The Brain 101

1. The Neuron

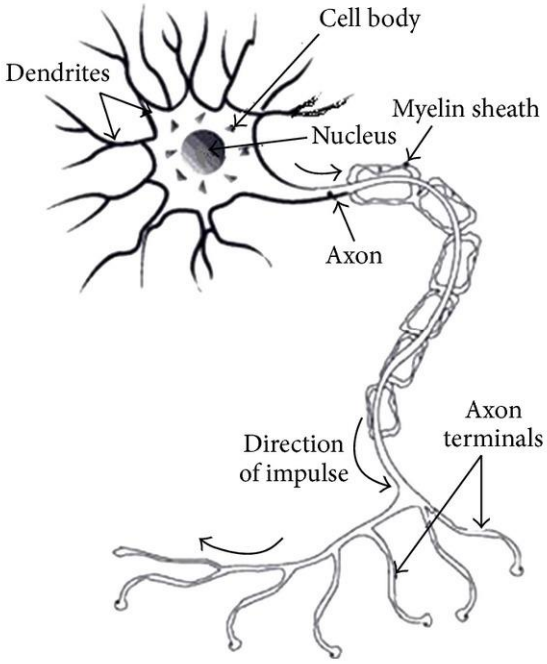

Figure 1
Neuron Structure

The *neuron* is the basic cell type of the nervous system. It is typically called a "*brain cell*."[1]

● The inputs of a *neuron* are called *dendrites*.

● The impulse travels down a single long cable called an *axon* -- a long thin tube that is electrically active.[2]

● The axon then splits up into branches called axon terminals which are the outputs.

● Axon terminals connect to dendrites of other neurons.

● An average neuron in the brain has about ten thousand dendrites and about the same number of axon terminals.

● The brain has more than a hundred billion neurons. [3]

● In the infinitely dense tangle of billions of brain cells there are trillions of neural connections.[4]

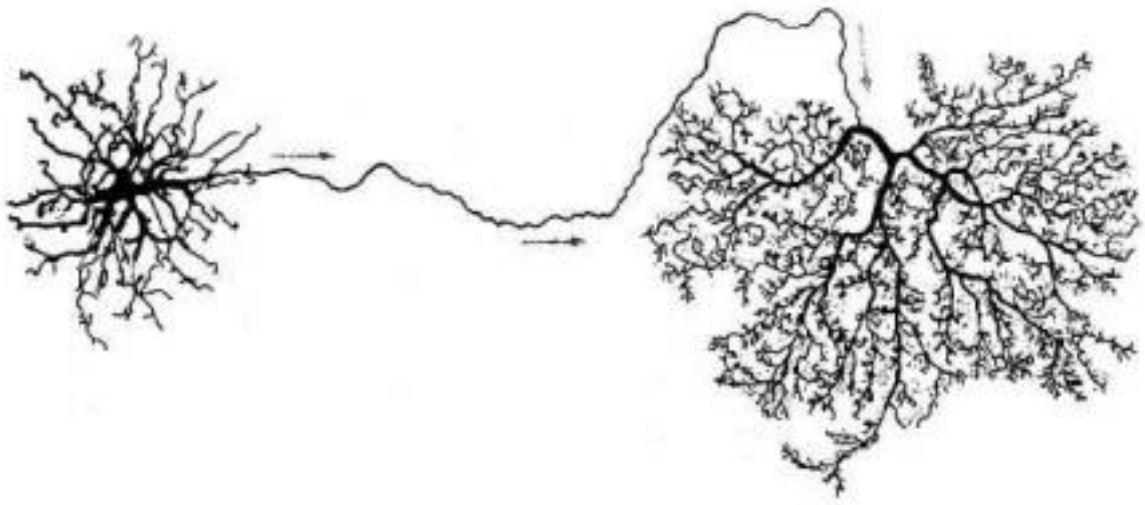

Figure 2
Example of Potential Numbers of Connections of One Neuron

2. The Brain

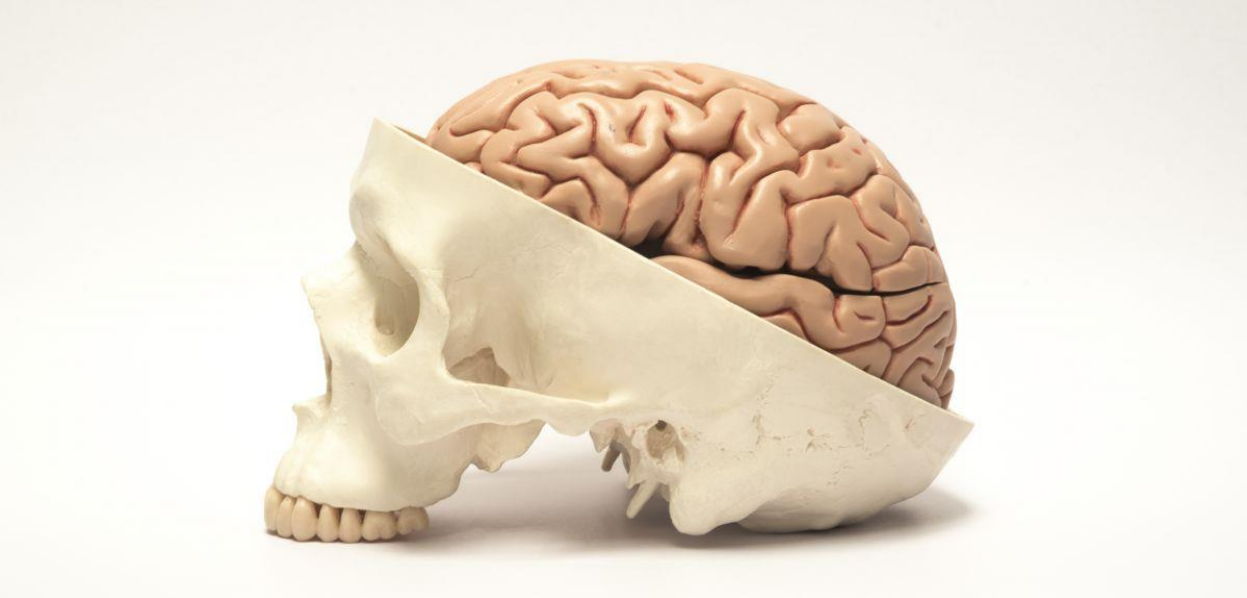

Figure 3
The brain sealed within the dark, silent chamber of the skull.

The brain has no access to the world outside. Sealed within the dark, silent chamber of your skull, your brain has never directly experienced the external world, and it never will. Instead, there's only one way that information from out there gets into the brain. Your sensory organs — your eyes, ears, nose, mouth, and skin — act as interpreters. They detect a motley crew of information sources -- *including photons, air compression waves, molecular concentrations, pressure, texture, temperature* -- and translate them into the common currency of the brain: electrochemical signals.[5]

These electrochemical signals dash through dense networks of neurons, the main signaling cells of the brain. There are a hundred billion neurons in the human brain, and each neuron sends tens or hundreds of electrical pulses to thousands of other neurons every second of your life. Everything you experience — *every sight, sound, smell* — rather than being a direct experience, is an electrochemical rendition in a dark theater. [6]

3. The Senses

Figure 4

Sense Organs

It feels as though you have direct access to the world through your senses. Reach out and touch something. Although it feels like the touch is happening in your fingers, in fact it's all happening in the mission control center of the brain. It's the same across all your sensory experiences.

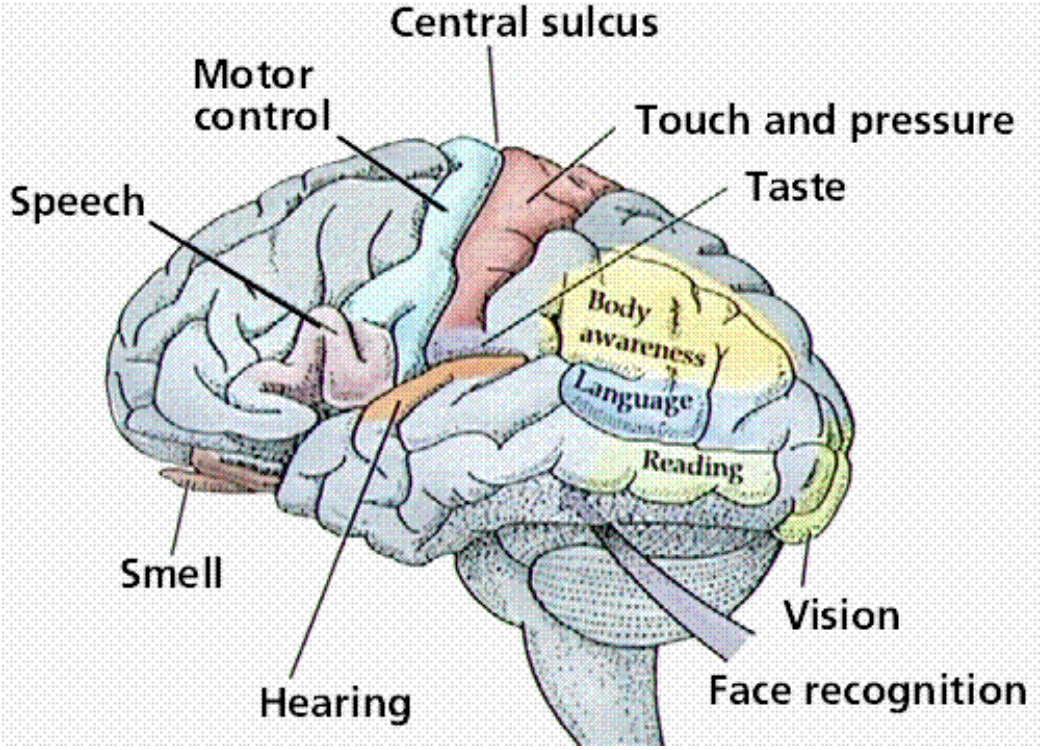

Figure 5
Sensory Processing Centers of the Brain

Seeing isn't happening in your eyes; hearing isn't taking place in your ears; smell isn't happening in your nose. All of your sensory experiences are taking place in storms of activity within the computational material of your brain.[7]

How does the brain turn its immense electrochemical patterns into a useful understanding of the world – *a Reality*? It does so by comparing the signals it receives from the different sensory inputs to patterns stored in memories or prewired genetic structures and making its best guesses about what's "out there." This subconscious operation is so powerful that its work seems effortless. The act of seeing feels so natural that it's hard to appreciate the immense machinery that makes it happen. About a third of the human brain is dedicated to the mission of vision, to turning raw photons of light into our mother's face, or our loving pet, or the couch we're about to nap on.[8]

Humans aren't born with brains that are hardwired with areas connected to sense areas that are ready to operate at their full capacity. At birth we humans are helpless. We spend about a year unable to walk, about two more before we can articulate full thoughts, and many more years unable to fend for ourselves. We are totally dependent on those around us for our survival. Now compare this to many other mammals. Dolphins, for instance, are born swimming; giraffes learn

to stand within hours; a baby zebra can run within forty-five minutes of birth. Across the animal kingdom, our cousins are strikingly independent soon after they're born.[9]
Instead the human brain is born remarkably unfinished. Instead of arriving with everything wired up — let's call it "hardwired" — a human brain is shaped by the details of life experience. This leads to long periods of helplessness as the young brain is slowly molded by its environment. We call this "livewired."[10] The brain is like a book, the first draft of which is written by the genes during fetal development. No chapters are complete at birth, and some are just rough outlines waiting to be filled in during childhood. But not a single chapter — be it on sexuality, language, food preferences, or morality — consists of blank pages on which a society can inscribe any conceivable set of words. Nature provides a first draft, which experience then revises it.[11]

4. How Neurons Connect Sensory Organs and the Brain

How does the biological wetware of the brain give rise to our experience: the sight of emerald green, the taste of cinnamon, the smell of wet soil? What if I told you that the world around you, with its rich colors, textures, sounds, and scents is an illusion, a show put on for you by your brain? If you could perceive reality as it really is, you would be shocked by its colorless, odorless, tasteless silence. Outside your brain, there is just energy and matter.[12] Our perception of reality has less to do with what's happening out there, and more to do with what's happening inside our brain.[13]

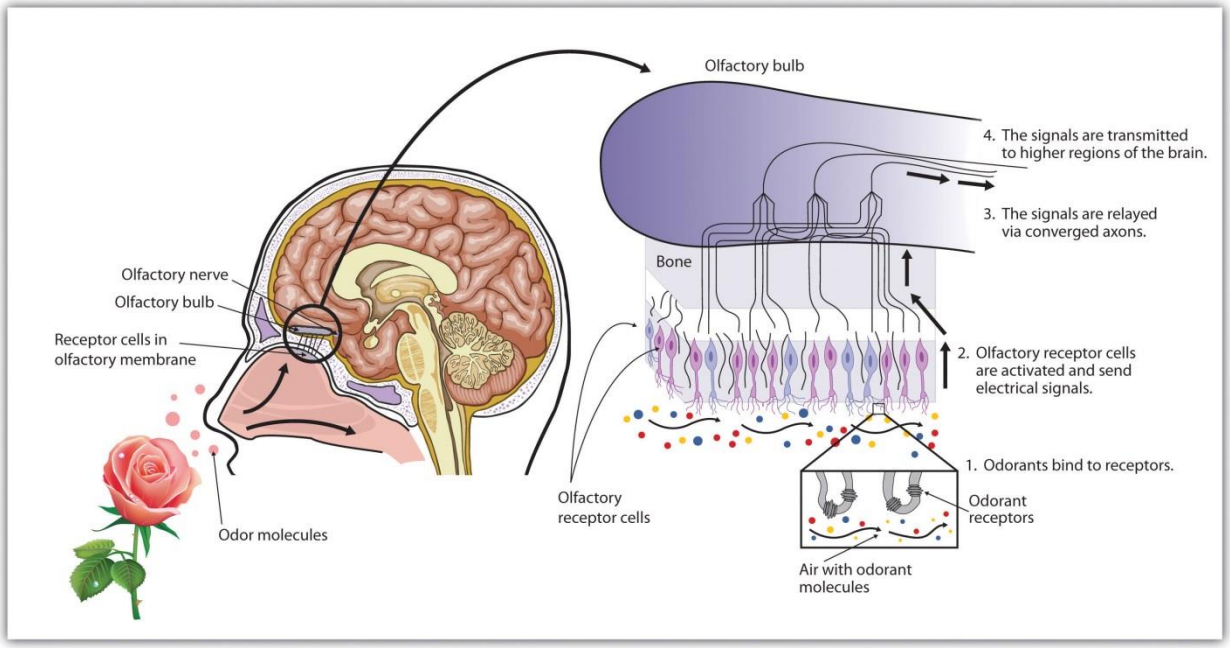

Figure 6
Sensory Transduction

Sensory Transduction is when signals from the environment, such as photons (sight), air compression waves (hearing) or scent molecules (smell) are converted (transduced) into **action potentials** by specialized cells. It is the first step by which information from outside the body is received by the brain.[14] An **action potential** is a brief (one millisecond) event in which the

voltage across a neuron reaches a threshold, causing a propagating chain reaction of ion exchange across the cell membrane.[15]

5. Synapse

The **synapse** is the space typically between an axon of one neuron and a dendrite of another neuron.[16] When a electrical impulse is generated in the first cell, it flows down to the end of the axon. The electrical impulse doesn't leap across the synapse -- it gets translated into a different type of signal. Sitting inside each axon terminal, tethered to the membrane, are little balloons called vesicles, filled with many copies of a chemical messenger. Along comes the electrical impulse that sweeps over the terminal and triggers the release of those chemical messengers into the synapse. They float across it and fit into the dendritic spine of the neuron on the other side, where they excite it and create another electrical impulse. These chemical messengers are called *neurotransmitters*.[17]

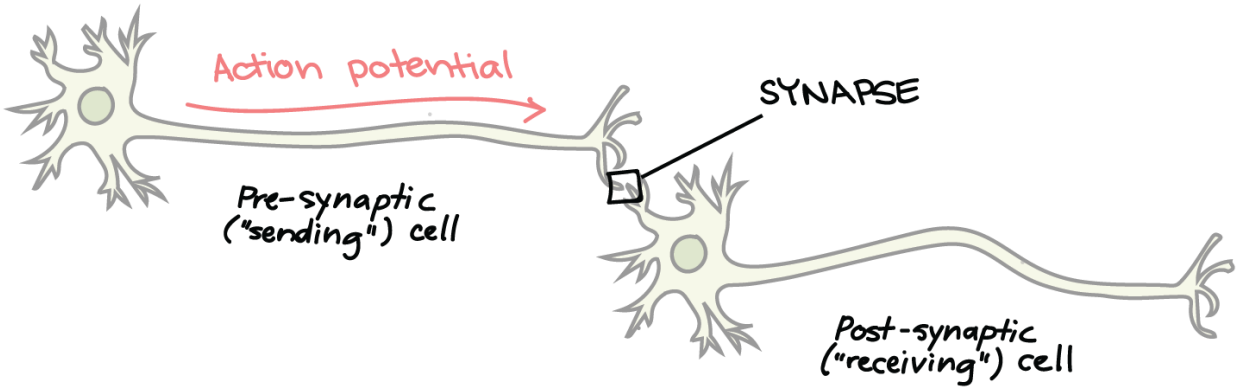

Figure 7
A Synapse (firing) [18]

Neurotransmitters and receptors can be described as floating keys that fit into specific locks. The **firing axon** then shoots the neurotransmitters across the synapse to bind to the receptors on the dendrites of the next cell. Each neuron has a cell body that makes proteins so the neuron can stay alive, and neurotransmitters that allow neurons to communicate with each other.[19]

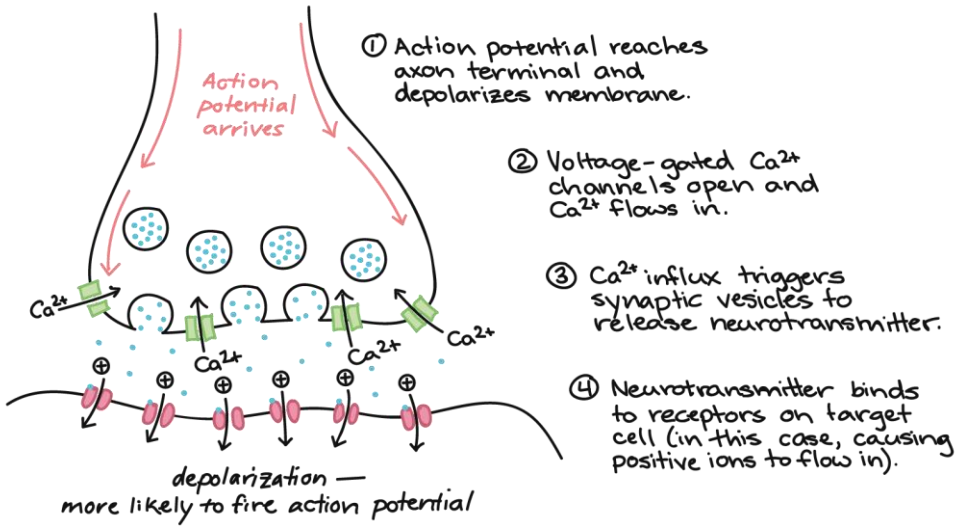

Figure 8
Neurotransmitters Release and Bind [20]

Neurotransmitters are chemicals that are released from one neuron to another recipient neuron, usually across a synapse. These are found in the central and peripheral nervous systems including the brain, spinal cord, and sensory neurons throughout the body. Neurons may release more than one neurotransmitter.[21] The receptor has a binding pocket of a distinctive shape that is perfectly complementary to the shape of the neurotransmitter. And thus the neurotransmitter fits into the receptor like a key into a lock. No other molecule fits snugly into that receptor; the neurotransmitter molecule won't fit snugly into any other type of receptor. Neurotransmitter binds to receptor, which triggers those channels to open, and the currents of ionic excitation begin in the dendritic spine.[22]

7. Neural Pathways

There are hundreds of brain areas that have evolved to perform different functions (as we saw in Figure 5 above). The parietal lobes are where touch is interpreted. The frontal lobes cause muscle movement. The occipital lobes are where we see. The temporal lobes are where we hear. But where do we laugh and cry? Where are joy and sadness and fear and disgust and anger felt? They take place in the limbic, or emotional, brain. This system comprises a set of specialized structures deep within the brain, which are all interconnected. And those connections lead to stereotyped emotions in each and every one of us.[23]

The brain's limbic or emotion regulation system consists of three major pathways that send and receive chemical information that is translated into positive and negative emotions. The interplay between these three distinct pathways dictates both the perception of emotion and the resultant behavioral responses.[24]

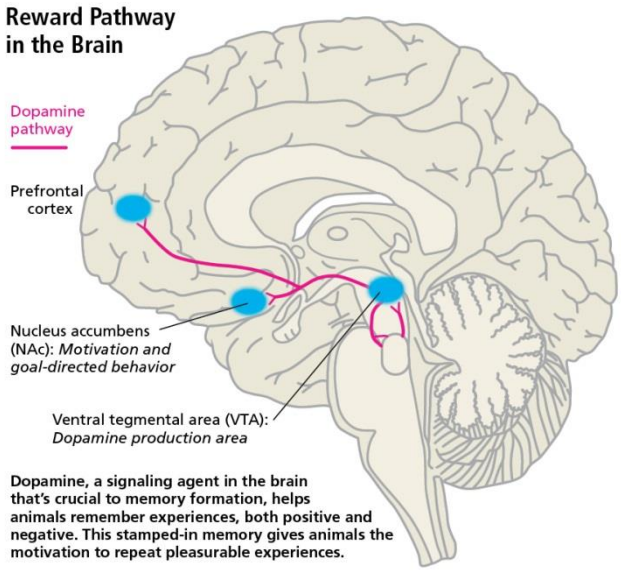

Figure 9 [25]

The **Reward Pathway** utilizes the neurotransmitter *dopamine* to communicate between the neurons of the *ventral tegmental area* (**VTA**) and the dopamine receptors of the *nucleus accumbens* (**NA**). When neurons in the VTA fire, they send their dopamine to NA to generate the feelings of motivation that attend reward. The NA is also a "learning" pathway — *so we learn what feels good*.

Those neurons then release a set of neurochemicals known as *endogenous opioid peptides* (**EOP**s), which have the same effects on the brain as *morphine* and *heroin*, and which generate the *feeling of pleasure or bliss*.[26]

The **Contentment Pathway** utilizes the neurotransmitter *serotonin* to communicate between neurons of the *dorsal raphe nucleus* (**DRN**) and multiple sites throughout the *cerebral cortex*, the thinking part of the brain where you process experiences and make judgments like "*That's good*" or "*That's bad*." *Serotonin* acts in different ways on different neurons, depending on each neuron's function and the type of receptor.[27] *Serotonin* neurons fan out to many different part of the brain. When these signals are interpreted either separately or together, we describe the neural experience as some version of *happiness*.[28]

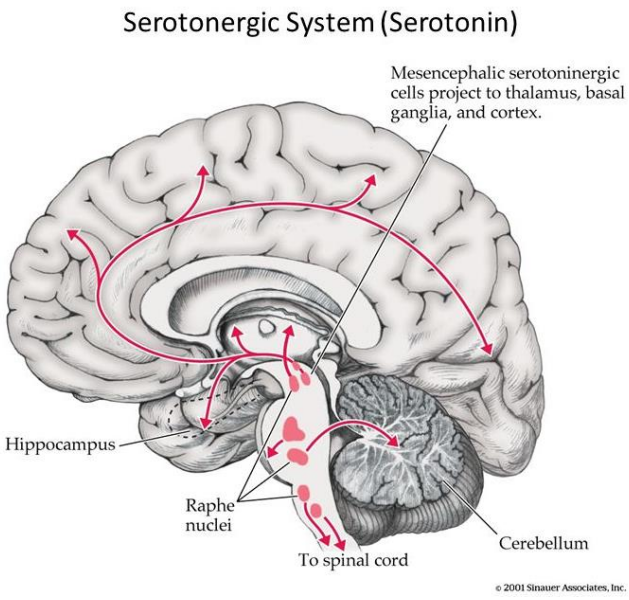

Figure 10

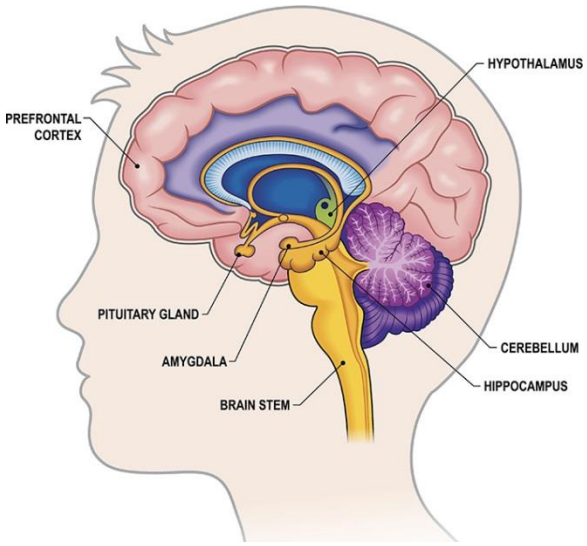

Figure 11

The **Stress-Fear-Memory Pathway** consists of four areas. The *amygdala*, or your stress center, is in communication with the *hypothalamus*, which controls the stress hormone *cortisol*. The *hippocampus*, or your *memory center*, interprets memories as both good and bad. The *amygdala* and the *hippocampus* are reciprocal to each other. When your *amygdala* figures out that an experience is not a good one, that information ends up stored in the *hippocampus*. The fourth area is the *prefrontal cortex* (**PFC**); this is the wise area of the brain that *inhibits behaviors* that put you at risk. These four areas together keep your outward behavior in check.[29]

These three pathways generate virtually all human emotion, and in particular those of reward and contentment.[30]

[1] *Behave: The Biology of Humans at Our Best and Worst* by Robert M. Sapolsky © 2017; Penguin Press, New York, NY; p. 680.
[2] http://umdberg.pbworks.com/w/page/84111850/Capacitance%20in%20nerve%20cells
[3] *Behave: The Biology of Humans at Our Best and Worst*; p. 686-687.
[4] *The Brain: The Story of You* by David Eagleman © 2015, Vintage Books, New York, NY; p. 2.
[5] *The Brain: The Story of You*; p. 41.
[6] *The Brain: The Story of You*; p. 41.
[7] *The Brain: The Story of You*; p. 40.
[8] *The Brain: The Story of You*; p. 42.
[9] *The Brain: The Story of You*; p. 5.
[10] *The Brain: The Story of You*; p. 6.
[11] *The Righteous Mind: Why Good People Are Divided By Politics and Religion* By Jonathan Haidt © 2012; Vintage Books, A Division of Random Books, Inc. New York, NY; p. 152.
[12] *The Brain: The Story of You*; p. 37.
[13] *The Brain: The Story of You*; p. 40.
[14] *The Brain: The Story of You*; p. 245.
[15] *The Brain: The Story of You*; p. 243.
[16] *The Brain: The Story of You*; p. 246.
[17] *Behave: The Biology of Humans at Our Best and Worsts*; p. 689.

[18] https://www.khanacademy.org/science/biology/human-biology/neuron-nervous-system/a/the-synapse
[19] *The Hacking of the American Mind: The Science Behind the Corporate Takeover of Our Bodies and Brains* by Robert H. Lustig © 2017; Penguin Random House, LLC, New York, NY; p. 28.
[20] https://www.khanacademy.org/science/biology/human-biology/neuron-nervous-system/a/the-synapse
[21] *The Brain: The Story of You*; p. 245.
[22] *Behave: The Biology of Humans at Our Best and Worsts*; p. 689.
[23] *The Hacking of the American Mind*; p. 28.
[24] *The Hacking of the American Mind*; p. 29.
[25] http://discovermagazine.com/2015/may/17-resetting-the-addictive-brain
[26] *The Hacking of the American Mind*; p. 29.
[27] *The Hacking of the American Mind*; p. 30.
[28] *The Hacking of the American Mind*; p. 101.
[29] *The Hacking of the American Mind*; p. 31.
[30] *The Hacking of the American Mind*; p. 32.