Help with Homeostasis

Have you ever wondered how your body keeps itself functioning properly in so many different situations? When you walk across campus on a freezing cold day, why doesn't your body temperature drop so low that you literally freeze to death? When you see someone you're in love with walk by, and your heart starts pounding, why don't you have a heart attack? Why is it that when you cut yourself shaving, you don't bleed to death?

The reason is that the body responds to the signals it receives from the outside world, and signals from the body itself, and adjusts itself to maintain a stable internal environment. We call this ability to maintain a stable environment homeostasis. We call the adjustments the body makes to maintain stability homeostatic regulation. Without this ability to adapt to change, we would die very quickly.

In this section, we are going to talk about some of the different ways that homeostasis can be achieved, and the direct relationship between problems with homeostasis and disease. We'll break the discussion into four parts: First we'll talk more about what homeostasis is. Then we'll discuss the mechanisms involved in maintaining homeostasis. Third, we'll go over the feedback mechanisms that regulate homeostatic responses. Finally, we'll talk about the relationship between homeostatic imbalance and disease and the effect of aging on the body's ability to maintain homeostasis. Let's start with a description of what homeostasis is.

Homeostasis literally means “Everything stays the same.” In terms of the human body, it means maintaining normal function in all of your body systems. Your body is made up of 100 trillion cells all trying to do the same thing – keep everything balanced. This means that your internal conditions vary within narrow ranges that are acceptable for normal function. These ranges are important because they allow your body to adapt to the incoming signals and changing conditions in order to maintain homeostasis.

What is so impressive about homeostasis is that it occurs at the cellular level. This means that the cells play an enormous role in managing processes and events that affect tissues, organs, and the whole body. Let's look at the example of a bad sunburn. You feel the pain and discomfort. But by the time you feel it, your body is already busy at the cellular level getting rid of the dead, damaged cells. And at the molecular level it's busy repairing the UV damage to the DNA in your cells. If it didn't do this, you could get skin cancer after the first sunburn and you would be a walking tumor. But we aren't walking tumors because cellular homeostasis has consequences at the tissue level by correcting problems that occur, helping maintain health at the tissue, organ, and whole body level.

To maintain normal function, your body compromises. As I mentioned earlier, that's because homeostasis involves ranges of acceptable function and some of these ranges are gray areas. Take blood pressure, for example. Generally, we think of 120 over 80 as the norm for blood pressure. But there are no hard and fast figures that represent one single normal blood pressure. Anywhere between 110 over 70 and 125 over 80 is considered to be a normal blood pressure range for an adult. But someone with naturally low blood pressure may typically have a blood pressure of about 100 over 60. An older person might have a blood pressure of 140 over 90, which would be normal for a senior citizen but high for younger adults. So the bottom line is that homeostasis involves acceptable ranges of physiologic function. This is simply because everybody is different.

Now all the body systems have one thing in common with respect to these acceptable ranges of function. These ranges are dynamic. They are always changing to adjust back to homeostasis. This is called dynamic equilibrium. Think about body temperature, for example. In order for your body to function normally, your core body temperature must stay close to 37 degrees Celsius. In order to maintain this consistent temperature, your body makes continuous adjustments. When you are hot, you sweat. By dispersing the sweat along the skin surface, the body ensures that external conditions cool the blood and reduce the core body temperature. In contrast, if you go out in the cold, your body responds to the external environment and protects the body's core temperature by shivering to generate heat. In this way, the body's systems maintain homeostasis of your core body temperature.

The reason your body can adjust to temperature changes through dynamic equilibrium is because there is a set point for your body temperature. This set point is, of course, 37 degrees Celsius. If the temperature deviates dramatically from this set point, your homeostatic adjustments kick in to either reduce your body temperature--by sweating for example--or increase your body temperature by shivering. Without set points, your body wouldn't know whether the conditions were in the homeostatic range. Say you work out at the gym and get your heart rate up. If your body didn't know that your set point for a resting heart rate was seventy-two beats per minute, your heart rate would keep getting faster and faster until a blood vessel burst or your heart gave out.

Now let's turn to our second topic, how the body “knows;” how to respond to different stimuli. What are the components involved in homeostatic regulation? These components are: the Receptor; the Control Center; and the Effector. Let's discuss the receptor first.

Everything that goes on in the human body has to be regulated. Everything from secreting saliva when you eat bread to giving birth to a baby requires homeostatic control. This process relies first of all on receptors.

The receptor, as the name implies, is receiving information. Receptors are sensors that monitor changes in both the internal environment and the external environment. They could be neural receptors on the skin, endocrine receptors in the blood, or the muscular signals your body generates to tell you it is time to go to the bathroom. Receptors don't make judgments about how we should respond. They only relay the information to a control center in the form of signals. The control center is the component in homeostatic regulation that decides what the response should be. In the case of your body, the control center is the brain and spinal cord. They comprise your central nervous system. Depending upon the strength of the incoming signal, the control center determines a course of action. How this course of action is executed is a function of the effectors. Let's discuss them next.

Effectors are the cells, tissues, and organs that generate your body's response to change. In other words, they do the work of making something happen. This response is based on the information supplied by the receptor and the impression it gives the control center. In your body, there are only two types of effector cells. They are either muscle cells or gland cells. Your muscle cells can either relax or contact. Your gland cells can either secrete their products or not.

The complexity of their responses is a dynamic equilibrium and is a result of all the different factors that can be included in the response to get back to the set point. For example, let's compare two situations: what happens when you want to ask someone you just met on a date versus what happens when you make plans to go to the movies with your best friend. In the first case, you will probably experience anxiety. Your mouth will get dry (lack of salivary gland secretions), your palms will get sweaty (due to sweat gland secretions), your heart will beat faster, your pupils will dilate, and your breathing will get faster, all due to different muscle contractions. Put these all together and you have a complex response to a feeling of anxiety – all because you want to ask someone on a date and you are worried about the outcome. In contrast, when you invite your best friend to the movies, you are probably not feeling any anxiety, so none of these physiological events will occur.

Now let's turn to our third topic, the ways in which your body maintains its stable internal environment. Homeostatic regulation controls and coordinates all these simultaneous responses. The response relies on feedback loops. There are two types of feedback loops: negative feedback and positive feedback. Most of the homeostatic responses in your body involve negative feedback loops. Just like the name implies, negative feedback loops function to negate or minimize change. In contrast, positive feedback loops are generated in response to infrequent or extreme events. So while negative feedback loops work to minimize change, positive feedback loops increase change.

Let's first talk about the way negative feedback works using an example: It is a Saturday afternoon and you are shopping in the mall. It is around lunch time and you feel hungry. As you get closer to the food court, you smell the pizza, hamburgers, and baked goods and your mouth starts to water. The scent of the food sends a signal to your digestive system to get ready for food. You eat a hamburger, fries, and a drink. Since you started to salivate before you got the food, there are plenty of enzymes to break down the bread and start on the French fries while they are still in your mouth. As you eat, the glands in your mouth continue to secrete more enzymes until you finish chewing and swallow.

Once you're done, your body stops producing enzymes in your mouth so that you don't drool everywhere. That is because your body sends a signal to those glands indicating that you are finished eating. As a result, production and secretion of the saliva stops. This is negative feedback. In a nutshell, it works like this: if you get a signal to respond (in this case with saliva) your body will continue to respond until it receives a second signal that the response was successful. Then it stops. So when the signal comes in that you are full or done, the response is to shut it off – this is a negative response. It is a little like pushing down on the brake in a car. As the signal occurs, it causes the car to slow down until it stops.

As we said earlier, most homeostatic responses are negative feedback loops. Negative feedback minimizes the amount the body veers away from the steady state. It stops a process so that the body can reach equilibrium again. Another example of negative feedback is how your body detects changes in temperature internally and how it deals with the problem. If you are working out, your muscles generate heat. That raises your body temperature past the set point of 37°C. So it signals your glands to start producing sweat, which is secreted onto your skin surface. This helps to radiate heat and as the sweat evaporates, it cools you off.

Positive feedback is the opposite kind of response. Unlike negative feedback, positive feedback keeps building upon the initial response to the stimulus. It makes a response continue, growing ever more intense until finally a negative feedback signal causes the response to shut off. Positive feedback loops typically occur when the body is facing a dangerous or stressful situation. Hopefully, this won't happen often. Blood clotting is a common positive feedback response. When you get wounded, your blood vessels and the tissues in the wounded area send out signals for help. In response to this loss of blood, your body sends platelets to the wound. The platelets stick to the blood vessel wall, trying to stop the loss of more blood. These platelets release chemicals that will attract more platelets. This keeps going until a clot is formed and the bleeding stops. This causes the feedback to stop because no more chemical signals are being sent.

Another, more dramatic, example of positive feedback is childbirth. When a woman is in labor, a positive feedback loop increases her body's response until birth occurs. As labor starts, the uterus receives a signal to contract. That signal continues, causing the uterus to contract and making the contractions get stronger and stronger, until the baby emerges.

The ever-increasing contractions of childbirth are a positive feedback response, because it keeps going and compounding. With positive feedback control it takes a dramatic change to signal the response to stop. It stops when a major event happens, like the birth of the baby. In the case of blood clotting, the positive feedback loops ends when a blood clot forms. You can think of positive feedback as being like pushing on the accelerator of a car. The car keeps speeding up faster and faster. Then if you slam on the brakes or the car hits a wall, negative feedback occurs and the car stops.

Negative feedback loops maintain homeostasis by reining in the body's response. We typically find it in long-term operations, such as keeping your blood sugar levels within normal limits. Positive feedback involves quick, dramatic, decisive responses, usually to a situation that is perceived as dangerous.

Now let's turn to our final topic, homeostasis and disease. Most diseases cause a homeostatic imbalance. Infections cause fever, swelling, inflammation, and sometimes nausea. The symptoms are a combination of the lack of homeostasis and your body's efforts to re-establish homeostasis. For example, let's say you contract pleurisy, a viral infection that causes an imbalance at the cell and tissue level through the toxic secretions from the virus. So, to try to re-establish homeostasis, your body initiates an immune response. In this case, the immune response is inflammation of the membranes around the lungs, a localized increase in temperature that helps kill the virus and the virally infected cells. The membranes around the lungs are normally smooth and well-lubricated. But when they become inflamed, it is very painful because the membranes feel like sandpaper rubbing together inside your chest. So, it's actually the inflammation that is causing the painful friction. This friction causes a build-up of fluid that results in problems breathing.

As this example demonstrates, there is a delicate balance between homeostatic regulation and disease. Sometimes, in order to re-establish homeostasis, your body creates problems that compound the condition. That is where medical treatments can be most helpful. They aid your body in returning to homeostasis by trying to directly attack the cause of the problem, like antibiotics for bacterial infections or vaccines for viruses.

As we age, it becomes more difficult to re-establish homeostasis. One example of this is thermoregulation. Body fat serves as an insulator. But as people grow old, they lose body fat. Also, their skin becomes thinner and they can't sweat as efficiently. So, older people have a lot of trouble regulating body heat. In hot weather, they can't dissipate increased body heat because they don't sweat well. In winter, their thin skin and lack of insulating body fat makes it hard to retain body heat.

Sometimes homeostatic imbalance occurs when the negative feedback mechanisms don't work correctly. One example of this is menopause. In menopausal women, the ovaries cease to work and production of the hormones estrogen and progesterone shuts down. Estrogen and progesterone operate via the brain's hypothalamus in a negative feedback cycle, controlling the regular cycle of the female reproductive system. Once this system shuts down, there is no negative feedback to the hypothalamus, the control center for the endocrine system. So the body keeps pumping out hormones trying to initiate estrogen and progesterone production. High levels of these hormones are a clinical sign of menopause.

So as you get older, your control systems become less efficient and your internal operating systems become less and less stable. That is why as you age, you become more prone to illness and disease. You could say that the changes associated with age are a result of the slow breakdown of homeostasis.

We've now defined homeostasis and discussed the mechanisms involved in maintaining homeostasis. We've also covered the mechanisms that regulate homeostatic responses. Lastly, we talked about the relationship between homeostatic imbalance and disease, and the effect of aging on homeostasis.
