



THE CYCLE OF STRESS: FROM INDIVIDUALS TO THE WORLD AND BACK

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YOUNG REVIEWERS:



AIDYN

AGE: 14



HENRY

AGE: 15



MASON

AGE: 11

Stress is a feeling of being worried, scared, or overwhelmed, caused by challenging situations or big life changes. Not all stress is bad, and some kinds of stress, like exercise, can even be good for us. However, when stress is severe or lasts a long time, it can harm our health. Severe stress causes inflammation, which is the body's way of protecting itself. Inflammation helps the body heal, but long-lasting inflammation can lead to health problems. Stress can also affect the brain, making it hard to think clearly or make good decisions. In our work, we linked all these stress-related factors together (using math) to explain our hypothesis that stress can spread from person to person through our actions, words, and body language—and even over social media—until it affects whole societies and eventually the entire planet! This is a dangerous cycle that can lead to even *more*

stress and inflammation, making problems worse. To break the cycle, we each need to focus on reducing stress in our own lives.

Have you ever felt really worried about something in your life, maybe for days at a time? Perhaps you can remember a time when you struggled to keep your grades up or to balance your schoolwork with your extracurricular activities. Or maybe you experienced bullying or discrimination and constantly felt nervous about going to school. Some of you might even feel worried because you live in a neighborhood that has a lot of crime, or in a country where there are food shortages, or even war. There are many challenging situations that can cause kids (and adults!) to feel worried, scared, or overwhelmed, and these feelings are called **stress**.

STRESS

Feelings of worry, fear, or being overwhelmed that can be good or bad for you, depending on how severe they are and how long they last.

EUSTRESS

A good type of stress that can help you feel excited or motivated. Exercise is also a form of eustress.

DISTRESS

A bad type of stress that feels like being overwhelmed or upset by whatever is happening to you. It can cause inflammation and eventual health problems.

INFLAMMATION

The body's normal response to infection or injury. Inflamed areas are often warm, red, and swollen, but inflammation can affect our internal organs, too, including the brain.

STRESS CAN BE GOOD OR BAD

If you have experienced feelings of stress in your life, you are certainly not alone—everyone feels stress sometimes. Stress is the body's natural way of responding to challenging situations or life changes. While stress might not feel good at the time, it is important to know that not all stress is bad. For example, short periods of stress sometimes help us to feel motivated so that we get things done. If you did not feel a little bit of stress before an exam, for example, you might not study! Also, exercise can put stress on the body, but we know exercise has many benefits, such as strengthening the heart and lungs, increasing muscle strength, and even improving mood and self-esteem. Stress that is "good" for us is called **eustress**.

However, stress becomes unhealthy when it is extremely serious or lasts a long time. Think about the way you feel right before a really important test, sports match, or some other high-pressure situation—and imagine that you felt that way *all the time*. You would probably start to feel tired, sick, or even depressed. Stress that harms our health is called **distress**. Today, even those of us living in relatively peaceful places still experience a high degree of stress. If you watch 24-hour news channels or spend a lot of time on social media, you may feel like there is *always* something to worry about—from climate change to school shootings to pandemics. Because of the internet, the amount of stressful news that reaches us and the speed at which such news spreads are unmatched in human history. Some reports suggest that people living today are under **more stress than ever**.

STRESS AT THE INDIVIDUAL LEVEL: INFLAMMATION IN THE BODY

Stress, particularly distress, causes **inflammation** in the body. What is inflammation? Have you ever had a sprained ankle or a splinter in your finger and noticed that the injured area is warm, red, and

CHRONIC

Describes something that has been going on for a long time and does not go away easily. Chronic inflammation can last months or years and cause many health problems.

COGNITIVE FUNCTIONS

The mental processes and abilities that allow us to think, learn, remember, reason, and solve problems. Examples include attention, memory, perception, language, and decision making.

swollen? Inflammation is one of the body's normal ways of protecting itself. When the body detects an injury or infection, special cells and chemicals are activated to help it heal. Usually, when the germ or injury is gone, the body's powerful inflammation-control mechanisms stop the inflammation, too [1]. This is important because while inflammation helps people heal, uncontrolled or **chronic** inflammation can cause even more damage to the body, leading to health problems including heart disease, cancer, and autoimmune diseases, to name a few [2].

We can think of stress as just another cause of inflammation, like an injury or infection. If stress is temporary, this is similar to getting a splinter—the inflammation goes away after the stress is gone. But what happens when stress is frequent or even constant? Long-term stress can interfere with the body's ability to control inflammation, so that any inflammation a person gets when they are feeling stressed for a long time can become chronic—and can even spread throughout the body, perhaps causing long-term health problems. So, we have a dangerous cycle: too much stress causes chronic inflammation, and chronic inflammation adds *more* stress to the body...which can cause even more inflammation, and so on!

Chronic inflammation is not only bad for the body—it is bad for the brain, too. The relationship between inflammation and the brain is still being studied, but it seems that inflammation can affect our moods, change our behavior, and weaken our **cognitive functions**, including the ability to think clearly, remember things, pay attention, and make good decisions [3, 4]. When we are so stressed that we do not feel well and our brains are not working optimally, the stressful things in our lives might feel *even more* stressful, and we might make poor decisions and generally act badly! Can you see how this could also become part of the dangerous cycle of stress (Figure 1)? And what happens when a whole group of people feels stress at the same time?

STRESS AT THE COMMUNITY LEVEL: INFLAMMATION IN SOCIETY

It is not uncommon to feel like emotions are “contagious” and can spread from one person to another. We often feel happier around happy people and more depressed around people who are always negative, for example. The same is true for stress—our actions, words, body language, and possibly even chemicals released by our bodies communicate our stress to the people we interact with [5, 6]. Think back to the early days of the COVID-19 pandemic. Do you remember hearing stories of people pushing and shoving in grocery stores as they loaded their carts with food or groups of people getting into fights over the last box of masks or the last package of toilet paper? What was going on there—why were those people acting so crazy?

Figure 1

The cycle of stress within a person. When a person experiences frequent or constant distress, the body can lose its ability to control inflammation. Chronic inflammation can affect both the body and the brain, causing health issues and leading to mood problems and weakened cognitive functions. When a person's brain is not functioning at its best, that person may make poor decisions that lead to even more stress, perpetuating the cycle.

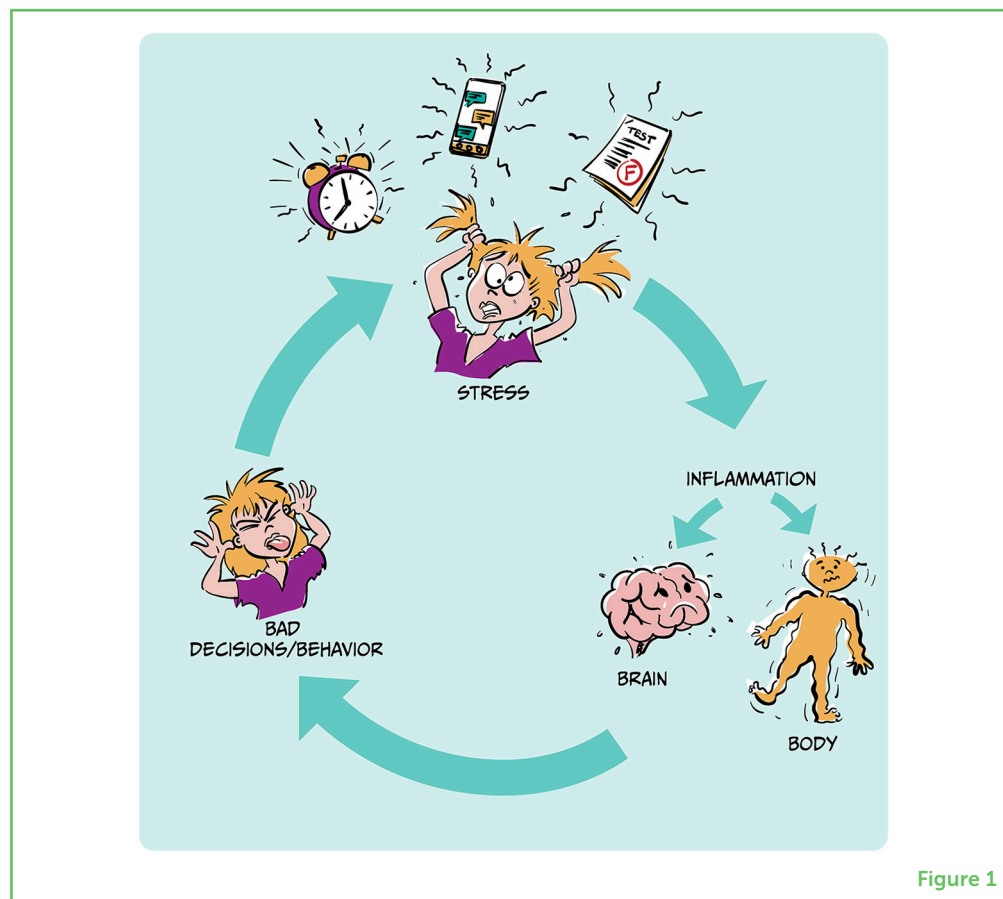


Figure 1

MATHEMATICAL MODEL

Mathematical modeling uses math to create explanations of things we see in the real world. Scientists make models to show how something works or predict how it might change.

In our work, we used a **mathematical model** to explain the cycle of stress. Mathematical modeling is a scientific technique that uses math to create explanations of things we see in the real world. At the start of the pandemic, many people were stressed. No one knew much about the COVID-19 virus yet, and people were afraid of getting sick and worried about how lockdowns might affect their lives. As you just learned, stress can negatively affect the brain, often causing people to make poor decisions and to act in ways they normally would not—maybe hoarding masks instead of sharing or pushing and shoving to grab a gallon of milk. When other stressed-out shoppers see people being rude or even violent, they might start to feel *more* stress themselves, which could push *them* closer to making bad decisions, too! In these situations, the growing stress and resulting poor behavior can escalate quickly, leading to fights and even law-breaking actions like stealing.

Our mathematical model shows that the spread of stress between people is like a type of uncontrolled “inflammation” at the community level. Community-wide stress can look like alarm or panic and can sometimes lead to the “disease” of bad (even law-breaking) behavior (Figure 2).

Figure 2

The cycle of stress in society. When individuals feel stress, this feeling can “spread” to the other people around them through their words, their body language, or chemicals their bodies produce. This expands the cycle of stress—namely, when people start acting badly because their cognitive functions are not working properly, they might become rude or violent or otherwise act in ways that increase the individual stress of people around them. In these situations, poor behavior can escalate quickly, turning into wide-spread alarm or panic.

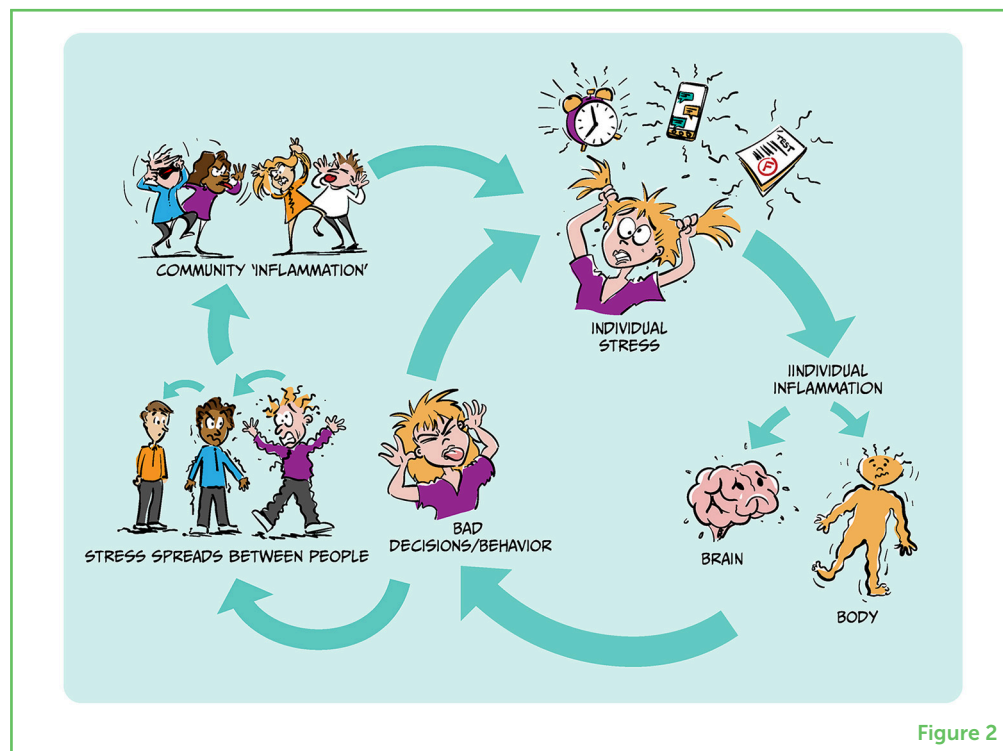


Figure 2

STRESS AT THE PLANETARY SCALE: INFLAMMATION OF THE EARTH?

In today's internet age, stress does not even need direct human contact to spread. As we mentioned, stressful news, and the long-term stress it causes, travels everywhere, almost instantly. According to our mathematical model, this can lead to large numbers of people all over the world who are highly stressed and possibly making poor decisions—all at the same time. Will people in such a stressed-out state be good at protecting the environment from harm and taking care of our planet for future generations? Probably not. If we think about the damage humans are doing to the environment as a kind of injury or disease that is causing the Earth to “feel stress,” then we could view **global warming and the related severe weather events** being seen across the world as “inflammation” of the planet, as Earth tries to protect itself or heal.

Thus, stress leads to a dangerous cycle at the planetary scale, too: as Earth becomes “inflamed”, living conditions can worsen for many people. Extremely hot temperatures or flooding can cause food shortages, and natural disasters can cause deaths and destruction—all of which increase peoples' stress even further. If scientists, government leaders, and lawmakers suffer from chronic, stress-related inflammation, they may not be as good at solving our planet-wide problems, and Earth's “inflammation” might continue to worsen.

BREAKING THE CYCLE

So now you know that long-term stress causes chronic inflammation, which can decrease important cognitive functions like memory, clear thinking, and good decision making. Stress that begins in individuals can spread across whole societies, either from person to person or over the internet. Stressed societies can then make bad decisions that lead to more stress—eventually affecting the entire planet. When Earth itself is “stressed out” by human actions like pollution and greenhouse gas release, the planet’s “inflammation” can make conditions even worse for everyone, further increasing individual stress and making it harder for us to find solutions to problems like climate change. So, how do we stop this dangerous cycle?

The most important thing *you* can do to help break the cycle of stress is to limit the amount of stress in your own life (Figure 3). Of course, there will always be stressful things that you cannot prevent, like schoolwork, difficult family situations, or poverty, for example. But there *are* things you can do to keep your overall stress level low, so that you can better manage the unavoidable stresses. For example, you can keep your body healthy by getting enough sleep, eating nutritious foods, and drinking plenty of water. Exercise is a great way to reduce stress and improve mood, as is spending time with animals if you enjoy them and can do so. Since screen time, especially social media, can contribute to stress, take breaks, and spend time with friends or doing other enjoyable activities. Relaxation techniques like deep breathing and visualizing peaceful scenes can also reduce stress. Finally, talking about your feelings with someone you trust can help, too. Just think:

Figure 3

There are many things that you can do in your own life to reduce the amount of stress you feel. When individuals feel less stress, this can help to break the stress cycle by stopping the spread of stress from ourselves to others, as shown in the left corner of Figure 2.

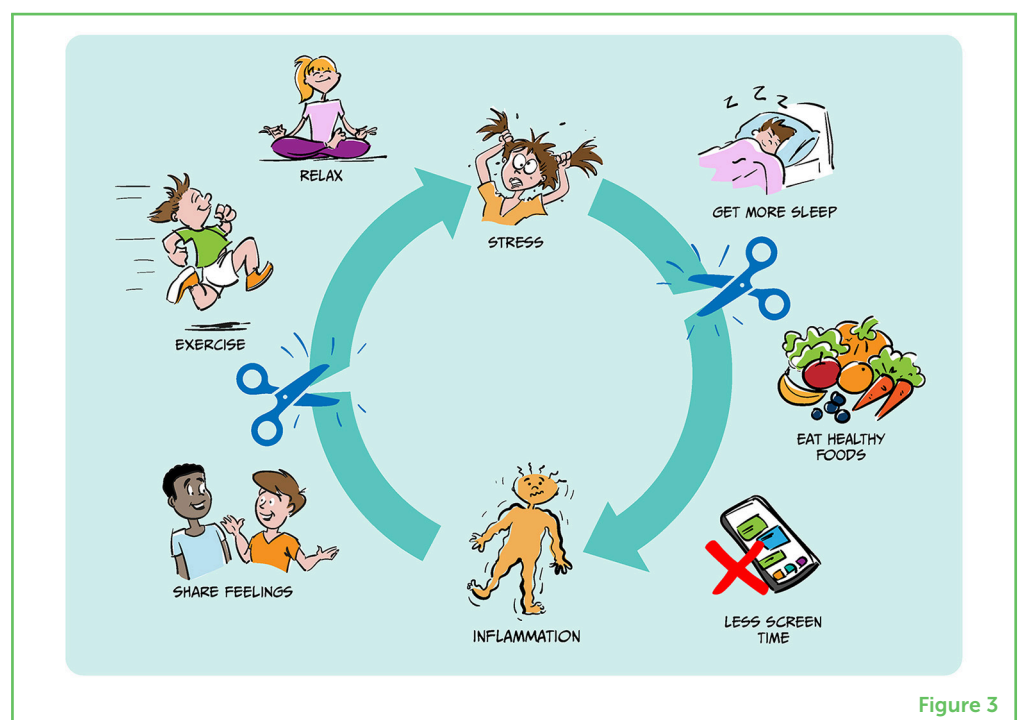


Figure 3

if *everyone* did some of these small things to reduce stress, the overall level of stress in society would go down—and that might even help to make the *entire planet* a healthier, happier place! Breaking the stress cycle starts with you!

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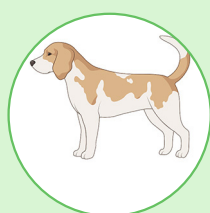
YOUNG REVIEWERS

AIDYN, AGE: 14

My name is Aidyn and I am 14 years old. I have a passion for computer science. I enjoy coding in Python, Java, JavaScript, and C#. I also spend my time creating and learning about AI. In addition to coding, I enjoy playing chess, reading, drawing, and playing sports such as soccer, tennis, and basketball. I also love to play many different types of board games.

HENRY, AGE: 15

I am Henry and I am a high school student in the U.K. Currently I am studying Biology, Chemistry, Philosophy, and Russian at A-Level.





MASON, AGE: 11

Hi! I am Mason and I am 11 years old. I love science and animals in nature, especially zoology and birdwatching. I also enjoy origami and landscape painting. Additionally, I play piano, cello, and taiko. In my free time, I can often be found reading or cooking. I really enjoyed working on this project.

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Dr. Yoram Vodovotz is currently a Professor of Surgery, Immunology, Computational and Systems Biology, Bioengineering, Clinical and Translational Science, and Communication Science and Disorders at the University of Pittsburgh School of Medicine. He is also the Field Chief Editor of *Frontiers in Systems Biology*. He has been interested in biology, computers, and math since he was young, and so his group studies the inflammatory response by measuring many of the molecules that are involved, combined with mathematical modeling. *vodovotzy@upmc.edu



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Julia Arciero is an Associate Professor of Applied Mathematics at Indiana University-Purdue University Indianapolis. Although she never wanted to be a medical doctor, she has always been interested in medicine, and so she loves being a math biologist because she gets to use mathematical equations to help understand various components of medicine and disease. In particular, she has built math models of blood flow and of the immune system and she works with medical doctors and other scientists to understand medical conditions including glaucoma, heart transplants, peripheral arterial disease, and sepsis.



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David L. Katz, MD, MPH is a specialist in internal medicine and preventive medicine with specific expertise in chronic disease prevention, health promotion, lifestyle medicine, and nutrition. He was the founding director of Yale University's Prevention Research Center, past president of the American College of Lifestyle Medicine, founder of the non-profit True Health Initiative, and founder/CEO of Diet ID, Inc. Dr. Katz directs his many efforts in public health medicine to the goal of healthy, vital people on a healthy, vital planet.