Introduction

You've likely heard the term *homeostasis* in a biology-related class before: the body's ability to maintain stable internal environmental systems despite external changes.

However, have you heard the term *allostasis* or the body's ability to adjust the internal environmental systems to meet external stressors? Are you familiar with the term *allostatic load* or the price we pay to change our internal environmental systems to meet external stressors, a price that increases over time?

Homeostasis vs Allostasis

Homeostasis was a concept that came into being as the system underlying physiological regulation slightly before 1930, and it has dominated the medical establishment's view for nearly a century. Homeostasis is a robust model oriented around maintaining critical bodily functions with efficiency to minimize energy costs using reflexive negative feedback loops that occur after a change to the regulated variable, such as blood glucose, body temperature, or pH balance.[1] A core principle was that two opposing effectors—which are components that control the regulated variables in different directions, like defences for conserving heat and defenses for dissipating heat—will not be active above baseline levels simultaneously because that is energy inefficient; consider the merits of running both the heater and the air conditioner at the same time, using double the power and adding wear and tear to both pieces of machinery.[1]

However, over the decades, research has shown that opposing effectors *can and do* activate simultaneously in ways that violate the principles of homeostasis.[1] This required adjustments to the model of homeostasis, and this is where allostasis enters the scene. While homeostasis maintains key body systems in an energy efficient way, allostasis occurs when maintaining key body systems comes at the cost of efficiency and as a result there is a significant physiological cost to keep that balance; this costly physiological burden of inefficiency is called allostatic load.[1]

Allostasis incorporates anticipation, learning, and adjusting body systems in advance of changes, especially psychosocial stressors, which the homeostatic model did not include, and involves the ability to adjust regulatory variables away from the baseline for a sustained time, whereas in homeostasis variables are expected to be much more stable and return to the set point or balance point of where the variable rests when its effectors are operating at minimal, baseline activity.[1] Researchers propose that allostasis is "a dysregulatory or disordered form of physiological regulation that involves effector loops that over-respond in magnitude or duration and/or that compete concurrently with other effectors" that demonstrates a "fragility" in the otherwise robust homeostatic regulatory system which occurs due to evolutionary tinkering adding increased system complexity to cope with naturalistic disturbances and comes with an equal increase in susceptibility to failure against unusual, unanticipated situations, for which modern society increasingly offers circumstances that have not existed previously in an evolutionary sense and which the homeostatic system is not equipped to handle.[1]

Allostasis, Allostatic Load, and Allostatic Overload

Allostasis is the body's ability to adapt to stressors in the environment and respond through one or multiple different feedback systems to maintain homeostasis and keep the body in a physiologically balanced state.[2, 3] It is the ability to achieve "stability through change."[4, 5] In ideal circumstances, the stress response will be activated occasionally to address a stressor, then there will be a period of recovery to return to baseline; the stress response will not need to be utilized too frequently or too long, and the individual will remain flexible and resilient when adaptation is required. Life is not always an ideal scenario.

Allostatic load is the result of too much stress or an ineffective stress response, such as a repeated, prolonged, inadequate, or lack of response.[3] It is the cumulative "wear and tear" of chronic stress over a lifetime, and it comes with negative health consequences, such as accelerated aging and increased disease outcomes.[2] It is "the price of adaption."[5] The short-term positives to adapt to handle the stressor in the moment can come with long-term drawbacks and physiological dysregulation over time. Allostatic load is not only the result of major life events, but also the sum of daily living as well as genetics, individual habits around factors like diet, exercise, and substance use, and developmental experiences that set patterns of behavior and physiology for a lifetime.[6] Allostatic load is also affected by factors such as an individual's gender, race, ethnicity, socioeconomic status, workplace, lifestyle, social relationships, and social dominance hierarchies.[7, 6, 8]

Psychosocial stress in the form of competitive interactions between individuals and the formation of dominance hierarchies are some formidable stressors in the animal kingdom, particularly for humans; the social order creates a gradient of health outcomes, with those at the lower end of the scale being more severely affected, though those competing for more dominant positions also bear a higher allostatic load.[4] Those who have to cope with more stressors with limited resources and less social support have an increased burden on their physiological systems, which leads to worse health outcomes down the line due to the increased allostatic load. The effects of having few resources appear to be cumulative, with those of lower socioeconomic status having greater strain being put on the body through environmental, psychological, and behavioral characteristics and experiences that are linked to biological patterns of higher risk, including elevated stress hormones, poorer metabolic profiles, and increased cardiovascular disease risk.[8] This accumulation of risk due to low socioeconomic status over a lifetime would have the greatest impact in later adulthood, with those who experience it persistently expected to fare the worst while those who experience upward mobility may mitigate some of the effects, though early life socioeconomic adversity may calibrate developing systems in a permanent way.[8]

If the stressors or challenges outstrip a person's ability to cope with the circumstances, then allostatic overload occurs.[9, 4] In allostatic overload, the stress response system is constantly activated and no longer able to adapt adequately to the stressor; it serves no useful purpose and sharply increases detrimental health outcomes by causing chronic activation of the pro-immune and neuroendocrine system, which can dysregulate downstream systems, such as the cardiovascular, metabolic, and acquired/adaptive immune systems.[4] Allostatic overload is the result of chronic, repeated exposure to stressors, often of a psychosocial nature.[10]

Regulation of Body Systems, Emotions, and the Brain

The brain assesses whether stimuli is a stressor and mounts the adaptive stress response to address the issue; this will activate the HPA axis and the sympathetic nervous system, so they can release glucocorticoids and catecholamines and the body can prepare to fight or flee.[3] While the brain assesses stress and begins the response to it, it is also altered by that same prolonged stress in order to maintain stability with the other dysregulated systems in the body.

Over time, the chronic stress of allostatic load affects multiple brain areas in structure and function, particularly the prefrontal cortex, the hippocampus, and the amygdala;[3] these areas are responsible for, respectively: executive functioning, emotion regulation, social cognition, personality, memory processing, and goal-directed behavior; memory formation, spatial navigation, emotional processing, social behavior, and flexible thinking; and emotional processing, particularly fear and aggression and recognizing threats, social cognition, and decision making.

It is thought these brain changes primarily happen through four mechanisms: neurodegenerations, vascular changes, inflammation, and oxidative stress.[3] A person's "brain reserve"—or their ability to withstand damage and still function due to structural capacity to tolerate harm before cognitive decline becomes noticeable—may offer some protection against these changes; an individual with low brain reserve, such as an elderly person or someone with thinner cortical areas due to a neurological condition, would be more likely to experience the effects of allostatic load in the brain tissue, as they have less structural buffer.[3]

Allostatic load and biological dysregulation—particularly in the immune, metabolic, and parasympathetic systems—have been associated with poorer mental health outcomes.[11] In this study, participants were put into four groups based on their biomarkers: low levels of dysregulation; metabolic and immune dysregulation; parasympathetic systems dysregulation; and sympathomedullary pathway dysregulation. Individuals who met the criteria for depression using the CES-D screening tool had an 80% greater risk of being in the metabolic-inflammatory group and a 71% greater risk of being in the parasympathetic dysregulation group than being in the low dysregulation control group.[11] Individuals who met the criteria for anxiety using the MASQ-GDD screening tool had a 78% greater risk of being in the metabolic-inflammatory group. Individuals who met the CES-D depression screening, regardless of their group, had a 13% higher cumulative allostatic load; those who met the MASQ anxiety screening had a 14% higher allostatic load, and those who met the anhedonia screening had a 21% higher allostatic load.[11]

While emerging work appears to show that emotion regulation strategies (active coping, anger expression, withdrawal-avoidance) in general do not impact allostatic load, anger-related strategies and how often different strategies were used did appear to be related.[12] Coping is "cognitive and behavioral efforts to master, reduce, or tolerate the internal and/or external demands," and different strategies are often described as adaptive (actively coping) or maladaptive (prevent one from adapting in a healthy way) due to their health outcomes. Emotion regulation is how individuals experience and express their emotions, and these strategies are also often separated into adaptive and maladaptive approaches. Researchers posit that both coping and emotion regulation may be adaptive or maladaptive depending on the context, and so best use of regulation strategy is instead characterized by flexibility and being able to choose the appropriate regulation strategy for the current context.[12]

A great deal of research has focused on anger-regulation specifically, especially as aggressive/disruptive anger has been related to higher cancer and cardiovascular risks. Anger expression (communicating the emotion to others) was associated with lower allostatic load while anger control (managing the emotion internally) was associated with higher allostatic load, particularly among more educated adults who had attended at least some college.[12] Adults who had few coping and regulation strategies (less flexibility, applying the same approach to multiple contexts) displayed lower allostatic load than those with multiple strategies, which surprised the researchers; however, individuals with fewer strategies were also associated with a shorter lifespan, so limited emotion regulation approaches may offer a protective factor but only to a certain point.[12]

Children and ACEs

Children are particularly vulnerable to the effects of stressful experiences, as their highly plastic nervous systems are undergoing key developmental periods that are experience-dependent, time-sensitive, and will impact them for a lifetime.[4, 10] Adverse Childhood Experiences (ACEs) have been tied to poorer health outcomes and increased allostatic loads in adulthood; exposure to one ACE doubles the likelihood of poorer health outcomes as an adult, and exposure to four or more ACEs triples it.[4] Chronic or repeated toxic stress harms the developing brain in a permanent way, reducing hippocampal volume and altering the prefrontal cortex and the amygdala, as well as the endocrine, immune, and nervous systems more broadly, including increased activation of the HPA axis and higher inflammation levels.[4, 10]

Children are reliant on their caregivers to meet their physical and emotional needs and provide an environment and experiences that promote flexibility and adaptability rather than rigidity and maladaptability.[4] Early interventions for at-risk individuals may be able to reduce their allostatic load and its detrimental health burden, particularly as the timing, duration, type, and severity of the ACEs experienced likely play a significant role in the overall wear and tear cumulation.[4]

Adaptive Calibration Model

The Adaptive Calibration Model expands further on the risk-benefit of repeated essential survival stress responses in the moment and their long-term detriments to health and wellness.[13] It posits that, during the course of human development and particularly during key periods like childhood, individuals respond to their environmental stimuli in an adaptive way that promotes their survival in the moment, and that these "decision nodes" each further calibrate the individual's nervous system to respond in a particular way when faced with threats and stressors in the future, resulting in differences in how information is filtered and embedded, how resources are allocated, how open the individual is to environmental inputs, and how they regulate strategies to meet their environment.[13] Each "decision node" during a lifetime sets the stage for the next decision node, creating a chain that becomes how the individual's stress response system allocates resources and sets regulatory parameters.[13]

There are four main responsivity patterns in the Adaptive Calibration Model: Sensitive, with high baseline activity and high reactivity with a preference for developing in conditions of protected, low environmental stress, with parasympathetic-dominance, high vagal tone, and high responsivity to active social engagement; Buffered, with moderate baseline activity and moderate reactivity with preference for developing in conditions of low-to-moderate environmental stress, with autonomic functions tilted towards parasympathetic activity and the benefits of active social engagement; Vigilant, with high baseline activity and high reactivity with a preference for developing in conditions of high environmental stress, with sympathetic-dominance, low parasympathetic tone, and social engagement often viewed as threatening or competitive rather than supportive; and Unemotional, with low baseline activity and low reactivity with a preference for developing in conditions of high environmental stress, with sympathetic activation augmented by parasympathetic activation to remain calm during an aggressive confrontation and significantly blunted social engagement.[14]

Outcomes that are considered biologically maladaptive could be an adaptive response to a stressful environment, particularly if the person is highly responsive to stress, often the 'sensitive' or 'vigilant' response patterns.[3] Historically, many stressors were survival threats that required an immediate mobilization response to run or attack and were short-term, then the person could return to homeostatic baseline after the survival threat had passed and their stress hormones could decrease. In the modern world, stress is often chronic and the stress response begins before the stressor arrives, leading to prolonged activation of the HPA and sympathetic systems.[3]

In Relationships and Society

While research into allostatic load has primarily oriented around how individual biological systems adjust, cope with, and recover from stress, some researchers propose that these same principles work on a larger scale in dyadic relationships like couples and parent-child, small groups like families, workplaces, friend groups, and large groups like online social networks, social gatherings, and society more broadly.[15] Allostasis is a regulatory process that arises in response to environmental demands, usually of a psychosocial nature, and allostatic load is marked by decreased flexibility in the stress response and impaired recovery, increasing dysfunction. Social allostasis is a physiological entangling with several individuals to maintain a low intensity baseline within a group and allow each individual to conserve more of their energy than if they were acting alone by being able to distribute the load of responding to the environment among more individuals and more efficiently accomplish shared goals through cooperation.[15]

Evidence has demonstrated that groups of people can coordinate emotional and physiological states and have a tendency to converge around a particular range of low intensity, calm, neutral-to-positive emotional and physical arousal even without conscious awareness that they are attuning to those around them, sharing the regulatory burden across many individuals, becoming an interdependent system rather than remaining individual units, and creating group stress patterns that can stay flexible and adaptable or become rigid and maladaptive.[15] In this way, relationships can offer both immense protection from stress and be our greatest source of stress, as they can promote both support and conflict while being regulators of physiological arousal; this concept is known as coregulation or codysregulation.[15]

When the group's baseline starts to pull away from that low intensity baseline, regulatory measures are implemented to help bring the dysregulated individual(s) back to the calm, neutral-to-positive state, whether that is a parent soothing an upset child or a friend or partner assisting an agitated adult.[15] Regulation still carries a cost, even though it is less burdensome when distributed among many people rather than all carried by one. Animals use groups to regulate and reduce their own risk and effort through risk distribution, and highly social species including humans also use them for load sharing, based on trust and interdependence, meaning that social allostatic load and the regulation of social relationships is stronger in close bonds rather than loose or distant ones.[15]

High-quality social relationships reduce the cognitive effort of self-regulation in the prefrontal cortex.[15] Brain areas activated during emotional self-regulation are less active when with a loved one than when alone, indicating it requires more mental energy and cognitive resources to regulate emotions by oneself.[15] When contextual demands for energy and resources are high, the prefrontal cortex may not get all the energy it requires to properly carry out its functions, particularly as it requires a great deal of energy to properly do its job. Physical activity leads to reduced resources for the prefrontal cortex, as resources are allocated to areas of the brain responsible for motor functions, coordination, perception, and autonomic activity, which may be even more demanding than the standard individual if you are disabled.[15] Additionally, threats perceived as high-intensity will divert brain resources away from the prefrontal cortex to more basic brain function more critical to survival.[15] Tasks directed by the prefrontal cortex can get left behind when there is only so much brain power to use, and self-regulation is a prefrontal cortex task.

High-quality relationships free up mental energy by reducing the amount of self-regulation required, as the brain assesses that tasks will be easier when undertaken with reliable others.[15] Being in the presence of other people who share one's goals, attention, and trust signals relatively low contextual demand and the conservation of energy resources.[15] However, if the relationship is not reliable and the individual needs to increase energy expenditure on vigilance, problem solving, and reducing ambiguity, this can increase the cognitive load.[15]

Just like individual stress responses, if overutilized, social stress responses can lose flexibility and efficiency in their regulatory function over time due to both internal and external stressors, such as under conditions of chronic stress, conflict, emotional distress, physical or mental illness, threat, food scarcity, poverty, social exclusion, class stratification, violence, income inequality, racial discrimination, natural disasters, and other factors.[15, 16] In all of these situations, higher stress decreased social support and social embeddedness rather than increasing it, suggesting stress can corrode the quality of social support over time and that increased regulatory load on groups—whether dyadic or much larger—can compromise relationship quality and function over time and promote codysregulation away from the low intensity baseline.[15] As allostatic load damages individual physiological systems, social allostatic load damages relationships.

Relationships showing the wear and tear of social allostatic load will be more inflexible, more prone to escalation and overresponding to each other, showing poor recovery and a lack of repair, be marked by withdrawal and disengagement, and the baseline will shift over time to chronic up- or down-regulation with certain states dominating the system in frequency and intensity.[15]

Closing

Allostasis and its cumulative load to adjust to the stressors and demands of the environment are helpful concepts to understand, especially for individuals with stress-mediated health conditions. Allostasis utilizes innate and learned knowledge to act in advance to address and minimize problems, even if that means chronically altering the regulatory variable away from its baseline value to better suit the context, and it often does this in inefficient ways that are extra large, extra long, or have opposing effectors active simultaneously while carrying a pathophysiological burden, which can increase negative health outcomes in the long-term even if it is useful to address environmental demands and psychosocial stress in the short-term.

Thanks for sticking with me, I hope you learned something, and I hope to see you next time.

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