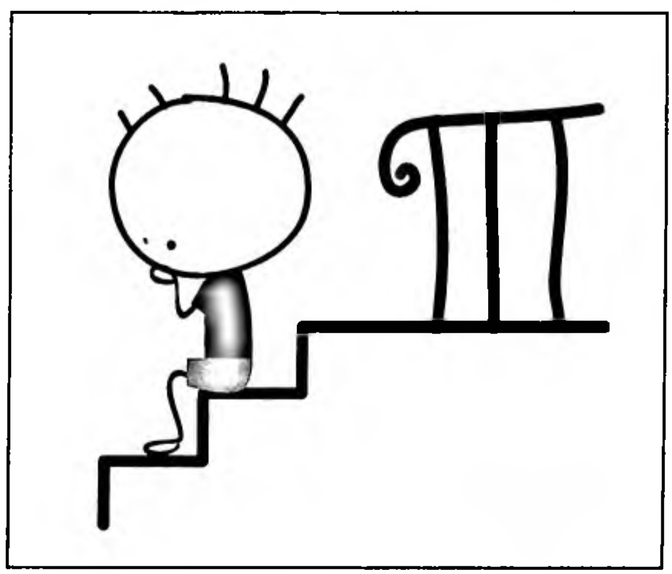
- **Alertness and facilitation:** During the day, we allow more stimulation in, which allows us to perform daily functions.
- **Sleep and inhibition:** We need less stimulation when it is time for rest at night.
- **Attention:** You may also allow in more sensory stimulation during social activities, such as a nice outing with friends, versus sitting in a lecture or a work meeting.

The RAS also plays a role in the sleep/wake cycle, breathing, digestion, heart rate, muscle activation, and other functions vital to life. Your experiences and your focus on the environment program your RAS over time. Neurological deficits play a role in how a person's RAS functions: A poorly "programmed" RAS leads to poor interaction and behavioral responses.

So, let us go back to the airport security metaphor. As you know, only certain items are acceptable to bring on a plane, and others will not pass inspection. While one goal of security is to allow passengers to get through to their gates, another goal is to preserve safety and identify anything that could be a threat. The presence of a less than desirable item, such as a weapon, will cause an alert. In our RAS we receive an "alert" in the presence of a threat.

When there is a lot of information coming in at once, such as the sights and sounds at a children's party, our RAS becomes excited. In this case, excitement can be interpreted as either joy or fear. Either way, your body responds with heightened arousal. Similarly, if you hear a fire alarm, your RAS allows an increase in the amount of stimulation entering. This allows you to be hypervigilant in reaction to possible danger, it is a protective and vital process.

Dysfunction can occur at the RAS level. Some people's RAS lets in **too much sensory information** to process input efficiently. If the RAS does not limit the amount of stimulation entering, over-responsiveness can occur. Think about an invasion of people attempting to push through the airport security gates all at once. That could be an overwhelming situation. The person experiencing an influx of sensory stimulation may become over-aroused by all of the sensations approaching the RAS, and may have difficulty paying attention and prioritizing information. The person becomes hypervigilant and may be inattentive as they focus on decreasing or avoiding such overstimulation. They may also prefer activities that elicit more effective responses to help them to limit the stimulation and may seek out certain sensations and experiences.



Children with this sort of pattern are constantly in what we call **"fight-or-flight" mode**. It is the SNS that controls fight or flight reactions. When the RAS receives notice of a threat, the body automatically kicks into protection mode. The muscles tense, the pupils of the eyes dilate, and the ears become hypersensitive to sound. All of this happens from an automatic chemical release allowing the individual to see, hear, run, or fight for their survival. While this system is necessary, it is not needed at the same level of intensity that may have been required before modern times.

Unlike our cave-dwelling counterparts, there is not always a bear or tiger lurking behind the bushes ready to have us for dinner. But, our bodies still react to a nonthreatening stimulus, such as a sound, in the same manner as a life-threatening event because the RAS interprets the stimulus as something of importance or danger. It sends the alert out the SNS to allow the body to react and attend to the stimuli.

Brain Nugget

The "fight or flight" reaction is part of our nervous system called the autonomic system. The division is the sympathetic nervous system (SNS). The other division is called the parasympathetic nervous system (PNS). It is primarily responsible for regulation of vital functions such as heart rate and breathing.

Take a look into some children's eyes, specifically those with hyperactivity or hypervigilant behaviors. Their pupils are probably dilated, and their arms and legs are tense. They may overreact when you attempt to engage or touch them by crying or running away. Often, they have physiological responses such as sweating and breathing quickly. Some may even appear to enjoy stimulation, indicated by their engaging in frequent movement, climbing, and jumping.

These children seek these activities to utilize their stronger, more efficient sensory systems; seeking more stimulation activates the pleasure areas of the brain. However, when these children behave in ways to avoid personal interaction, it is an indication of their feeling unsafe. Such children are comfortable performing the gross motor activities that bring a sense of security, but anxiousness may be present, as they anticipate the possible presentation of undesired stimuli, such as your touch or voice. They may become angry or aggressive when you attempt to stop their seeking behavior.

The fight-or-flight system is constantly active in some children. Although the primary culprit is the SNS, the opposite division of the autonomic nervous system (ANS), the PNS, also plays an important role. The PNS is responsible for restoring vital functions of rest and digestion, among others. This division of the nervous system must communicate with the areas of the brain to assess the situation and then regulate breathing, heart rate, digestion, and muscle relaxation as appropriate.

When sensory dysfunction is present, the PNS may lack the needed activity that allows it to modulate the abundance of stimuli sent forth by the RAS. Because of this partnership between the RAS and PNS, all areas of vitality can be affected when dysfunction is present.

Dysfunction with the PNS includes issues with:

- Sleeping
- Eating
- Digestion
- Muscle tone

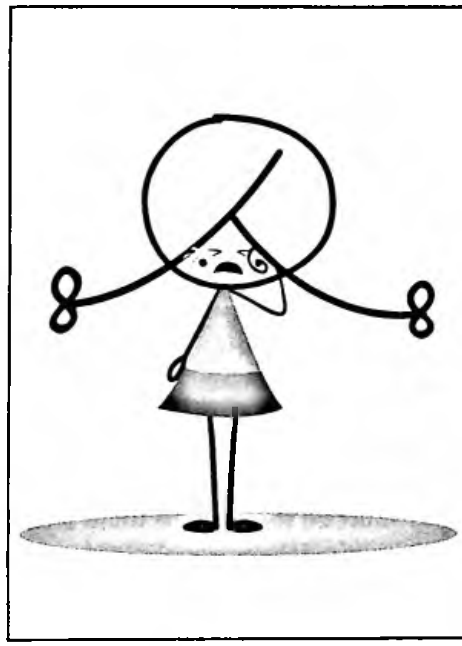
The child may:

- Be sensitive to light
- Dislike certain textures and touch
- Avoid or prefer specific foods
- Present as socially awkward
- Be aggressive at times
- Have gastrointestinal dysfunction, as in constipation or diarrhea
- Experience frequent illnesses, such as respiratory infections, due to stress on the body

Dysfunction occurs when sensory pain receptors become overly involved in processing stimulation. Due to the muscle tensing caused by the SNS, the pain receptors may react in the presence of a nonthreatening sensation, such as light touch. Increased pupil dilation may lead to painful responses to artificial light. In these situations, the RAS sends out an alert, resulting in an ongoing cycle, leading the person's RAS to be "wired" to be on the lookout for such threats. It may even react with simply the idea or anticipation of undesired stimuli making a strong connection to our emotions.

This becomes a challenge for many children. Perhaps they cry in the presence of certain food, entering a new environment, or being taken away from a desired activity. These emotional responses are the children's attempt to protect themselves from undesired stimulation, so stress and anxiety play a big role in the behavioral reactions we see with some.

There are motor behaviors related to the activation of the RAS—"*sensory in . . . motor out!*" Equilibrium, posture, and eye movements are functions directly influenced by the RAS. If the processing of the incoming information lacks efficiency, the output will also be inefficient. Children with dysfunctions in sensory processing (i.e., SPD, Autism Spectrum Disorder, ADHD) may present the following:



- Poor sitting posture
- Challenges with sitting tolerance
- Poor balance
- Difficulty with coordinating gross motor and fine motor activities
- Challenges with coordinating head, trunk, and eye movements for functional tasks (e.g., sitting at a desk and looking at a classroom board)

Primitive reflexes in some children, often present at the start of life (i.e., in babies and toddlers), that may integrate to functional movement as the child gets older. Retained primitive reflexes may present as the child has difficulty sitting against the back of a chair and appearing "wiggly"; a child not able to master the bilateral skills (i.e., being able to using both sides of the body together, also called "crossing the midline") or having trouble integrating movement in the upper body and the lower reflects further dysfunction. Hypervigilance and sensitivity to light, sounds, and tactile stimuli are additional indicators of retained primitive reflexes. For such children, activities such as gross motor games, handwriting, and self-help skills (e.g., shoe tying) are a challenge.

Distinguishing between the various characteristics of stimuli becomes complex due to the receipt of too much sensory information and a lack of filtering by the RAS. Distinguishing hot from cold and soft versus prickly or being able to identify an object through touch are compromised. Children with retained primitive reflexes may have difficulty finishing assignments on time, have sloppy desks or lockers, or have trouble sequencing activities from start to completion. Again, anxiety and stress come into play. The cycle of the overactive RAS continues. These are just a few examples of poor integration of primitive reflexes.

When a child feels safe, the PNS allows for social interaction and participation with the environment. If the RAS is overresponsive to a stimulus, the child presents with protective behaviors due to fight-or-flight activity. Many patterns of behavior we witness in children stem from self-preservation.

If something causes discomfort, the child will seek out what leads them to a sense of **security**. Even when a threatening stimulus is not present, discomfort could occur if the child does not receive enough of the desired stimuli, and the anticipation of the stimulus leads to anxiety and stress. When the RAS receives what it craves, the result is a **good feeling** or a **sense of well-being** produced by the internal chemicals released. The child will seek out the stimulation that works best for them to produce this good feeling. If they typically get a good reaction from spinning, they will seek out spinning. If crawling under the table and plugging their ears works best, that is what they will do.

Some children are on the extreme ends of the spectrum: It all depends on their protective measures. That is why some of the same interventions work for a variety of children. The differences lie within what happens internally. Our goal must be to change the child's focus. **The child will use their most efficient method of feeling good.** They are not interested in exploring new ideas that may cause stress.

Provide novel experiences and methods to help them navigate and participate. Let them know that liking movement is a good thing or that disliking certain textures or tastes is okay. The child must learn to allow for new and challenging opportunities. We start with addressing the **least-threatening sensory areas**.

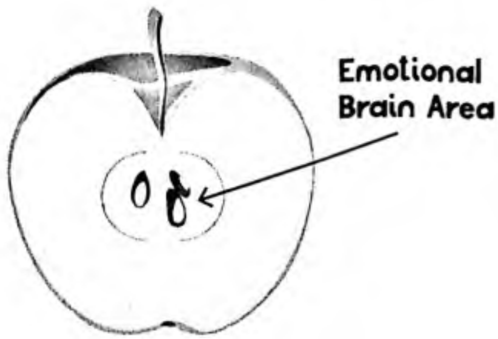
When we help the child to make changes to behaviors related to certain sensory areas, the RAS has an opportunity to expand its focus from a few primary areas to other sensory systems. The RAS can then properly communicate with the PNS and not so much with the sympathetic division, dampening the heightened arousal state in the brain. Then, the senses will start to work together to more effectively interpret the environment, with less emphasis on what is in excess or missing.

Now, the first step in implementing this concept is teaching the child. They must gain an understanding of how their body works and the possibility of making changes.

First you have a feeling (i.e., sensation), and then you have an emotion. The emotion is the result of the feeling. There are areas in the brain that are specific to our emotions. The feelings, or sensory stimuli, coming into our body must go through the brain area regulating emotion before the message can continue to the higher areas of the brain. There is a guide, or relay station, that then directs the information to the various parts of the brain for it to make sense of things and produce a response. However, it is not that simple. Our emotions are a powerful thing! That part of our brain is very primitive and highly "wired."

THE APPLE: OUR EMOTIONAL BRAIN

Picture a stem connecting an apple to the tree. As the apple hangs off of the branch, anything traveling through the tree must reach that stem area first, then enter inside the apple. Let us think of the stem as the **RAS**. The apple is like the emotional part of our brain, deep inside of the largest part of the brain. Any information received from the outside world goes to the RAS and then to the emotional brain area. Which is why you have a feeling before an emotion and an emotion before you have a thought.



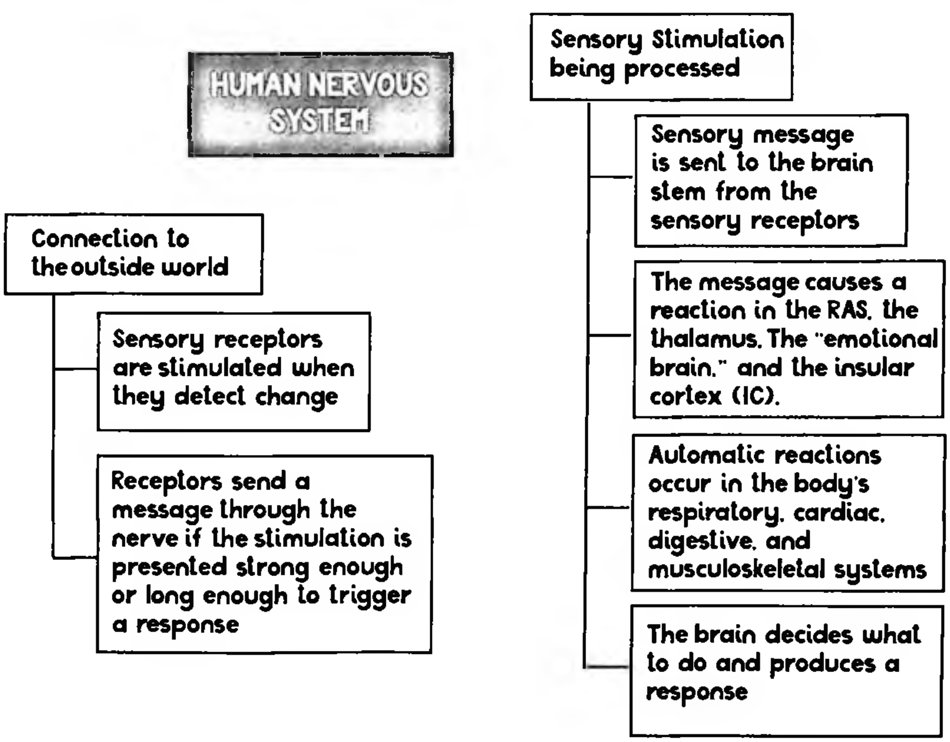
Brain Nugget

The "emotional brain" is called our limbic system. It consists of the amygdala, which helps identify the emotion, encodes it, and communicates with the hippocampus, which stores the emotion. Another region of the limbic system is the septal region, which connects to the hippocampus to identify pleasure and a sense of reward.

When a message reaches our emotional brain, the various structures of that area go to work. They investigate whether the stimulus is something of pleasure or distress. Such information is categorized and then filed away in our storage cabinets so we know what to do when presented with similar stimuli. Memory and emotions are connected, the stronger the emotion is, the stronger the memory.

Emotional reactions can be automatic, similar to a reflex. For example, a classmate hits a peer on the arm. The child's RAS sends out a message that there was a physical threat. The emotional brain may then respond with fear or anger, and the response is to strike back. Unfortunately, the original "threat" may have simply been another child running and accidently bumping into their peer. This example is one in which there was not a lot of thought or planning: The reaction to hit was not appropriate and caused distress to the child and others around them. This is the **"short path"** of fear (i.e., an automatic response to a stimulus rather than a thought-out one), which is closely connected to the fight-or-flight reaction.

The structure which directs sensory information throughout the brain, is called the **thalamus**. Now, think about the process of information traveling from the sensory receptors to the RAS and finally to the emotional brain. It takes a lot to get a message delivered to the higher areas of the brain. Once we get through the feelings and the emotions, the information travels to the top.



THE "LEADER"

Think about how your brain is positioned in your head. The part of the brain that is just beneath your forehead is the **frontal lobe**. It is the "leader" of the brain. The most superior part of this section of the brain, just at the tip, is the **prefrontal cortex**. Being flexible in one's thinking, making decisions, using judgment, inhibiting unwanted or negative actions, problem-solving, planning, and making sense of emotions all happen in this area.

> **Brain Nugget**
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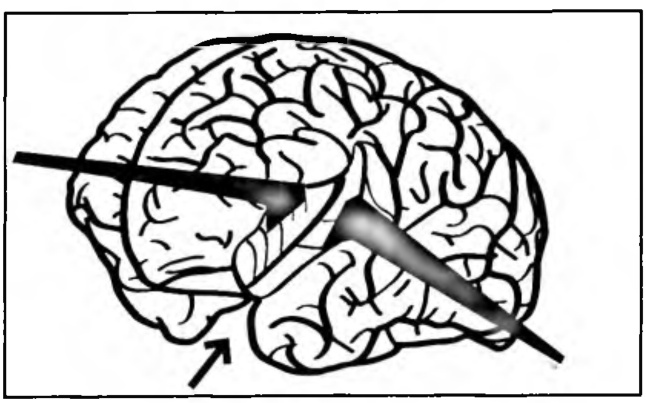
> **The cingulate gyrus connects the frontal lobe, the IC, and the limbic system. It is considered part of the limbic system.**

The long path of fear involves the prefrontal cortex, which is important for the proper assessment of stimuli. Once the prefrontal cortex has reviewed the factors pertaining to the event, it can generate an appropriate response. There are structures inside the brain that connect this area to the emotional brain. They help you reappraise what occurred, specifically in the presence of negative stimuli and pain. While a lot of emphasis is given to the prefrontal cortex, some forms of therapy may not work for the child with neurological dysfunction. Some intervention strategies that emphasize conscious activation of the front part of the brain to help children learn to control their emotions remain ineffective for some.

One major structure is the **insular cortex (IC)**. The IC is an amazing structure of the brain, located close to the emotional brain area and just below the front part of the brain, it is our "self-regulation" hub. The sensory, emotional, and executive function paths all make a stop at the IC. The functions of the IC directly align with the goals of mindfulness in that the IC increases activity during self-awareness of one's emotions. Attention, making moral decisions, consciousness, self-awareness, interpersonal experience, empathy, and regulation of vital processes are just a few of the functions identified in the IC (Augustine, 1996; Hermans et al., 2011; Kurth et al., 2010; Menon & Uddin, 2010; Nieuwenhuys, 2012).



The IC mostly receives information from the emotional brain. It has a strong connection that allows us to produce socially appropriate responses to sensory input. Some consider the IC to be part of the emotional brain system. Various neurological conditions, such as autism, have been correlated with dysfunction in the IC (DiMartino et al., 2009; Menon & Uddin, 2010; Wylie & Tregellas, 2010).

While the prefrontal cortex produces more conscious responses, the IC produces unconscious ones. Following are some facts about how the IC functions:

- The IC produces physiological activation of pleasure and pain reactions in connection to emotional stimuli.
- Activity in the IC changes between experiences and environments.

chapter 2

The Science Behind Self-Regulation & Mindfulness

This section begins to outline some of the history behind specific conditions and diagnoses. Although you may have chosen to read this book because of a child of concern, the information pertains to any and every child as we explore self-regulation and the benefits of mindfulness approaches. I encourage you to keep your mind open, the evidence may directly relate to a child in your life. Surprisingly, that child may or may not be the one you initially intended to help. You may discover that the findings can relate to most children. This allows the techniques to be easily applied in different scenarios, as we can share the principles with an entire classroom or simply one child. However, to start, we will directly review the history of SPD, ASD, and ADHD. Some of you work in the fields of occupational therapy, speech language pathology, or physical therapy. The next section, on the history of multisensory integration, is likely already familiar to practitioners.

SENSORY PROCESSING DISORDER

Sensory integration is the organization of sensation for use.

—Dr. Jean Ayres, *Sensory Integration and the Child, 1979*

Let me start by reiterating that self-regulation comprises a few factors, one being **multisensory integration**. Jean Ayres (1963) is a name known by many occupational therapists. She was a true pioneer, being the first to use the term **sensory integration dysfunction**. Dr. Ayres acknowledged the connection between the nervous system and the behaviors seen in individuals of all ages. **If the information from the environment enters the individual's sensory system in a disorganized fashion, the produced behavior would in turn be disorganized**.

Ayres theorized that therapy interventions needed to first target the "emotional brain." She knew one had to meet the child at their level and find their motivation. As she worked with children having challenges in learning and social behaviors, Ayres claimed that by targeting the innate and automatic sensory system, one could address the deep-rooted neurological causes. Successful integration of the senses, motor input, emotions, and cognition is necessary for successful engagement and participation. Changes in the brain occur as a result of presenting the "just-right" challenge in various forms of fun and playful sensory stimulation.