A Rollercoaster of Emotions

Dr. Magdelana Markowska from the University of Warsaw's Faculty of Biology explains where emotions come from and why negative emotions are not the only ones that are problematic for the body.

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Fear causes both animals and people to freeze or respond with avoidance. Triggering the fight-or-flight response requires stronger negative emotions.

ACADEMIA: **Is it possible to provide an unambiguous definition of what emotions are?**
MAGDALENA MARKOWSKA: There is no single definition. Emotions are studied by biologists, psychologists, and sociologists. Each of these branches looks at this phenomenon from a somewhat different scientific perspective. I myself would describe emotions as a set of behaviors and feelings that take place as a result of many physiological responses occurring in the body in response to stimuli. The way emotions are understood in respect to humans is reflected in a division into good emotions, or ones that are related to pleasure, vs. bad emotions, which cause unpleasant feelings. A neurobiologist would say that emotions trigger responses that may be aversive, when we avoid the related stimulus, or appetitive, when we desire the stimulus. From the biological point of view, however, anxiety and fear are also positive emotions, because they allow for adaptation to stressful situations or escape from danger. In a sense, the level of intensity of emotions makes it possible to determine the magnitude of the danger. If what an animal feels is just anxiety, it becomes more cautious and starts looking around carefully. A stronger response, fear, will cause the animal to freeze, which is a typical defensive response in many species, or to respond with avoidance. Finally, the most powerful negative emotions trigger the "fight-or-flight" response. Moreover, animals can learn that an unpleasant stimulus such as noise doesn't necessarily mean that they should take flight in panic, because it doesn't always mean an actual threat.

The notions of anxiety, fear, and fright are a convenient model, though not exactly an easy for studying the neuronal mechanisms of emotions that neurobiologists use in their work. These emotions are treated as an important field of research, because they can accompany mental disorders, addictions, and nervous system diseases.

What physiological processes are associated with emotions?
Initially, all emotions are associated with a response from the nervous system. The brain integrates information about a stimulus that carries significance from the perspective of biology, and an adequate biological response is generated. It is commonly believed that this integration takes place in the hypothalamus, which controls autonomic and neurohormonal activity in the body. An important role is played by the amygdala, which determines the biological significance of a stimulus – in other words, it starts an emotional response. Generally speaking, the cortical and subcortical structures of the limbic system play a fundamental role in triggering emotions and regulating associated behaviors.

A response from the nervous system, increased activity of the sympathetic nervous system, the secretion of noradrenaline in nerve endings and adrenaline in the adrenal medulla trigger typical changes in the cardiovascular system, the respiratory system, and skeletal muscles, which mobilize the body to take flight, to fight, or to freeze. When we say that someone is "pale with fear," that is because such mobilization diverts the blood away from the skin, the digestive system, and the excretory system into the brain and skeletal muscles to enable faster contractions. Also, the regulation of the heart changes: the heart rate increases, so the blood can be diverted more effectively into the parts of the body that need it. At the metabolic level, glycogen, which is stored in the liver as an energy reserve, is broken down into glucose, which can reach the brain and muscles. Also, the body starts breaking down fats and proteins. If the danger is brief, the stress response causes the body to mobilize, and this is a good thing.

If this response is something good, why is stress believed to have devastating effects on the body?
In nature, intensive threats seldom continue for longer periods. For example, when a predator is nearing, an animal needs to flee. Once the predator hunts down a different target, however, the danger is no longer present. Humans, in turn, are often exposed to chronic stress, which forces their bodies into constant mobilization. Maintaining this state for a longer period has a devastating effect on the body. In response to stress, the blood pressure rises, which increases whole-body efficiency. If it continues for a long time, however, it may lead to hypertension. Stress activates the hypothalamic-pituitary-adrenal axis, or the HPA axis. As a result of this, the adrenal cortex starts producing hormones (glucocorticoids and mineralocorticoids), whose task is to sustain mobilization. In chronic stress situations, the activation of these hormones leads to blood glucose levels being consistently elevated. In the long run, this may lead to diabetes. Mineralocorticoids, in turn, cause the reabsorption of sodium ions

and water from the primary urine, so blood volume increases and so does blood pressure.

This looks like a vicious circle. Individuals who grapple with chronic stress get even more stressed, because their health is deteriorating.
Yes, and this is very exhausting. If the levels of glucocorticoids are elevated for a long time, the immune system weakens, so those under a lot of stress are more prone to infections. Meanwhile, small doses of glucocorticoids stimulate the immune system. Again, short-term stress causes the body to mobilize quickly and fight pathogens, whereas long-term stress weakens it.

Immunosuppression caused by high levels of glucocorticoids can be explained physiologically. When the body has to deal with an injury or invading pathogens, this triggers an immune response, which causes inflammation and a rise in the body temperature. In order for this response not to spin out of control, stress in the form of inflammation and fever activates the HPA axis, glucocorticoids are secreted, and the immune response is ultimately alleviated. Again, this makes sense for brief dangers, but works to our disadvantage when stress persists for a long time.

How about the physiology of positive emotions? Do they have an equally devastating effect on the body?
Analyzing positive emotions is more difficult than studying aversive emotions yet by no means less important. A loss of the ability to feel pleasure, referred to as anhedonia, is associated with depressive disorders. For that reason, exploring the mechanisms by which positive emotions and, by the same token, their disorders emerge may have clinical significance. Pleasurable experiences are associated with the release of catecholamines in the brain, chiefly dopamine. Catecholamines activate relevant structures responsible for the feeling of pleasure. There is an entire network of neurons in the brain that are activated in response to pleasant stimuli – they form the so-called reward system. Here, the biological mechanism may become distorted as well. If a substance activates this part of the brain effectively, you can easily become addicted. This is especially important when natural positive stimuli no longer cause pleasure, for example when the release of dopamine becomes impaired. In such situations, people start to look for replacements that enhance the feeling of pleasure. These include psychoactive substances, drugs, alcohol. The growing problem posed by addictions on the one hand and the prevalence of depressive disorders on the other one are the reasons behind intensive studies on brain structures responsible for positive emotions.

Getting back to stress, I think it's worth mentioning that chronic stress may lead to emotional disorders that can result in depression. The mechanisms governing this phenomenon are not one-sided and include both glucocorticoids and cytokines, or the chemical messengers produced by immune cells. All this is reflected in the ancient maxim *Mens sana in corpore sano*, a sound mind in a sound body.

What physiological responses are associated with long-term positive emotions, such as the bond between mother and child or the relations between family members?
That is a very interesting question. Studies show that the substances involved in these responses include oxytocin and prolactin. Oxytocin is synthesized in the hypothalamus, transported to the pituitary gland, where it is released into the bloodstream. Elevated oxytocin levels are observed before childbirth, because this hormone strengthens contractions, and during the postpartum period. Secretion of oxytocin is activated by the parasympathetic nervous system, which is associated with the feeling of relaxation. It is involved in the shaping of not only maternal but also social behaviors. In turn, prolactin is synthesized in the pituitary gland. Its role in mammals involves stimulating lactation, among other things. For that matter, this hormone has many functions. Both prolactin and oxytocin are related to the dopaminergic system in the brain, which I mentioned when I was talking about positive emotions. Interestingly, this system also begins to malfunction under chronic stress. For that reason, animals under stress often reject their offspring. In addition, decreased oxytocin levels may be conducive to depression.

> In biology, **emotions are defined as a set of behaviors and feelings** that take place as a result of numerous physiological responses occurring in the body in response to stimuli.

It's also worth adding that the brains of animals are characterized by the presence of neurosteroids, the derivatives of cholesterol whose structure is similar to that of sex hormones. In birds, they mediate in interactions between males and females, in particular by affecting the song of males during the breeding season. In mammals, they play a role in countering stress in the brain, mood disorders, and depression. Maybe they support long-term positive emotions, too?

Interview by **Agnieszka Kloch**
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