frontiers | Frontiers for Young Minds

NEUROSCIENCE AND PSYCHOLOGY
Published: 30 October 2023
doi: 10.3389/frym.2023.1023491

BRAIN CHEMICALS THAT MAKE US HAPPY OR SAD

Amy Kim[1], *Panisara Sutthipong*[1], *Mya LeVaughn*[1] *and Nico Osier*[2*]

[1]*College of Natural Sciences, The University of Texas at Austin, Austin, TX, United States*
[2]*School of Nursing, The University of Texas at Austin, Austin, TX, United States*

YOUNG REVIEWERS:

C.R.
AGE: 9

JIA
AGE: 15

Every day, you experience many kinds of emotions that affect the way you think and act. However, you probably never stop to think about why you feel this way: teeny-tiny chemicals are responsible. These chemicals, called neurotransmitters, can control your mood and activity. Your body is made up of many small parts called cells and, using dozens of types of chemical signals called neurotransmitters, cells communicate with each other. It is as if the cells are "passing notes" around, sending messages back and forth from the brain to the rest of the body. Learning more about the neurotransmitters flowing throughout the body and how they work in cell communication can help us understand more about how our emotions work and it can also help scientists create medications for people with certain mental health conditions. In this article, we discuss three major neurotransmitters and the emotions they cause.

WHY DO YOU FEEL?

Think back to a time when you felt excited and happy. Now, remember a time when you felt sad or disappointed or even angry. Have you ever thought about why you felt those things or why your body reacted the way it did when you experienced those emotions? You can thank some itty-bitty chemicals produced by nerve cells that are at work all throughout your body.

NEURONS

Cells that make up the brain, spinal cord, and nerves. They consist of dendrites, a cell body, and an axon.

DENDRITE

Short branched structures on neuron cell bodies that receive chemical signals from other cells.

AXON

The long thin part in the middle of a neuron that sends signals from the cell body to the axon terminal, releasing chemicals that lead to signaling in other neurons.

SYNAPTIC GAP

The space between the end of one neuron and the start of another neuron, which neurotransmitters cross for cell-to-cell communication.

NEURONS CONTROL YOUR BODY

Cells are the basic building blocks of life. Your body is made up of trillions of cells! Nerve cells (also called **neurons**) are one of the body's many cell types, and they have two main functions: to sense the outside world and to control your body's responses to the outside world. How do neurons do this? By working together!

Neurons, which are found in the brain, spinal cord, and all other organs, communicate with one another using chemical signals to relay information throughout the body. They do this through their unique structure (Figure 1). The cell body is the "main area" of the neuron. **Dendrites** are short branches extending from the cell body that *receive* chemical signals from other cells. The **axon** is a long, thin fiber extending from the cell body that branches out at the ends. The very ends of the branches are called axon terminals and they *release* chemical signals into the small space between two neurons, which is called the **synaptic gap**. So, in summary, a neuron receives signals through its dendrites, the signal moves through the cell body and down the axon, and is passed on at the axon terminals, so that another neuron can receive it. Together, neurons can control many things about us, including our emotions [1].

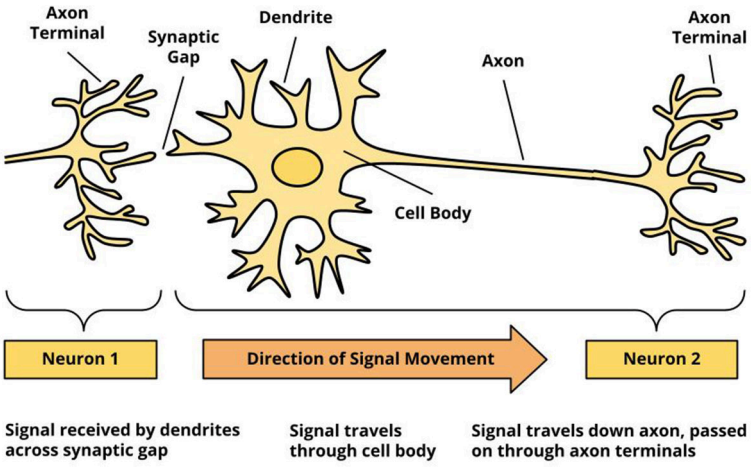

Figure 1

Neurons consist of three main structures: dendrites, the cell body, and the axon. Dendrites receive signals from the environment or from other cells. The signals travel through the cell body and then down the axon, which passes the message on to more neurons across the synaptic gap.

WHAT ARE NEUROTRANSMITTERS?

What exactly are the signals sent between neurons? They are made of chemicals called **neurotransmitters**. Imagine two friends playing a game of catch with a baseball. The "thrower" throws the ball across the lawn to the "catcher." Similarly, imagine two neurons are communicating using neurotransmitters (Figure 2). The "thrower" neuron is called the presynaptic neuron—"pre" means "before" and tells us this neuron is before the synaptic gap. The presynaptic neuron releases the neurotransmitter across the "lawn" (synaptic gap), where it is caught by the "catcher" neuron, called the postsynaptic neuron (meaning "after" the synaptic gap).

NEUROTRANSMITTERS

Chemical messengers that transfer signals from one nerve cell to another.

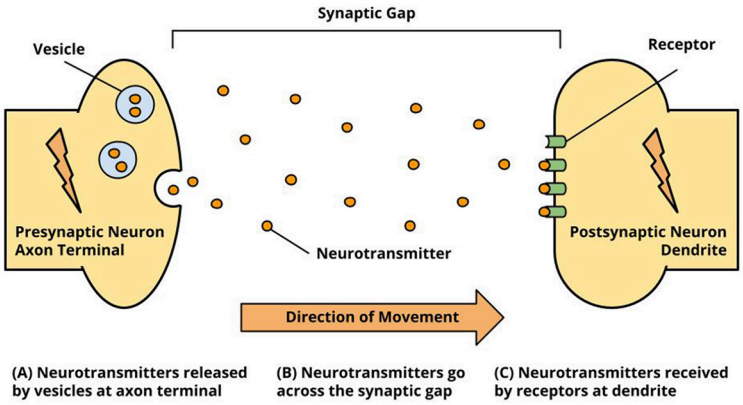

Figure 2

Details of how neurotransmitters work. **(A)** An electrical signal travels down the presynaptic neuron to the axon terminal, causing neurotransmitters to be released from vesicles. **(B)** Neurotransmitters cross the synaptic gap. **(C)** Neurotransmitters bind to the receptors on the dendrites of the postsynaptic neuron, transmitting an electrical signal that travels through the neuron.

VESICLES

Sac-like structures at the axon terminal that contain neurotransmitters and release them into the synaptic gap in response to a high enough electrical signal.

RECEPTORS

Structures on a cell that receive ("catch") molecules and can send a signal into the cell in response. In neurons, receptors trigger an electrical signal that travels through the cell.

While this is what generally happens, the details are a little more complex. Neurotransmitters are stored in tiny sac-like structures called **vesicles** at the axon terminal. When neurotransmitters travel across the synaptic gap, they bind to molecules called **receptors** on the dendrites of the "catching" neuron—you can think of receptors as the "hands" doing the catching. When enough receptors "catch" the neurotransmitters, an electrical change is created in the receiving neuron, and this charge moves through the cell body and down the axon [2]. When the electrical signal reaches the end of the axon, the vesicles in the axon terminal release their neurotransmitters into the synaptic gap, and they travel across to communicate with even more neurons by the same method. This is the basic method by which the neurotransmitters in your brain influence the emotions you feel.

The three most common neurotransmitters involved in emotions are dopamine, serotonin, and norepinephrine [3] (Figure 3). These three different "balls" control your everyday moods and emotions! A good balance between "throwing" and "catching" each of these neurotransmitters is important to keep you physically and mentally healthy.

Figure 3

The three main neurotransmitters associated with emotions are dopamine, serotonin, and norepinephrine. Dopamine is the "reward and pleasure" neurotransmitter. Serotonin is the "satisfaction and self-confidence" neurotransmitter. Norepinephrine is the "attention and reaction to stress" neurotransmitter. Understanding these three neurotransmitters can explain their roles in our everyday emotions and can help doctors treat some psychiatric conditions and other diseases that affect mood.

	General Role	Low Levels	High Levels
Dopamine	Reward Pleasure	Anxiety Parkinson's Depression	Addiction Schizophrenia
Serotonin	Satisfaction Self-Confidence	Guilt/Shame Anger Depression	Serotonin Syndrome
Norepinephrine	Attention Stress-Reaction	Alzheimer's Parkinson's ADHD Depression	Schizophrenia

Figure 3

DOPAMINE

Dopamine is a neurotransmitter associated with emotions such as interest, enjoyment, fear, and anger. However, dopamine alone cannot cause these emotions [3]. Dopamine is a special neurotransmitter that works together with other neurotransmitters, such as serotonin and norepinephrine, to form these emotions. Dopamine also works in the brain's reward system. Dopamine is released from neurons when the brain receives an unexpected reward, like when you receive a surprise gift [4]. However, too much dopamine can be problematic, as it is linked to addiction and a **psychiatric disorder** called schizophrenia. The symptoms of schizophrenia include losing touch with reality, for example seeing or hearing things that are not really there. Scientists know that excessive dopamine and dopamine receptors are one of the causes of schizophrenia, but they are unsure of the exact mechanism [5].

PSYCHIATRIC DISORDER

Health conditions that affect the way a person feels, thinks, and behaves. Examples include schizophrenia and depression.

If you are denied an expected reward, like if you find out your favorite show was canceled, dopamine activity is decreased [4]. Low dopamine levels are associated with emotions like surprise, distress, shame, and disgust [3]. Even lower levels are associated with anxiety and Parkinson's disease, a nervous system disease that causes movement difficulty. Thus, one treatment for such conditions includes a special chemical that helps the body create more dopamine, which reduces symptoms [5].

SEROTONIN

Serotonin is a neurotransmitter associated with emotions such as interest, enjoyment, and surprise. It is also related to disgust, as stimulation of serotonin receptors is linked with disliking the taste of a food [3]. The next time you feel disgusted from eating your most

hated dish, you will know it is from the serotonin firing in your brain. Extremely high levels of serotonin in neurons can lead to serotonin toxicity, which involves symptoms such as nervousness, insomnia, nausea, and shaking [6].

Low levels of serotonin are associated with feelings of distress, fear, shame, and anger [3]. The way these low-serotonin emotions are felt also differs by the person. For example, if you are highly sensitive to the emotions of others and you do something wrong, you will probably feel much more guilt and shame than someone who is less sensitive, who is more likely to feel annoyed or even angry in the same situation [7]. Very low levels of serotonin are associated with psychiatric disorders including depression [3]. Some medications can increase the time that serotonin stays in the synaptic gap, which can sometimes treat the symptoms of depression [7].

NOREPINEPHRINE

Norepinephrine is a neurotransmitter that plays a key role in attention and alertness as well as in the "fight or flight" response. During times of stress or anxiety, norepinephrine is released and binds to receptors throughout the body. This increases heart rate, dilates pupils, slows down digestion, and heightens the senses—a reaction you may have felt at a time when you were nervous or scared [8]. High levels of norepinephrine make you feel active, aroused, and attentive. So, whether you are being chased by a bear in the woods, are extremely focused on taking a test, excited about performing in a competition, or even feeling attracted to your significant other, high levels of norepinephrine are flowing throughout your body.

Both high and low levels of norepinephrine are related to diseases: low levels are related to Alzheimer's and Parkinson's diseases, attention-deficit/hyperactivity disorder (ADHD), and depression, while high levels are related to schizophrenia [8]. Now that you know how norepinephrine affects your reactions, you may be able to understand why high norepinephrine levels can explain emotions such as interest, surprise, distress, and anger while low norepinephrine levels explain terror, shame, and disgust [3].

SO WHAT?

Hopefully you now have a better understanding of how and why you feel the way you feel! Different combinations of serotonin, dopamine, and norepinephrine create our basic emotions. When all three neurotransmitters are at high levels, we can feel interest and excitement, while having all three at low levels can generate feelings of shame and humiliation [3]. Control of feelings, thoughts, and actions is complex and are affected by other factors than the three neurotransmitters discussed in this article. Still, serotonin, dopamine,

and norepinephrine do play a major role in our mood. So, whenever you feel happy, sad or anything in between, remember that these tiny chemicals are at work all over your body to make you feel that way.

REFERENCES

1. Lerner, K. L., and Minderovic, C. M. Neuron. 2014. In: *The Gale Encyclopedia of Science*. Detroit, MI: Gale, a Cengage Company. Available online at: https://link.gale.com/apps/doc/CX3727801669/GVRL?u=txshracd2598&sid=bookmark-GVRL&xid=743dabf1 (accessed December 10, 2023).
2. Finley, M. 2014. Neurotransmitter. In: *The Gale Encyclopedia of Science*. Detroit, MI: Gale, a Cengage Company. Available online at: https://link.gale.com/apps/doc/CX3727801672/GVRL?u=txshracd2598&sid=bookmark-GVRL&xid=d23322a7 (accessed December 10, 2023).
3. Lövheim, H. 2012. A new three-dimensional model for emotions and monoamine neurotransmitters. *Med. Hypotheses.* 78:341–8. doi: 10.1016/j.mehy.2011.11.016
4. Girault, J. A., and Greengard, P. 2004. The neurobiology of dopamine signaling. *Arch Neurol*. 61:641. doi: 10.1001/archneur.61.5.641
5. Gotlib, J., and Dopamine, L. 2015. *Gale, a Cengage Company*, 1–2. Available online at: https://link.gale.com/apps/doc/CX8124400793/SCIC?u=txshracd2598&sid=bookmark-SCIC&xid=68b75c36 (accessed December 10, 2023).
6. Foong A. L., Grindrod K. A., Patel T., and Kellar J. 2018. Demystifying serotonin syndrome (or serotonin toxicity). *Can. Fam. Physician*. 64:720–7.
7. Kanen J.W., Arntz F. E., Yellowlees R, Cardinal R. N., Price A., Christmas D. M., et al. 2021. Serotonin depletion amplifies distinct human social emotions as a function of individual differences in personality. *Transl. Psychiatry*. 11:81. doi: 10.1038/s41398-020-00880-9
8. Hussain L. S., Reddy V., and Maani C. V. 2021. Physiology, noradrenergic synapse. In: *StatPearls*. Treasure Island (FL): StatPearls Publishing. Available online at: https://www.ncbi.nlm.nih.gov/books/NBK540977/ (accessed December 10, 2023).

SUBMITTED: 19 August 2022; **ACCEPTED:** 12 October 2023;
PUBLISHED ONLINE: 30 October 2023.

EDITOR: Axel Cleeremans, Université libre de Bruxelles, Belgium

SCIENCE MENTORS: Sok King Ong and J. Patrick Mayo

CITATION: Kim A, Sutthipong P, LeVaughn M and Osier N (2023) Brain Chemicals That Make Us Happy Or Sad. Front. Young Minds 11:1023491. doi: 10.3389/frym.2023.1023491

YOUNG REVIEWERS

C.R., AGE: 9
I like rock music and playing soccer. Math is my favorite subject at school. I really do not know what else to add.

JIA, AGE: 15
I enjoy reading, watching shows and learning new things. I find science particularly facinating due to it being all around us.

AUTHORS

AMY KIM
Hello! I am currently an undergraduate student at The University of Texas at Austin, pursuing a Bachelor of Science in biochemistry. After completing my degree, I plan to pursue a career in science. I hope to grow and learn in this field to help and serve others, and to ultimately be a positive influence on all those around me. In my free time, I enjoy singing, crocheting, and watching dramas. I find my faith to be a great source of comfort and motivation.

PANISARA SUTTHIPONG
I am an undergraduate student at the University of Texas at Austin pursuing a Bachelor of Science in medical laboratory science. I am on the pre-medical track. After graduation, I plan to attend medical school and become a pathologist. My goal is to become more involved in and educate people about the lesser-known aspects of healthcare, such as laboratory work. In my spare time, I enjoy playing the violin in UT's University Orchestra, drawing in my sketchbook, making digital art on my tablet, and playing games with my friends.

MYA LEVAUGHN
I am an undergraduate student at the University of Texas at Austin pursuing a Bachelor of Science and Arts in neuroscience. After completing my bachelor's degree, I plan to attend medical school in hopes of increasing diversity in healthcare and providing greater comfort for patients from various backgrounds. I love spending my free time hiking, swimming, and painting.

NICO OSIER

I am a principal investigator at the University of Texas at Austin. I have a bachelor's degree in nutritional science and nursing from Michigan State University, and a Ph.D. from the University of Pittsburgh. I am fascinated by the brain and how it impacts people throughout their lives. To learn more about my laboratory, visit my publicly available website: https://nicoleosier.wixsite.com/osierlaboratory/ or follow @osierlaboratory on Facebook, Twitter, or Instagram. In my free time, I enjoy traveling the world. *nicoosier@utexas.edu