

## **SYSTEM STRESS: CONCEPTUAL FOUNDATIONS FOR UNDERSTANDING SYSTEM-LEVEL DISRUPTION**

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### **Abstract**

Systems science provides powerful tools for analyzing structural interdependence, adaptation, and transformation. Yet it offers comparatively less attention to how systems themselves experience and respond to sustained pressure—and the implications of these responses for long-term functioning. This paper introduces the concept of system stress to describe the condition that arises when the acute or cumulative demands placed on a system exceed its available resources, resulting in observable changes to its structure (form), internal dynamics (functioning), or intended purpose (function). Drawing on critical systems theory, trauma-informed practice, and resilience research, we conceptualize system stress as a multi-scalar, relational, and context-specific phenomenon that shapes both system vulnerability and adaptive capacity. In contrast to models that center individual trauma or dysfunction, system stress emphasizes broader dynamics of feedback, boundary regulation, and subsystem overload. This framing supports a more precise analysis of how systemic distress accumulates, manifests, and transforms over time. The paper defines the attributes of system stress and illustrates its relevance through three domains—COVID-19 response, HIV care ecosystems, and reproductive justice movements. Ultimately, naming and conceptualizing system stress offers a critical tool for scholars and practitioners seeking to surface hidden stressors, assess resilience, and design equity-informed systems change interventions.

### **Keywords**

system stress, resilience, systems theory, trauma-informed practice, complexity science

### **Introduction**

Recent global crises, most notably the COVID-19 pandemic, have illuminated the acute and sustained stressors that impact social systems. The pandemic, for example, placed profound pressure on healthcare systems—generating acute surges in hospitalizations, leading to critical shortages in medical personnel and supplies—while simultaneously destabilizing educational infrastructures, global supply chains, labor markets, and many other interdependent systems. Beyond the pandemic, parallel crises such as heightened climate change impacts and enduring systemic racism further compounded these stressors. Even as the most immediate shocks of COVID-19 begin to subside, residual pressures persist, leaving an enduring impact on our social, economic, political, and ecological systems.

Such system stressors do not merely alter short-term operations; they expose the vulnerability of systems under extreme strain and underscore the urgent need for more nuanced understandings of how systems cope, adapt, and transform under duress. According to Kim (1999), a system can be defined as “any group of interacting, interrelated, or interdependent parts that form a complex and unified whole and that has a specific purpose”. Foster-Fishman (2007) expands this to describe a social system as a “patterned network of relationships constituting a coherent whole” spanning diverse domains—from families and neighborhoods to organizations, school districts, and coalitions (Foster-Fishman et al., 2007). Scholars and practitioners recognize that social systems exist within multifaceted contexts shaped by complex histories, interactions, and adaptive processes. Consequently, systems change literature underscores that sustainable and meaningful change requires interventions tailored to each system’s unique structure and circumstances rather than a one-size-fits-all approach (Godeke & Briaud, 2020).

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While the practice of systems change has produced robust tools and lexicons—drawing from systems science (von Bertalanffy, 1956), complexity theory (Gleick, 1987), trauma-informed practice (SAMHSA, 2014), and community psychology (Bennett et al., 1966) —among others, much of this scholarship has focused on mapping relationships, power dynamics, identifying leverage points, and best practices for designing strategic interventions. Less developed, however, is a consistent conceptual vocabulary for describing the stress of the system itself. Just as stress, trauma, and resilience-focused frameworks have long acknowledged the interplay between stress, trauma, and resilience and adaptation at the individual level (Lazarus & Folkman, 1984; Masten et al., 1990; Rutter, 1987), a comparable language is needed to describe these processes at the systemic scale. Without a shared language to describe system distress—its precursors, manifestations, and implications—practitioners and theorists lack a vital lens for understanding how stressors hurt or catalyze system performance and transformation over time.

System stress is the condition that arises when acute or cumulative demands exceed a system’s available resources or adaptive capacity, resulting in observable changes to its structure (form), internal processes (functioning), or underlying purpose (function).

By incorporating system stress into our theoretical and practical lexicon, we are better equipped to examine the subtle yet significant ways that stress shapes social systems. Ultimately, this vocabulary equips researchers and practitioners to identify system stressors more precisely, examine stress-induced system transformations with greater depth, and design more contextually nuanced, and in some cases, equity-centered interventions. In this way, system stress functions as both a theoretical and applied tool for advancing scholarship and the implementation of systems change.

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### **Introducing System Stress as a Theoretical Construct**

The concept of system stress holds significant value for both theoretical advancement and applied systems change practice. Theoretically, it offers a unifying lens that synthesizes insights across disciplines to explain how stress accumulates, cascades, and alters complex systems. Practically, it provides a conceptual anchor and shared language for more contextually responsive diagnoses of system readiness, vulnerability, and resilience. In doing so, it aligns with recent calls to embed systems change efforts within a deeper understanding of historical inequities, dynamic conditions, and contextual complexity (Godeke & Briaud, 2020; Kania, 2021).

### **Grounding in Individual-Level Stress, Trauma, and Resilience**

Conceptualizations of system stress benefit from grounding in the substantial literature on individual-level stress, trauma, and resilience. At the individual level, stress is defined as a state of distress that arises when perceived or actual demands exceed a person's capacity to cope—particularly under conditions of limited psychosocial, financial, or emotional support (Lazarus & Folkman, 1984; Selye, 1976). The literature has established a nuanced typology that includes acute, episodic-acute, and chronic stress (Segerstrom & Miller, 2004; McEwen & McEwen, 2022), as well as categorizations of positive, tolerable, and toxic stress (Center on the Developing Child at Harvard University, 2023).

Similarly, trauma is commonly understood as an emotional and physiological response to distressing or potentially life-threatening events (SAMHSA, 2022), and it may take acute, chronic, or complex forms (Sharma & Pathak, 2022). The experience and impact of both stress

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and trauma are significantly shaped by an individual's capacity for resilience—broadly defined as a dynamic process of positive adaptation in the face of adversity (Luthar et al., 2000). Extensive research has shown that individual resilience is shaped by a combination of internal protective factors (e.g., temperament, self-regulation) and external support (e.g., social relationships, cultural traditions, supportive communities), which help buffer the effects of adversity across the lifespan. This includes early-life experiences of neglect or abuse (Teicher & Samson, 2016) and stressors in adulthood such as bereavement or divorce (Amato, 2010; Stroebe et al., 2007; Carter & Blanch, 2019; Mofatteh, 2021). Chronic exposure to stress and trauma has been shown to negatively impact not only psychological outcomes (McLaughlin et al., 2019), but also physical health (Danese & McEwen, 2012; Shonkoff et al., 2009), social functioning, and long-term developmental trajectories.

A robust evidence base also supports prevention and intervention strategies at the individual level. Trauma- and stress-informed models—anchored in principles such as safety, trustworthiness, peer support, collaboration, empowerment, and cultural responsiveness—have become recognized as best practice across sectors including healthcare, education, social services, and justice (SAMHSA, 2014; Center for Health Care Strategies, 2021; Government of the United Kingdom, 2022; Trauma and Learning Policy Initiative, 2016). In parallel, strengths-based frameworks and trauma-informed care approaches aim to mitigate the impact of stress and foster resilience at both individual and collective levels (Agency for Healthcare Research and Quality [AHRQ], 2023; Edelman et al., 2023; Hennessy, 2011).

While these individual-level frameworks offer essential insights, they are insufficient for understanding the complex dynamics of stress within social systems. System stress should not be understood as merely the accumulation of individual distress across a population. Rather, it is a distinct phenomenon that arises at the systemic level—manifesting in a system's form (its structural configuration and boundaries), functioning (its decision-making, coordination, and resource flows), and function (its underlying mission or purpose). Unlike individual stress, which is often observable through emotional or behavioral symptoms, system stress may present as structural rigidity, distorted feedback, breakdowns in communication, or erosion of adaptive capacity—even when individual actors appear to be coping.

### **Scholarship on Systemic Stress, Trauma, and Resilience**

While the term system stress has not yet been formally conceptualized in the academic literature, a growing body of scholarship across adjacent domains—such as trauma-informed practice, disaster recovery, organizational psychology, and social-ecological resilience—offers important conceptual scaffolding. These literatures acknowledge that social systems can experience significant disruption, dysfunction, or even collapse in response to chronic or acute pressures. However, they typically stop short of naming or defining system stress as a distinct theoretical construct. Instead, stress is often embedded implicitly within discussions of trauma, breakdown, resilience, or adaptation, without a systematic account of how stress arises within systems, accumulates over time, or transmits across system boundaries. In what follows, we examine key literatures that engage with related concepts and dynamics—such as trauma, organizational dysfunction, and systemic resilience—that collectively lay the groundwork for articulating system stress as a distinct construct. Our proposed definition builds upon these foundations, aiming to synthesize and extend them within a broader systems theory framework.

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The concept of *collective trauma* has been developed and applied across multiple disciplines, including psychology, sociology, trauma studies, and public health. In psychology and psychiatry, it refers to the shared psychological impact of large-scale traumatic events, such as war, genocide, or natural disaster, that affect entire groups or communities (Yehuda et al., 2015). Sociologist Kai Erikson (1976) first introduced the term to describe how disasters can damage the social fabric of communities, not merely through individual trauma but via the loss of shared identity and cohesion. In cultural sociology, Alexander (2004) further elaborated on collective trauma as a narrative process through which societies interpret and respond to traumatic events, influencing national memory and public discourse. Trauma studies and genocide research have explored collective trauma in the context of historical violence, focusing on how traumatic experiences are passed down intergenerationally and embedded in collective memory (Sangalang & Vang, 2017). Public health and community psychology have recently adapted the term to understand how communities experience and recover from systemic traumas such as racism, pandemics, and community violence (Pinderhughes et al., 2015). Across these fields, collective trauma is increasingly recognized as a multidimensional phenomenon that affects both individuals and the communities in which they live. With that said, even when community-level impacts are considered, the analytic lens remains largely individual-centric.

Similarly, studies on school shootings have noted the long-term effects on school climate, staff turnover, and community trust, yet still frame those outcomes primarily in terms of their effects on individual outcomes. Hobfoll's (1989, 2007) Conservation of Resources theory begins to address trauma's broader societal impact by showing how resource loss at the community level compounds individual and collective distress, however, this work, too, stops short of conceptualizing systems as distinct stress or trauma-bearing entities. In trauma-informed systems design, Harris and Fallot (2001) were among the first to apply trauma theory to service delivery environments. They advocated for integrating principles such as safety, trustworthiness, collaboration, and empowerment into organizational structures, marking a critical shift from focusing solely on individual trauma symptoms to transforming the systems in which individuals live and work. While their work emphasized the importance of trauma-informed practice at the institutional level, it did not explicitly define or theorize system stress or trauma as distinct constructs.

Emerging literature on community and ecosystem resilience moves closer to a systemic lens. The RAND Corporation (n.d.) defines community resilience as a system's ability to mobilize resources and recover from adverse events, while the Waterloo Institute for Social Innovation and Resilience (2014) defines ecosystem resilience as the capacity to tolerate disturbance without collapsing into a fundamentally different state. These perspectives introduce valuable language around systemic adaptation, transformation, and collapse—but they do so without identifying or defining “systems stress” as the pressure that precedes or catalyzes those shifts.

The closest conceptual precedent appears in James Grier Miller's (1978) Living Systems Theory, which provides a comprehensive model for understanding how systems—from individuals to societies—maintain equilibrium through interdependent subsystems. While Miller did not define systems stress as a theoretical construct, his work describes conditions that resemble it: instances in which the input of energy, information, etc. exceeds a system's capacity to process or regulate it. These imbalances may lead to feedback blockages, information overload, or increasing entropy—what Miller refers to as “organizational pathologies.” His language offers early insight

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into how systems can become strained or destabilized under pressure, but it remains descriptive rather than conceptual.

This paper builds upon these foundations to offer the first explicit definition of systems stress: a condition that arises when acute or cumulative demands exceed a system's available resources or adaptive capacity, resulting in observable changes to its structure (form), internal processes (functioning), or underlying purpose (function). By formalizing this concept, we seek to fill a conceptual and analytical gap in systems literature and provide scholars and practitioners with a vocabulary for identifying, responding to, and ultimately transforming systems under sustained pressure.

### **Broader Resilience Literature as a Foundation**

While Miller's (1978) Living Systems Theory provides an early descriptive account of systemic overload, resilience scholarship offers complementary insights into how systems absorb, reorganize, or transform under sustained pressure. This body of work is especially valuable for understanding how stress interacts with thresholds, cross-scale dynamics, and institutional adaptation.

C. S. Holling's foundational work (1973, 1996) introduced the adaptive cycle to explain phases of growth, conservation, release, and reorganization, positioning stress as a potential catalyst for renewal rather than only a destructive force. Gunderson and Holling (2002) extended this model into panarchy theory, showing how stress at one level of a system can cascade upward or downward, influencing resilience options across scales. Walker and Salt (2006) built on these insights by emphasizing the practical implications of thresholds and feedbacks for human-ecological systems.

At the community level, Adger (2000, 2003) highlights social resilience, focusing on how groups navigate vulnerability and collective adaptation in response to environmental and political stressors. Disaster resilience scholarship similarly emphasizes relational and collective processes of mobilization and recovery (Manyena, 2006; Joseph, 2013; Norris et al., 2008).

Organizational resilience literature extends these insights to institutions facing chronic or unexpected disruptions. Vogus and Sutcliffe (2007) describe resilience as "mindful organizing," or attentiveness to weak signals and small failures, while Lengnick-Hall et al. (2011) conceptualize resilience as a capacity for renewal and strategic adaptation, supported by learning, redundancy, and flexible resource deployment.

Together, these traditions situate system stress within a wider lineage of resilience thinking. They illustrate that resilience is not a single property but a multifaceted process spanning ecological, community, and organizational contexts. Table 1 summarizes these contributions and their relevance for conceptualizing system stress.

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Exhibit 1. Key Resilience Traditions and Their Relevance to System Stress

Domain	Key Scholars/Works	Core Contribution	Relevance to System Stress
<b>Ecological Resilience</b>	Holling (1973, 1996); Gunderson & Holling (2002); Walker & Salt (2006)	Adaptive cycle; panarchy; thresholds and feedbacks	Shows how stress can trigger collapse, release, and reorganization across scales.
<b>Social/Community Resilience</b>	Adger (2000, 2003); Manyena (2006); Joseph (2013); Norris et al. (2008)	Community adaptation, vulnerability, recovery processes	Demonstrates how stress manifests relationally and collectively, not just structurally.
<b>Organizational Resilience</b>	Vogus & Sutcliffe (2007); Lengnick-Hall et al. (2011)	Mindful organizing; capacity for renewal and adaptation	Highlights how institutions absorb disruption, anticipate weak signals, and transform under stress.

## Defining Key Concepts: Systemic Trauma, Stressors, Outcomes, and Resilience

To clarify and operationalize the concept of system stress, we propose a set of interrelated definitions that distinguish it from—but connect it to—adjacent constructs such as systemic trauma, system stressors, systemic outcomes, and system resilience. These definitions build upon foundational insights from systems theory, trauma studies, and resilience research, but represent new conceptual contributions intended to support more precise analysis of how complex social systems respond to pressure and disruption. In some cases, existing literature offers partial precedents; in others, we extend or reinterpret existing work to articulate a novel systems-level framing.

*Systemic trauma* refers to the lasting and structural harm experienced by a system when acute or chronic stressors overwhelm its adaptive capacity, degrade its core functions, and result in persistent dysfunction. We emphasize that, as with individual trauma, systemic trauma is not defined solely by exposure to a catastrophic event but by the system's impaired ability to absorb, adapt to, or reorganize in the aftermath. This framing draws on and expands Miller's (1978) notion of *organizational pathology*, which describes how overloaded or under-regulated subsystems can develop chronic dysfunction, thereby undermining the coherence and resilience of the larger system.

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*Systemic stressors* are the forces or conditions that place significant demands on a system. These stressors may be internal (e.g., leadership breakdown, toxic organizational culture) or external (e.g., natural disasters, policy shifts, economic shocks). Whether discrete or cumulative—and whether arising from individual actions (e.g., a school shooting) or systemic dynamics (e.g., regime change)—stressors become *systemic* when they disrupt a system’s architecture, impair its operational integrity, or divert it from its intended purpose (Palinkas et al., 2004; Checkland, 1981).

*Systemic outcomes* refer to the observable shifts in a system’s structure, functioning, or purpose that emerge in response to stress. These may include communication breakdowns, misalignment between goals and practices, resource misallocation, degraded decision-making processes, or disrupted feedback loops. Systemic outcomes serve as key indicators of whether a system is adapting constructively in response to stress or exhibiting signs of deeper dysfunction. As such, they offer insight into both a system’s current level of stress and its underlying resilience or fragility.

### Distinguishing Stress from Resilience

It is important to emphasize that system stress and system resilience are not opposites but complementary constructs. Stress describes the condition that arises when external or internal pressures exceed a system’s available resources or adaptive capacity. In contrast, resilience refers to the processes and abilities by which systems absorb, reorganize, or transform in the face of these pressures.

In this sense, resilience is not defined by the absence of stress but by the ways in which stress is metabolized. A system under stress may demonstrate resilience by sustaining essential functions, reorganizing internal processes, or transforming its structure to better align with changing conditions. Conversely, a system that lacks resilience may experience breakdown, dysfunction, or long-term trauma when faced with similar pressures.

This distinction underscores the analytic value of system stress as a construct. Whereas resilience research has often focused on how systems cope with or bounce back from disruption, the concept of stress brings attention to the threshold conditions that activate resilience processes. Stress signals the moment when demands begin to overwhelm resources, while resilience describes the range of pathways a system may follow in response—whether adaptation, reconfiguration, or collapse.

#### Exhibit 2. Distinction Between Stress and Resilience

<b>Construct</b>	<b>Definition</b>	<b>Key Focus</b>
System Stress	Condition when demands exceed resources or adaptive capacity.	Signals threshold crossing; highlights pressures and overload.
System Resilience	Processes by which systems absorb, reorganize, or transform under stress.	Describes adaptation or collapse pathways once stress emerges.

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**Exhibit 3. Distinctions Among Key System Concepts**

Term	Definition	Key Characteristics	Overlap with Other Terms	Distinctive Elements
<b>System Stress</b>	Condition that arises when acute or cumulative demands exceed a system’s available resources or adaptive capacity, resulting in observable changes to its structure (form), internal processes (functioning), or underlying purpose (function).	Multi-scalar, context-specific; includes latent and visible stress; shaped by feedback loops and subsystem interactions.	Related to systemic trauma, stressors, outcomes, and resilience.	<ul style="list-style-type: none"> <li>• Focuses on the pressure-induced condition that triggers disruption and activates resilience processes</li> <li>• Stress is the signal that capacity has been exceeded.</li> </ul>
<b>Systemic Trauma</b>	Lasting and structural harm experienced by a system when acute or chronic stressors overwhelm its adaptive capacity, degrade its core functions, and result in persistent dysfunction.	Persistent dysfunction; degraded feedback; institutional memory loss.	May result from prolonged system stress or unmitigated stressors.	Implies a state of enduring harm, not just temporary pressure or overload.

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<b>Systemic Stressors</b>	Internal or external forces that place significant demands on a system's resources, coordination, or goals.	Can be acute or chronic; internal (e.g., toxic culture) or external (e.g., policy shifts).	Cause of system stress and/or systemic trauma.	Defined by their disruptive potential, not by system response.
<b>Systemic Outcomes</b>	Observable consequences of how a system responds to stress or trauma.	Includes changes in structure, coordination, communication, and purpose.	Reflect system's resilience, adaptation, or breakdown.	Measured as indicators of system performance and change over time.
<b>Systemic Resilience</b>	The capacity of a system to absorb stress, reorganize, and continue functioning, adapting, or transforming in response to acute or chronic pressures without losing its core purpose or identity.	Dynamic and process-oriented; multi-scalar; emphasizes adaptation, redundancy, learning, and transformation rather than simple recovery.	Intersects with system stress (as the trigger condition), outcomes (as observed responses), and trauma (when resilience fails or adapts maladaptively).	<ul style="list-style-type: none"> <li>• Frames stress as metabolizable rather than purely harmful</li> <li>• Focuses on pathways of adaptation and renewal across scales</li> <li>• Highlights relational and structural capacities, not just individual or organizational coping</li> </ul>

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## **Attributes of System Stress**

In this section, we propose a set of core attributes that define system stress as a distinct construct. These attributes are proposed as part of a broader effort to formalize and operationalize system stress as a concept. While the term system stress has not been previously defined in the literature, each attribute outlined draws from and builds upon insights from systems theory, resilience research, trauma studies, and related disciplines.

## **System Stress Can Be Latent or Visible**

System stress is not always immediately observable through overt crises or visible breakdowns. In many instances, stress accumulates beneath the surface—embedded in institutional norms, bureaucratic routines, or outdated policies—without triggering immediate disruption. This latent form of stress is akin to what Bloom and Farragher (2011), writing in the context of trauma-informed organizational development, described as “incubated dysfunction,” wherein an organization may present a superficial appearance of operational normalcy while unresolved adversity—such as repeated crises or toxic leadership—erodes its internal coherence. Miller’s Living Systems Theory (1978) reinforces this idea of invisibility in noting that systems can appear to function normally even as internal entropy builds over time. His work highlights how systems may exhibit an outward equilibrium while experiencing gradual degradation in their subsystems—particularly when feedback mechanisms are blocked or overloaded. In these cases, stress is not absent but unrecognized, accumulating until a threshold is crossed that destabilizes the system.

## **System Stress Is Shaped by Power and Equity Dynamics**

System stress does not operate in a vacuum; its distribution and effects are mediated by power, privilege, and structural inequities. Within any system, stress may accumulate in ways that disproportionately burden those with the least institutional power, while shielding more privileged groups from its most destabilizing effects. These asymmetries reveal that system stress is not only a technical or functional matter—it is also a manifestation of systemic injustice.

Equity-oriented frameworks in systems thinking and trauma-informed practice call attention to the embedded hierarchies that shape how systems absorb, internalize, and respond to stress. Foster-Fishman et al. (2007) emphasize that systems change cannot be disentangled from the dynamics of marginalization and exclusion that characterize many institutional structures. Similarly, Bloom and Farragher (2011) illustrate how unresolved organizational trauma may replicate inequitable patterns, reinforcing harm along lines of race, class, or professional status. Understanding system stress, therefore, requires not only identifying pressure points within a system, but also interrogating the historical and structural forces that determine whose suffering is rendered visible—and whose is normalized or ignored.

## **System Stress Has Thresholds and Tipping Points**

Systems experiencing prolonged or intensifying strain can reach tipping points—critical thresholds at which accumulated stress overwhelms the system’s buffering capacity, resulting in cascading failures or transformative shifts (Meadows, 1999). These moments of rupture often lead to nonlinear, sometimes irreversible change, in which a system reconfigures into a

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qualitatively different state. This concept is central to resilience theory, which holds that systems can absorb disturbances up to a point, beyond which they may collapse, bifurcate, or undergo fundamental reorganization in structure and identity (Folke et al., 2010; Walker et al., 2004).

Miller's (1978) *Living Systems Theory* reinforces this framing by illustrating how escalating entropy within critical subsystems can erode a system's regulatory capacity. For example, the boundary subsystem governs what enters or exits a system—such as immigration policies in a nation-state or infection control protocols in a hospital—and plays a crucial role in regulating exposure to external stressors. The decider subsystem is responsible for coordination and control (e.g., school board governance or nonprofit executive leadership), determining how priorities are set and how resources are allocated under conditions of strain. The reproducer subsystem ensures continuity by maintaining personnel and institutional identity (e.g., teacher certification systems or healthcare workforce training), directly influencing a system's long-term resilience. When these subsystems become overloaded or dysregulated, the system's ability to coordinate, adapt, and maintain internal coherence is compromised, increasing its vulnerability to stress. Together, these subsystems mediate how stress is absorbed, processed, and acted upon. Miller's emphasis on environmental exchange and coordination between functional units reinforces the idea that no system experiences stress in the same way. Rather, stress is filtered through the structure and performance of subsystems, whose effectiveness is shaped by broader contextual factors such as governance quality, institutional memory, infrastructure robustness, and sociopolitical dynamics. This perspective underscores that understanding system stress requires attention not only to external shocks or internal vulnerabilities, but also to the situated configurations that determine how systems interpret and respond to stress over time.

Taleb (2012) further distinguishes between fragile systems that break under stress, robust systems that resist it, and antifragile systems that improve in response to volatility. While resilience theory emphasizes absorption and adaptation, antifragility introduces the possibility of transformation through exposure. In complex systems—especially entrepreneurial or emergent ecosystems—stress can catalyze innovation, suggesting a useful extension to resilience frameworks already embedded in systems theory (Folke et al., 2010; Walker et al., 2004).

Building on these perspectives, Holling's (1973, 1996) concept of the adaptive cycle offers a dynamic account of how systems evolve under stress. The adaptive cycle describes recurring phases of growth and accumulation ( $r$  and  $K$ ), collapse or release ( $\Omega$ ), and reorganization ( $\alpha$ ). Stress plays a catalytic role in this cycle: when accumulated pressures surpass a system's buffering capacity, they can trigger a "release" phase in which entrenched structures or routines unravel. This disruption, while destabilizing, may also create conditions for renewal, innovation, and reconfiguration in the subsequent reorganization phase. Stress, in this framing, is not solely destructive but can also be generative of systemic transformation.

Holling and colleagues later extended this model into panarchy theory (Gunderson & Holling, 2002), which highlights how adaptive cycles are interconnected across multiple scales. Stress experienced at one level—such as local organizational dysfunction—may cascade upward to destabilize regional or national systems, while pressures at higher scales—such as climate change or global pandemics—can cascade downward, constraining the adaptive options available to local actors. Panarchy underscores that system stress must be analyzed relationally,

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recognizing how pressures reverberate across nested systems and generate cross-scale feedback loops.

Together, these perspectives reinforce that resilience involves navigating multiple regimes of stability rather than merely returning to a single equilibrium. Under sustained stress, a system may reorganize into a fundamentally different state with new structures, dynamics, and purposes. For instance, a health system under chronic resource scarcity may transform into a leaner but more decentralized model of care, or conversely collapse into fragmentation and dysfunction. This regime-shift framing strengthens the argument that stress is both latent and visible: it accumulates over time, may remain hidden until thresholds are crossed, and often produces nonlinear outcomes that redefine the system's identity.

### **System Stress Manifests Across Varying Timescales**

System stress can emerge abruptly—such as in response to natural disasters, acts of violence, or political crises—or accumulate gradually over time, as seen with enduring stressors like systemic inequality, bureaucratic inertia, or climate change (Benight & Harper, 2005). The rate and duration of system stress are shaped by several factors, including the intensity and type of stressor, the system's historical exposure to adversity, and its adaptive capacity or resilience. While Miller's work (1978) did not formally categorize stress by type or duration, his work does distinguish between acute subsystem overloads (e.g., breakdowns in decision-making or communication flows) and the slow accumulation of entropy that erodes a system's regulatory capacity. This dual view parallels typologies in individual stress research, which classify stress as acute, chronic, or episodic (Selye, 1976; Segerstrom & Miller, 2004). Acknowledging the temporal variability of system stress—ranging from sudden shocks to prolonged strain—enables a more nuanced analysis of how complex systems experience and respond to pressure over time.

### **Systems Both Receive and Emit Stress**

Systems are not passive recipients of stress; they actively absorb and emit it, influencing both their internal components and the broader network of interconnected systems. Systemic stressors—such as war, genocide, or climate change—introduce strain that a system must attempt to regulate, adapt to, or resist. When the system cannot fully absorb or mitigate this strain, it may emit stress internally (e.g., through fragmentation, breakdown of subsystems, or escalating internal conflict) or externally (e.g., by destabilizing adjacent systems).

Most systems are engaged in both absorbing and emitting stress simultaneously, generating complex and often compounding feedback dynamics. For example, California's natural ecosystem is under sustained system stress due to climate change. A primary stressor—atmospheric heat accumulation driven by greenhouse gas emissions—has led to prolonged droughts and intensifying wildfires. These outcomes generate secondary stress in tightly linked systems such as agriculture, energy, and public health. Drought reduces water availability for crops and livestock, leading to economic strain and heightened food insecurity, while wildfires disrupt energy infrastructure and exacerbate respiratory illness.

This example illustrates the reciprocal nature of system stress, where one system's inability to manage pressure contributes to cascading stress across others. Understanding systems as both

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stress-bearing and stress-emitting entities is critical to mapping how vulnerability, dysfunction, and adaptation ripple through complex social and ecological networks.

### A Case for the Concept of System Stress

The concept of system stress makes a distinctive contribution by naming and defining the condition that emerges when cumulative or acute demands exceed a system's available resources or adaptive capacity. While resilience scholarship has described processes of absorption, adaptation, and transformation, and trauma studies have highlighted the lasting harm caused by overwhelming stressors, no existing framework has provided a precise vocabulary for the condition that activates these dynamics. System stress fills this gap by directing analytic attention to thresholds, subsystem overload, and feedback disruptions as the mechanisms through which stress manifests and reshapes systems over time. By situating stress alongside systemic trauma, systemic stressors, systemic outcomes, and systemic resilience (Table 3), this construct offers a conceptual bridge between descriptive accounts of dysfunction and applied strategies for systems change. Importantly, it highlights not only the vulnerabilities systems face under strain but also the generative possibilities of adaptation and reorganization triggered by stress.

### Conclusion

This paper has argued for the formalization of system stress as a distinct analytic construct. Defined as the condition that arises when acute or cumulative demands exceed a system's available resources or adaptive capacity, system stress clarifies the pressures that precede systemic trauma, activate resilience processes, and shape outcomes over time. By integrating insights from systems theory, trauma studies, and resilience research, this framework provides new language for identifying how pressures accumulate, how thresholds are crossed, and how systems reorganize in response.

The significance of this framing lies in its ability to surface hidden vulnerabilities, illuminate nonlinear pathways of change, and highlight the conditions under which systems either degrade or adapt. Future research should build on this foundation by developing empirical indicators of system stress, testing its utility across sectors, and applying it to the design of equity-informed interventions. By naming and conceptualizing system stress, we equip scholars and practitioners with a critical tool for diagnosing systemic vulnerability, anticipating tipping points, and advancing more resilient and just systems.

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### Appendix A. Miller's 20 Critical Subsystems (Living Systems Theory)

<b>Subsystem</b>	<b>Function</b>
<b>1. Reproducer</b>	Ensures continuity by producing system components or new systems.
<b>2. Boundary</b>	Regulates input/output exchanges with the environment (e.g., borders, policies).
<b>3. Ingestor</b>	Brings in matter, energy, or information from the environment.
<b>4. Distributor</b>	Transports inputs throughout the system.
<b>5. Converter</b>	Transforms inputs into usable forms (e.g., raw data into reports).
<b>6. Producer</b>	Assembles components into products or services for internal/external use.
<b>7. Matter–Energy Storage</b>	Stores materials or energy for future use.
<b>8. Extruder</b>	Expels waste or obsolete components from the system.
<b>9. Motor</b>	Generates physical force or movement.
<b>10. Supporter</b>	Maintains structural integrity (e.g., organizational scaffolding).
<b>11. Input Transducer</b>	Detects incoming signals from the environment.
<b>12. Internal Transducer</b>	Detects signals from within the system.
<b>13. Channel and Net</b>	Routes information between subsystems (e.g., communication infrastructure).

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|------------------------------|--|
| <b>14. Decoder</b>           | Converts incoming signals into usable forms.                   |
| <b>15. Associator</b>        | Connects new information with stored knowledge.                |
| <b>16. Memory</b>            | Stores and retrieves information.                              |
| <b>17. Decider</b>           | Makes decisions and coordinates subsystem activities.          |
| <b>18. Encoder</b>           | Prepares outgoing information for transmission.                |
| <b>19. Output Transducer</b> | Sends signals or products to the external environment.         |
| <b>20. Timer</b>             | Regulates system rhythms and timing (e.g., schedules, cycles). |