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Global Polycrisis: The Causal Mechanisms of Crisis Entanglement

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Non-Technical Summary (79 words): The term “polycrisis” appears with growing frequently to capture the interconnections between global crises, but the word lacks substantive content. In this article, we convert it from an empty buzzword into a conceptual framework and research program that enables us to better understand the causal linkages between contemporary crises. We draw upon the intersection of climate change, the covid-19 pandemic, and Russia’s war in Ukraine to illustrate these causal interconnections and explore key features of the world’s present polycrisis.

Technical Summary (169 words): Multiple global crises—including the pandemic, climate change, and Russia’s war on Ukraine—have recently linked together in ways that are significant in scope, devastating in effect, but poorly understood. A growing number of scholars and policymakers characterize the situation as a “polycrisis.” Yet this neologism remains poorly defined. We provide the concept with a substantive definition, highlight its value-added in comparison to related concepts, and develop a theoretical framework to explain the causal mechanisms currently entangling many of the world’s crises. In this framework, a global crisis arises when one or more fast-moving trigger events combines with slow-moving stresses to push a global system out of its established equilibrium and into a volatile and harmful state of disequilibrium. We then identify three causal pathways—common stresses, domino effects, and inter-systemic feedbacks—that can connect multiple global systems to produce synchronized crises. Drawing on current examples, we show that the polycrisis concept is a valuable tool for understanding unfolding crises, generating actionable insights, and opening avenues for future research.

Social Media Summary: No longer a mere buzzword, “polycrisis” analysis explores causal interactions among crises to help navigate a tumultuous future.

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1. Introduction: From perfect storms to polycrises

As war, extreme weather, hunger, energy scarcity, inflation, pandemics, and myriad other calamities fill our daily news feeds, political leaders often declare that humanity is facing a "perfect storm" of crises. This metaphor, however, is misleading (Homer-Dixon & Rockström, 2022). It implies the current confluence of unfortunate events is merely a temporary coincidence—just plain bad luck.

But many of these leaders also recognize that today's crises are intertwined in vital ways (for example, Georgieva, 2022; Malpass, 2022): one crisis often seems to trigger or worsen another, which then triggers or worsens yet another; and interacting crises can produce impacts that are both different from and worse than the harms the crises would have produced separately. These leaders seem to intuit that the world's conjoined crises must be understood and addressed as a whole.

The term "polycrisis" captures this intuition. It is being used by a growing number of commentators (Summers & Ahmed, 2022; Wolf, 2022), international agencies (UNDP, 2022; WEF, 2023; UNICEF, 2023), policymakers (Juncker, 2018), and scholars (Davies & Hobson, 2022; Tooze, 2021). Yet the term remains underspecified—a buzzword with little substantive content. It is not yet associated with a rigorous field of inquiry that includes a framework of precisely defined core concepts and research heuristics that can sustain disciplined knowledge cumulation (Lakatos & Musgrave, 1970). Without these elements, "polycrisis" adds little to our understanding; but with these elements, the concept could help scholars generate actionable insights into the world's interwoven crises.

In this article, we provide the polycrisis concept with substantive content. We develop a research agenda for studying the causal mechanisms that entangle multiple global systems and that appear to be generating near-simultaneous global crises. We argue that a better understanding of humanity's predicament as a polycrisis can help the world address its interconnected challenges.

In Section 2, we define "polycrisis" and highlight the concept's value in comparison with more familiar concepts. In Section 3, we argue that humanity is facing a global polycrisis; though not our first, it is unprecedented in crucial respects that we have yet to fully comprehend. Section 4 uses models from the complexity and sustainability literatures to identify several causal mechanisms likely operating among global crises today. It introduces two examples to illustrate these mechanisms: first, the cascading impacts of interactions between the Covid-19 pandemic, the Ukraine-Russia war, and climate change; and, second, the potentially reinforcing feedbacks between economic turmoil, nationalist authoritarianism, and declining international cooperation that could tip the world into mass violence. In the concluding section, we summarize some of this nascent field's key insights and policy implications, while identifying future research directions.

2. What is a (global) polycrisis?

Complexity theorists Edgar Morin and Anne Brigitte Kern coined the term "polycrisis" over two decades ago. They argued that the most "vital" problem of the day was not any single threat but the "complex

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intersolidarity of problems, antagonisms, crises, uncontrollable processes, and the general crisis of the planet" (Morin & Kern, 1999, p. 74). More recently, sustainability scholar Mark Swilling (2013, 2020) used "polycrisis" to capture the complex interactions between crises in the global political economy that multiply those crises' overall impact. In the 2010s, European scholars and leaders (most notably then-President of the European Commission Jean-Claude Juncker) adopted the term to label the simultaneous migration, financial, and Brexit crises afflicting Europe (Juncker, 2018; Zeitlin et al., 2019). And in the months following Russia's invasion of Ukraine in February 2022, Columbia University's Adam Tooze and researchers at the Cascade Institute used "polycrisis" to characterize the complex interactions between the effects of the war, climate change, and the pandemic (Tooze, 2022; Lawrence et al., 2022).

But it was only at the World Economic Forum's annual meeting in Davos in January 2023 that the polycrisis idea gained wide currency among commentators, policymakers, and business elites (Serhan, 2023). This surge in use engendered broad criticism of the concept and, unfortunately, more confusion than clarity (Homer-Dixon et al., 2023).

Some critics argue that the polycrisis idea obscures the operation of capitalist interests that are at the root of the world's woes (Sial, 2023); they associate the term with "Davos elites" and their supposed faults. Others argue that our present predicament is not truly novel; the world has seen intersecting crises before, so we do not need a new concept to describe our situation today (Kluth, 2023). And at least one International Relations scholar has muddied the waters by misrepresenting polycrisis arguments as "neo-Malthusian"—that is, explanations of complex social phenomena that overemphasize the causal role of population growth and resource depletion (Drezner, 2023).

Neologisms always provoke contention. But the disputes in this case risk distracting us from a core (and presumably shared) goal: to better understand and address our world's very real crises. We believe the polycrisis concept—if defined clearly and translated into a productive program of research and action—can help us pursue this goal.

In this spirit, we define a "global polycrisis" as *the causal entanglement of crises in multiple global systems in ways that significantly degrade humanity's prospects* (Lawrence et al., 2022). We unpack this definition by first defining "crisis," then by identifying interactions among crises that constitute a "global polycrisis," and finally by distinguishing this latter term from related concepts of "systemic risk," "catastrophic risk," and "existential risk."

We define a crisis as a sudden (non-linear) event or series of events that significantly harms, in a relatively short period of time, the wellbeing of a large number of people (Homer-Dixon et al., 2015).[i] More colloquially, it is an extremely harmful emergency that requires urgent response lest even greater harm ensue. This definition diverges slightly from early and modern understandings of the term: for ancient Greeks, a crisis was the decisive moment at which an illness veers towards death or recovery; in modern politics, it is an alarming situation that could steer the course of history and therefore demands

[i] We develop this definition further in Section 4. It's important to note that by this definition, the Cuban Missile Crisis was not truly a crisis; the event instead created an acute *risk* of a crisis (i.e., nuclear war) (Homer-Dixon et al., 2015).

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rapid resolution (Koselleck, 2006). Both early and modern usages reference a rupture of normalcy that has fateful consequences and thus requires decisive action. Modern usage also highlights epochal change over time (in ways that resonate with our discussion of system stresses in Section 4 below). In contrast, our definition of crisis emphasizes immediate harms.

Our definition of "crisis" is precise enough to support development of objective criteria of crisis occurrence and severity. Such criteria could make it harder to use the term selectively and inconsistently to emphasize some problems and solutions over others and thereby to serve particular interests. Declaration that a crisis is occurring is often a key step in the *securitization* of an issue: a problem like cross-border migration or climate change becomes a crisis, and thus a matter of *national* security not because of its inherent features, but because certain actors convince relevant audiences (generally policymakers) that the issue constitutes an existential threat to the nation and therefore requires responses outside the realm of normal politics (Buzan et al., 1998, pp. 21-47). Any definition of crisis will have political implications, but objective criteria (to the extent they can be developed) help limit politicized manipulation of the term. By referring to facts and evidence about actual—rather than counterfactual—occurrences, our definition helps to narrow the scope of what can be credibly and consistently labeled a crisis.

If a crisis is an extremely harmful emergency, then the *poly-* in polycrisis denotes multiple such events. But this prefix is of little use if it denotes *any* coincidence of crises or simply refers to all the world's ills.[ii] On this point, the concept's critics are correct. We therefore emphasize crises that are causally inter-related with one another, and we draw upon the systemic risk literature and systems thinking more broadly to discern the types of crisis connections that constitute a polycrisis.

Conventional risk assessment focuses on the likelihood and potential harm of particular events such as a car accident, fire, or bankruptcy. In contrast, systemic risk assessment focuses on "the risk or probability of breakdowns in an entire system, as opposed to breakdowns in individual parts or components, [as] evidenced by co-movements (correlations) among most or all parts" (Kaufman & Scott, 2003, p. 371). Our elaboration of the polycrisis concept here adopts two core implications of this systemic risk idea (Schweizer, 2021; Renn et al., 2019; Renn, 2016):

1. Intra-systemic impact: A disruption that affects one part or area of a single system quickly spreads to disturb the entire system (via multiple, ramifying chains of cause and effect, or some form of contagion, through the system's causal network).
2. Inter-systemic impact: The disruption of the initial system may spill outside that system's boundaries to disrupt other systems.

The concept of systemic risk "assumes a systems perspective" (Schweizer, 2021, p. 79). It presupposes that "connections between elements of the system" are sufficiently dense that a single disruption can sometimes generate ramifying impacts throughout the system. It also implies that discernable

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[ii] *Collins Dictionary*, for example, defines polycrisis simply as "The simultaneous occurrence of several catastrophic events."

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boundaries separate one system from another (Figure 1), although discrete systems may influence each other by exchanging energy, matter, information, and biota (Box 1).

[Figure 1: Global Systems]

Our polycrisis concept similarly assumes that initially limited disruptions can affect an entire system and then spread to other systems. But it differs from the systemic risk concept in three important ways. First, whereas the ultimate referent of the systemic risk concept (and of the risk concept more generally) is the *potential harm* that might arise, the referent of the polycrisis concept is the *realization (or activation) of chains of cause and effect that cause harms*. Second, a systemic risk is generally assumed to arise from just one or two systems, but a polycrisis (by definition) arises from interactions among *multiple* systems.[iii] And finally, whereas the systemic risk literature highlights the complexity of risks themselves, our approach to polycrisis instead emphasizes the complexity of the systems in which the risks develop. This complexity creates the possibility for systemic failure and inter-systemic effects; that is to say, systemic complexity *creates* systemic risks (Goldin & Mariathasan, 2016; Nyström et al., 2019). Box 2 presents the key features of global systems that enable polycrises to develop and grow.

By focusing on crises within and across systems, our approach highlights a crucial feature of polycrises: that the conjoined harms of multiple crises are different from, and generally worse than, the harms each crisis would produce in isolation, were their host systems not so deeply interconnected (Lawrence et al., 2022, p. 2). What may appear to be separate crises in different systems in fact exacerbate and reshape one another to form a conjoined polycrisis that must be understood and addressed as a whole. In the language of complexity scientists, a polycrisis is an *emergent* phenomenon.

Like systemic risk (ISC et al., 2022), a polycrisis can occur at different scales—local, national, regional, or global—indeed at any scale that hosts interacting systems. Here, however, we are particularly concerned with crises interacting at the *global* scale, with a spatial extent that affects the whole planet and/or all of humanity.[iv] Global polycrises (and global systemic risks) arise from the organization of human activities into complex *global* systems (as defined in Figure 1) structured in ways that enable disruptions to spread quickly around the world (as outlined in Box 2).

Box 1: Vectors and conduits of global polycrises

[iii] Technically, by this definition, a polycrisis could involve just two systems in crisis. But such a pairing can be effectively analyzed without invoking the polycrisis concept. Interactions among *three or more* interconnected systems are far more difficult to analyze, however, because the number of combinatorial possibilities explodes. The polycrisis concept permits better conceptualization of complex interactions between a multiplicity of crises, as in the examples presented in Section 4.

[iv] While other authors refer to "the" polycrisis, as a singular phenomenon, multiple polycrises could conceivably occur simultaneously but separately, each in a different set of systems. Each and every crisis is certainly not connected to each and every other crisis in a significant way, and the polycrisis concept should not be overextended to encompass every problem afflicting humanity. At the same time, the dense interconnectivity between global systems creates numerous pathways for crises to intersect. While multiple global polycrises could occur simultaneously but separately, we speculate that their interconnections will grow over time, and if these crises are not resolved, they will likely amalgamate into a single polycrisis.

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At a rudimentary level, four *vectors* can carry a crisis within and across systems and from one part of the world to another, thereby inflicting significant harms:

- Energy, such as the kinetic energy generated by earthquakes and hurricanes.
- Matter, such as the toxins and pollutants that harm organisms and ecosystems.
- Information, consisting of instructions and symbolic representations—including genetic and digital codes, news feeds, ideologies, money, policies, and laws—that can be communicated between agents.
- Biota, such as viruses, bacteria, and other organisms that can disrupt the biological and physiological functions of other organisms. (This category may be considered a special combination of energy, matter, and information that involves lifeforms.)

Any given crisis event will likely feature some combination of these vectors, whether simultaneously or sequentially. A hurricane, for example disperses kinetic *energy* through wind and rain, which can cause *matter* in the form of floodwater to inundate populated areas and create conditions for the spread of pathogenic *biota*; while *information* about the disaster may provoke panicked, inappropriate responses. Crises may stem either from vectors that carry harms or from sudden disruptions of vectors that carry necessities, as when energy outages leave households vulnerable to harsh winters. Social power can be understood as an actor's ability to manipulate these vectors to get another actor to do what they otherwise would not do (Dahl, 1957), in ways that can create a crisis by intention, negligence, or accident.

Today's planet-spanning webs of connections—including those arising from Earth's biophysical features and others produced by humanity's globalized economic activity—provide the *conduits* through which these vectors travel around the globe. This web of connections includes our societies' telecommunication networks; pipeline networks and electrical grids; roads, canals, and air and shipping routes; supply chains and trade, finance, and monetary systems; and links among elements of Earth's climate and ecological systems. **[End of Box 1]**

Box 2: Properties of global systems that enable polycrises

Operating together, the vectors and conduits described in Box 1 create highly complex global systems. These systems exhibit five key properties that help generate polycrises while hampering crisis mitigation.

- Multiple causes: The operation of many causes simultaneously makes cause and effect relationships difficult to trace and presents decisionmakers with acute policy trade-offs. Causes may also interact synergistically so that their combined effects are qualitatively different than the sum of effects they would have separately (Jervis, 1997).
- Non-linearity: Complex global systems exhibit nonlinear behavior—that is, perturbations of such systems can produce disproportionately large (or small) changes in the system's behavior. An important source of nonlinearity is the existence of multiple stable states or equilibria that are separated by thresholds. A system can flip from one equilibrium to another (a critical transition or

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tipping event) when feedbacks in key processes that sustain the system's equilibrium shift from negative to positive—i.e., from self-dampening to self-reinforcing causal loops (Scheffer, 2009). Tipping events can also result from interactions between adjacent systems (Rocha et al., 2018).

- Hysteresis: System flips are generally not reversible; a return to the previous system equilibrium is often impossible.
- Boundary permeability: Casual processes operate on multiple time scales within and among natural, social, and technological systems; they cross boundaries of administrative and political units and social sectors, while requiring integrated knowledge from diverse scientific disciplines.
- "Black swan" outcomes: The probability density functions describing the distribution of events generated by complex global systems are rarely normal (i.e., Gaussian); they often have long tails, indicating a non-negligible risk of extreme outcomes. Leaders, in contrast, face institutional pressures to concentrate on immediate and probable risks.

These five properties create deep uncertainty that profoundly hinders effective management of outcomes. Multiple causes and nonlinearity weaken decisionmakers' ability to predict *which* policy changes will matter *when*. Tipping events and hysteresis undermine trial-and-error learning; a maladaptive behavior can generate benefits until a threshold is crossed, at which point costs are unavoidable, damage irreversible, and any learning too late. Ineffective learning then lowers the public's willingness to accept costs to lessen risk (Barrett & Dannenberg, 2014).

Because risks arising within complex global systems tend to transcend administrative, social, and scientific boundaries, they often exceed managers' professional expertise and are consequently downplayed or even ignored. And when crises affect multiple administrative and political domains, actors may choose to free ride on others' investments in solutions. Finally, deep uncertainty fosters competing policy prescriptions, aggravating a pernicious loss of trust in governments' problem-solving capacity. In some cases, uncertainty can be reduced; in others, it is either practically or intrinsically irreducible (Janzwood, 2022; Walker et al., 2003). **[End of Box 2]**

In the interest of establishing a research agenda, we have adopted a harm threshold that remains somewhat ambiguous and hence leaves room for future refinements. In the extreme, a polycrisis could reach the severity of a "catastrophic risk," an event that kills 10 to 25 percent of humanity (Cotton-Barratt et al., 2016; Kemp et al., 2022) or brings about the collapse of human civilization (GCRI, 2023). It could even become an "existential risk" that extinguishes humanity entirely. But a polycrisis, by our definition, does not need to reach these levels of harm; and, in contrast to accounts of individual existential and catastrophic threats (arising from, for instance, an asteroid hitting Earth), a polycrisis necessarily involves *multiple* crisis events. It could involve massive immediate casualties, but also a widespread and sustained decline in the quality of life into the future.

Based on these considerations, we define a global polycrisis as *the causal entanglement of crises in multiple global systems in ways that significantly degrade humanity's prospects*. The causal interactions between constituent crises are significant enough to produce emergent harms that are different from, and usually greater than, the sum of the harms they would produce separately. Consequently, these

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crises must be addressed as a whole; they cannot be resolved individually. While our approach to polycrisis incorporates key aspects of other definitions, it is specifically intended to aid scientific research into the nature of polycrisis by emphasizing the *causal interactions* that connect *global systems* and spread crises among them. Our definition relates to other important concepts (such as systemic risk) but adds essential novelty by highlighting the causal entanglement of multiple crises—interconnections that abound but remain sparsely understood, as explained in the sections below.

3. Are we in a global polycrisis?

We argue here that the world is currently experiencing a global polycrisis and that this situation is worsening. Constituent crises include: the lingering health, social, and economic effects of the Covid-19 pandemic; stagflation (a persistent combination of inflation and low growth); volatility in global food and energy markets; geopolitical conflict, especially between assertive authoritarian regimes (including China and Russia) and the democratic West, which is leading to a partial decoupling of American and Chinese economies; political instability and civil unrest in countries both rich and poor arising from economic insecurity, ideological extremism, political polarization, and declining institutional legitimacy; and increasingly frequent and devastating weather events generated by climate heating. These crises are destroying livelihoods and lives around the globe and are undoubtedly diminishing humanity's prospects. Moreover, they are certainly interconnected, although exactly how remains unclear.

This is not humanity's first polycrisis. We experienced at least two additional instances in the last half century, though some may argue they were not truly global. The oil shocks of the 1970s arose from conflicts in the Middle East and generated severe international energy shortages that contributed to, and interacted with, stagflation in the world economy (Progressive International, 2023). The 2008-09 global financial crisis intersected with oil supply constraints and long-term stresses in food production to produce cascading bankruptcies, food price hikes, and political unrest worldwide (Homer-Dixon et al., 2015; Biggs et al., 2011).[v]

While the present polycrisis features some of the same constituent crises—including energy and food shocks, stagflation, and financial instability—it is unprecedented in crucial ways (Homer-Dixon, 2023; Lähde, 2023). First, the world is far more interconnected now than it was during the OPEC oil shocks. Between 1980 and 2020, air freight increased six-fold to 180 billion-ton-kilometers per year, the number of air passengers nearly tripled to 1.8 billion annually, and internet usage increased from virtually zero to sixty percent of the world's population. Meanwhile, the total value of world merchandise trade increased twelve-fold between 1980 and 2022 to nearly 25 trillion US dollars annually (at current prices), and container port traffic has more than tripled since 2000 to almost 800 million 20-foot-equivalent-units in 2020.[vi]

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[v] Beyond these two recent global examples, history provides many instances of polycrises at the regional scale, such as the trauma that accompanied Europe's "little ice age" of the seventeenth century, which devastated harvests and generated mass migrations, but laid some key foundations of modernity (Blom, 2019), and the natural disasters, foreign invasions, political upheavals, and trade disruptions that produced the collapse of Late Bronze Age Eurasian civilizations in the 12th century BC (Cline, 2014). For more historical examples, see: Hoyer et al., 2023.

[vi] Based on statistics from the World Bank's DataBank (https://databank.worldbank.org/home.aspx) and UNCTADstat (https://unctadstat.unctad.org/EN/Index.html).

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The “conduits” of this extreme connectivity—aircraft, container carriers, fiber-optic cables, and the like—now carry immense circum-planetary flows of the “vectors” of matter, energy, biota, and information (Box 1). The conduits also create and sustain multi-continental markets and globalized corporations that in turn encourage increasing standardization and homogenization among system elements, from financial instruments to germ plasm for agricultural goods to computer operating systems and social media platforms. This homogenization then enables even denser interconnection, in a powerful positive feedback.

Unfortunately, complex systems that feature *both* high connectivity and high homogeneity among system elements can be especially prone to rapid, discontinuous change (Scheffer et al., 2012), much as closely planted agricultural monocrops are susceptible to devastation by pathogens. By striving to maximize efficiency and open access to markets while stripping away social and environmental safeguards, neoliberal arrangements have exacerbated both homogenization and hyper-connectivity in the global economy, generating recurrent crises and worsening stresses both in the economy (for instance, by increasing inequality) and in other systems (for instance, by damaging the ecosphere).

Even in the absence of high homogenization, gradual shifts in exogenous conditions can erode a highly connected system’s resilience until its stabilizing feedbacks are overwhelmed, and it flips to a different equilibrium (Scheffer, 2009). And systems that may be resilient on their own can become more vulnerable to such flips when they become tightly connected to other systems (Buldyrev et al., 2010; Gao et al., 2015); unexpected vulnerabilities can arise when system elements not designed to work together are inadvertently connected (Perrow, 1999).

In sum, the interlinked architecture of our global systems is at the heart of the current polycrisis, because it worsens risks as diverse as financial turmoil, pandemics, economic inequality, and ideological extremism (Centeno et al., 2015; Helbing, 2013; Rodrik, 2011). These systemic risks are “endemic to globalization”; they can be managed (by reforming the neoliberal economic order, for instance) but not eliminated (Goldin & Mariathasan, 2016, p. xiii).

The present polycrisis is also unprecedented in a second respect. Human resource consumption and pollution output are pushing Earth’s physical and ecological systems far from their previous equilibria, imperiling the stability of many other global systems critical to human wellbeing, from food production to international security. For instance, our emissions of greenhouse gases have created an energy imbalance at the planet’s surface (more heat coming in from space than going out) of about 1.36 Watts per square metre (Hansen et al., 2023). This extra energy—now equivalent to nearly one million Hiroshima-sized atomic bombs exploded in the atmosphere *every day*—is producing increasingly extreme storms, floods, heat waves, and droughts, affecting billions of people and worsening population displacement, social instability, and conflict (Adelphi & PIK, 2020; Ide et al., 2020; Schleussner et al., 2016).

Together, hyper-connectivity and the destabilization of ecospheric systems are amplifying and accelerating crisis events worldwide (Figure 2). For example, since HIV first appeared four decades ago,

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outbreaks of zoonotic viral disease have become increasingly severe and frequent, from the SARS outbreak of 2002 to H1N1 in 2009, MERS in 2012, Ebola in 2014, Zika in 2015, Ebola again in 2018, Covid-19 in 2019, and most recently mpox and Marburg (Araf et al., 2023; CFR, 2023; Smith et al., 2014). Meanwhile, climate heating is also accelerating: between 1970 and 2010, Earth's tropospheric temperature increased about 0.18°C per decade; between 2010 and 2040, warming is predicted to increase to 0.27°C per decade, a rise in rate of 50 percent (Hansen et al., 2023, p. 21). And because this warming makes zoonotic disease outbreaks more likely, two seemingly discrete crises—pandemics and calamitous weather—are becoming increasingly entwined (Carlson et al., 2022).

[Figure 2: Crisis amplification and acceleration]

But global crises are not just amplifying and accelerating, they also appear to be *synchronizing*. "We're seeing what occurs when everything happens everywhere all at once," says International Relations theorist Stephen Walt (2022). Complex and largely unrecognized causal links among the world's economic, social, and ecological systems seem to be causing many risks to go critical at the same time or in quick succession (Figure 3). Indeed, "the failure to take into account feedbacks across systems" is a crucial emerging risk itself (Future Earth, 2020, p. 6).

While scientific knowledge of individual systemic risks like climate change and zoonotic viral disease is often deep, our grasp of causal mechanisms linking these risks and the crises they generate remains shallow (ISC et al., 2022, p. 8). For instance, the World Economic Forum's annual *Global Risk Report* identifies apparent links among risks but does not examine amplifying feedbacks in detail. Below, therefore, we offer an analytical framework to help advance our understanding of the causal mechanisms driving the present polycrisis.

[Figure 3: Crisis synchronization]

4. The causal mechanisms of crisis entanglement

"Synchronization" can mean several things. In physics, synchronization occurs when interactions between oscillating objects cause them to align their rhythms so that events happen at the same time or with the same periodicity (Pikovsky et al., 2007). Synchronization often homogenizes behavior by causing system elements to act in the same way, as when glow bugs flash in unison or investors all try to sell off bad stocks at the same time (Strogatz, 2003). And the term synchronization may be used more loosely to refer to events that occur in quick succession.

The apparent synchronization of global crises (in any of the above senses) raises a crucial question: what sorts of interactions and feedbacks are aligning crises in multiple global systems? These relationships remain opaque and underexplored. We therefore propose an analytical framework to guide investigation of the causal mechanisms connecting global crises.

The basic model: Crisis in a single system

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Scholars and policymakers tend to silo their analyses of, and responses to, crises; that is, they tend to see the causes and effects of a given crisis through the lens of a single system. Such parsimony can be a useful analytical starting point. Beginning, therefore, with a single system, our basic model (Figure 4) proposes that a crisis occurs when one or more slow-moving *stresses* interact with a fast-moving *trigger* event to push the system out of its established equilibrium and into a state of disequilibrium or instability.[vii] In line with our earlier definition of crisis (Section 2), this disequilibrium manifests itself as a sudden (non-linear) event or series of events that significantly harms a large number of people.

[Figure 4: Basic model of systemic crisis]

A complex system is not static. Constantly operating internal processes (such as negative feedbacks) keep the system's state (represented in Figure 4B as a ball) within a certain range of values (depicted as a "basin of attraction" in a "stability landscape"). Stresses are slow-moving processes—pressures, emerging contradictions, and deepening vulnerabilities—that accumulate in the system over time and weaken its stabilizing feedbacks, reducing their ability to hold the system's state within its established range.[viii] Metaphorically, the basin in which the system resides becomes shallower.

Stresses often operate at the global scale, and because they are slow-moving, their change over time is usually somewhat predictable. In global systems, stresses currently include growing socio-economic inequalities, increasing resource scarcities, economic over-leveraging, climate heating, and ecological degradation, among many others. By reshaping the stability landscape, these stresses shift the probabilities of future global developments and create systemic risks—that is, potential pathways across that landscape to crisis.

A trigger event is a fast-moving process that interacts with stresses to push a system state out of equilibrium. If stresses have made the system's basin of attraction shallower, a trigger event of a given magnitude will more easily cause such disequilibrium. Trigger events are usually stochastic, unpredictable, and local or regional in scale, but they have global-systemic consequences. They include phenomena like political uprisings, price spikes in critical goods and services, major corporate bankruptcies, and the loss of keystone species in specific ecosystems.

A system enters crisis when it leaves its established basin of attraction. A crisis thus has three defining properties: the system state is unstable (i.e., out of equilibrium), the change in system state occurs relatively suddenly, and the resulting instability causes significant human harm. Pushed from equilibrium, the system is in a turbulent state that disrupts stabilizing mechanisms and generates

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[vii] For our purposes, slow-moving (long-term) processes can be measured (roughly) in years and decades, while fast-moving (short-term) processes (or "events") can be measured in days and months.

[viii] *Pressures* are forces that accumulate over long periods of time until they are suddenly released, as when tectonic stresses produce earthquakes, or a long-aggrieved community erupts in revolt. *Contradictions* involve conflicting and often self-undermining forces within a system, such as the tendency of the neoliberal global economy to produce economic and ecospheric disruptions that threaten the social and environmental stability on which it depends. And *vulnerabilities* concern the potential pathways to systemic failure that a system develops as it grows more complex, as when the tight-coupling and homogeneity of the financial system enables a cascading global financial crisis.

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harmful outcomes, such as loss of income or deaths and injuries from violent conflict, malnutrition, starvation, or disease.

A crisis ends when the system returns to equilibrium—by either re-entering its original basin of attraction or moving to a new one. If the system state returns to its original basin and that basin remains shallow, a crisis will likely erupt again. If the system state settles into a new basin of attraction, it has completed a critical transition; it has flipped from one set of system behaviors to another with its own stabilizing internal processes.

Ideally, a crisis ends with the system entering a basin that reinforces normatively beneficial system behaviors and which is sufficiently deep (i.e., stable) to prevent another crisis. But the system could also enter a harmful and undesirable—but still highly stable—basin, perhaps one with widespread economic deprivation and political repression. In these circumstances, it is the system's newfound stability in a pernicious state, rather than its crisis instability, that creates significant harm.[ix] For example, systems such as slavery and imperialism caused immense suffering over long historical periods—not as crises, but due to their lamentable stability and resilience.

The global financial crisis of 2008-9 illustrates our basic model. It arose from the conjunction of several slow-process stresses, including growing worldwide trade in opaque financial instruments securitized by overvalued housing markets, and tightening balance-sheet interdependencies among major financial institutions stemming from cross-ownership of these instruments. The collapse of Lehman Brothers was the trigger event that started a cascade of defaults. The crisis ended when central banks rescued major commercial banks from default, slashed interest rates, and injected unprecedented amounts of liquidity into national economies. The global economic system settled into a new disinflationary equilibrium of weak demand, low growth, and exceptionally low interest rates that lasted until the Covid-19 pandemic.

Through this entire period and up to the present, the global economy has continued to experience additional powerful stresses—including rising economic inequality within most nations and worsening global heating—that have progressively weakened its social and ecological foundations and contributed to a long-term fall in the secular rate of global economic growth (Homer-Dixon, 2020, p. 204). These (and other—see, for example, Roubini, 2022) changes amount to a steady shallowing of global capitalism's basin of attraction that is boosting the risk of future systemic crises.

No conceptual schema can fully capture the intricate causal, spatial, and temporal features of specific global crises. But our basic single-system model should help researchers distinguish between the three core elements of stress, trigger, and crisis and then map interactions among these elements. Figure 5 shows possible types of within-system interaction.

[Figure 5: Crisis interactions within a single system]

[ix] Stated differently, all crises involve harms, but not all harms arise from crises. The instability condition captures the fast-moving nature of crises as abrupt (non-linear) departures from normalcy, allowing for the fact that normalcy (i.e., a state of non-crisis) too may be harmful.

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Crisis interaction between multiple systems

A global polycrisis, however, is characterized by relationships *between* systems. In Figure 6, we show how the elements of our basic model (stresses, triggers, and crises) can interact among multiple systems.

[Figure 6: Crisis interactions between multiple systems]

The possible inter-systemic interactions shown in Figure 6 draw upon—and echo—advances in ecological research. Just as other scholars and policy makers tend to address crises in single systems, ecologists have largely studied critical transitions in isolated ecosystems. But recent, leading-edge work in ecology identifies causal relationships *between* such transitions in *multiple* ecosystems (Rocha et al., 2018; Klose et al., 2021; Keys et al., 2019).

Rocha et al. (2018) compare the thirty ecosystem critical transitions mapped in the Regime Shifts Database[x] and identify three broad types of causal relationships between them:[xi]

- *Common stresses*: A common stress may weaken the resilience of multiple systems, or the stresses affecting one system may interact with stresses in another, as depicted in Figure 6A.
- *Domino effects*: A crisis in one system may affect the stresses in another system, cause a triggering event that pushes another system into crisis, or reshape a crisis in another system, as depicted in Figures 6E and 6F. Domino effects operate in temporal sequence.
- *Inter-systemic feedbacks*: Stresses, trigger events, and other events generated by a crisis can form feedback loops that either dampen or, more commonly, escalate crises in two or more systems. Feedback effects can be depicted by combinations of the processes shown in Figure 6, as illustrated in Figure 7.

We propose additional possibilities: "common triggers" by which the same event can activate crises in multiple systems (Figure 6B), as well as possible causal interactions between stresses in different system (Figure 6C) and stresses in one system that generate trigger events in another system (Figure 6D). All six forms of interaction depicted in Figure 6 can be thought of as ideal types; together they provide a "grammar" of causal interactions between systems that can be used to develop hypotheses in polycrisis research. The remainder of this section provides further applications and examples.

[Figure 7: An example of interactions between multiple systems]

Common stresses and systemic synchronization

[x] See: https://www.regimeshifts.org.

[xi] We have adjusted the terms Rocha et al. use to make them consistent with our crisis model; we have changed "shared drivers" to "common stresses" and "hidden feedbacks" to "inter-systemic feedbacks."

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Many global systems are currently undergoing radical change; this simultaneity of change is probably not coincidental. It suggests common stresses are causing synchronization of underlying system behavior (Figure 6A), which may account (at least in part) for the acceleration, amplification, and apparent synchronization of today's global crises.

- **The Earth environmental system** is leaving its Holocene equilibrium and entering a period of instability due to anthropogenic perturbation of the climate and other physical and ecological systems (Armstrong McKay et al., 2022; Rockström et al., 2021; Steffen et al., 2018; Barnosky et al., 2012). This instability is already causing enormous human harm, and its effects could become catastrophic in the near future (Xu et al., 2020; Kemp et al., 2022).
- **The global human energy system** has begun to shift away from its dependence on fossil fuels. Whether this shift will culminate in a new zero-carbon energy equilibrium is uncertain: technological bottlenecks and incumbent opposition may block its progress. The shift's economic benefits are also uncertain: it could ultimately force humanity to decrease its energy consumption per capita (Hall, 2018; Smil, 2022).
- **The international security system** is changing from a world order based on American leadership (a "pax Americana") towards an uncertain and likely less-stable multipolar order defined by the rise of China and the diffusion of power to a much wider range of actors (Gilpin, 2002; Ikenberry, 2014; Nye, 2011). Historically, such transitions have been accompanied more often than not by major war (Allison, 2017; Gilpin, 1988).
- **The global economic system** is shifting from a neoliberal economic regime—one undermining itself through worsening instability, inequality, and ecospheric externalities—to a yet indeterminate regime, but one likely involving increased dirigisme and economic integration within ideological blocs (Rodrik, 2019; Birdsall & Fukuyama, 2011; Monbiot, 2016; Rodrik, 2011).
- **The information system** is being revolutionized by artificial intelligence, with unclear but likely unprecedented implications for employment, decision making, and personal, national, and global security.

The simultaneity of radical change across these systems likely arises, in significant part, from their interdependence, as we argued in section 3 above. Stresses affecting one system can create (or constitute) stresses in others (Figures 6A and 6C). Stresses in the global energy system, for example, include the declining thermodynamic quality of remaining fossil fuel deposits, a trend that increases the energy cost (and therefore carbon emissions) of extraction. Fossil fuel emissions then create stresses in the Earth system, such as climate heating and ecosystem disruption. But possibilities for substituting other, zero-carbon energy sources remain limited (Hall, 2018). Most alternatives, for instance, have relatively low power density, which makes them ill-suited as primary energy sources for today's high power-density-of-consumption urban regions and manufacturing facilities (Smil, 2016). Fossil fuels also still provide energy for nearly all long-distance transportation and remain essential to steel, cement, plastic, and fertilizer production (Smil, 2022, pp. 76-102). Stresses in the global energy system thus create stresses in global food, transportation, and economic systems.

Additionally, stresses in one global system can stimulate or constrain reorganization in others. For example, the Earth system's post-Holocene transformation is influencing change in the global energy

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system and thereby the global economic system. Hegemonic competition in the international security system could reduce governmental collaboration to reorganize the global energy system so as to reduce, in turn, that system's impacts on the Earth system.

A framework called *adaptive cycle theory* suggests that a number of global systems may be on the cusp of catastrophic reorganization. Global energy, food, and financial systems have become increasingly complex, and their sub-components increasingly specialized and connected, as firms have competed to maximize productivity and efficiency. These changes have made these systems more rigid and less resilient in some respects. Systems exhibiting such characteristics, adaptive cycle theory argues, are susceptible to breakdown and reorganization (Gunderson & Holling, 2002; Holling, 2001). When multiple systems align at this phase of the cycle—as several global systems appear to be doing now—breakdown in one may trigger breakdowns in others.

Domino effects between global systems

Such a cascade of breakdowns across systems would be an example of domino effects. The domino metaphor implies a linear chain of cause and effect, in which one crisis causes another, and so on. The interactions between global crises are, of course, not so simple. Stresses and triggers can interact across systems (Figures 6C and 6D); a crisis in one system may affect the stresses and/or the trigger events that push another system into crisis (Figure 6E); and the events generated by one crisis may influence the behavior of another system in crisis (Figure 6F). These types of interactions combine across multiple systems to form multicausal networks, in contrast to simple causal chains.

Figure 8 illustrates domino effects by mapping a causal network of stresses, triggers, and crises among several global systems—specifically, the health, environmental, economic, transportation, international security, and social order and governance systems—from the past through the present to possible (and somewhat speculative) outcomes in the future. The left-to-right temporal logic of such maps helpfully traces the course of events, but it cannot capture the recursive feedback loops that powerfully drive synchronization. Those feedbacks are illustrated instead by the causal loop diagrams in Figure 9.

[Figure 8: Domino effects in the global polycrisis]

Inter-systemic feedback loops

Domino effects are *one-way* causal relationships. But system behaviors can sometimes influence their own causes, creating feedback loops. Negative (i.e., dampening) feedbacks tend to stabilize systems by counteracting change, such as when markets correct for overvalued assets. Positive (i.e., self-amplifying) feedbacks involve two or more variables that intensify one another in spirals of run-away growth or decay, such as arms races or stock market crashes.

We argue that feedbacks arise from combinations of the interactions depicted in Figure 6 and produce the crisis synchronization manifested in a polycrisis. Although one crisis may on occasion dampen another—as when, for example, a stock market crash produces a communication system outage that slows herd behavior—the real danger arises when interactions among two crises' causes and effects

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create a positive feedback in which each crisis keeps worsening the other. Positive feedbacks can quickly overwhelm institutional safeguards and controls. And they can create an acute policymaking dilemma in which one crisis cannot be resolved without remediating a second one—but the second cannot be resolved without remediating the first.

Figure 9 illustrates several harmful positive feedbacks that appear to be forming today within and between the global systems identified in Figure 1. Compared to Figure 8, which shows how stresses, triggers, and crises can cascade unidirectionally over time, Figure 9 illustrates the back-and-forth (or cyclical) interactions between crises, triggers, and stresses.

[Figure 9: Inter-systemic feedback loops in the global polycrisis]

In Figure 9A, economic turmoil arising, for instance, from inflation, financial crisis, and debt—or perhaps due to scarcities of key resources such as energy, food, water, and raw materials—creates mass grievances and institutional opportunities for populist leaders to capture political power and weaken the rule of law. These leaders' actions to establish authoritarian regimes simultaneously draw on and amplify nationalist, chauvinistic, and anti-globalization ideologies, often by scapegoating foreigners, cosmopolitan elites, and internal minorities. Although their efforts to decouple the national economy from the world economy generally worsen internal economic turmoil, this turmoil, paradoxically, often exacerbates the grievances and opportunities the leaders can exploit to consolidate their power (by blaming "foreign elements" or "internal enemies" for the economic crisis). In the last decade, this feedback has operated in such diverse countries as Venezuela, Nicaragua, Russia, Turkey, Zimbabwe, Myanmar, and Sri Lanka.

In Figure 9B, we show that populist authoritarian regimes espousing nationalist and anti-globalization ideologies generally decrease their participation in international institutions, reduce their international cooperation, and focus their attention and resources inward. They thus diminish opportunities for mutually beneficial economic exchange and forego the benefits of globalization, which can worsen both internal and global economic turmoil.

In Figure 9C, we indicate that, in the decades ahead, less international cooperation will perhaps fatally weaken international action to slow climate change. More frequent and severe extreme weather events will then trigger flows of migrants towards richer countries (Lustgarten, 2020; Xu et al., 2020), an influx that is likely to increase support for chauvinistic and isolationist ideologies in receiving societies. The resulting exacerbation of economic turmoil could ultimately propel out-migration from these countries.

Finally, Figure 9D shows that the chauvinistic reaction to mass migration is likely to precipitate violence against those seeking refuge and those deemed too sympathetic towards outsiders. Meanwhile, extreme weather events could worsen intercommunal tensions, trigger state collapse and civil war, and increase the probability of international conflicts over scarce resources, including water and food. Civil violence and interstate war tend to deepen nationalism while generating new waves of refugees and exacerbating economic turmoil. These pernicious feedbacks are certainly not inevitable; but if they were to take hold they would escalate all of the problems depicted in Figure 9 in a catastrophic spiral.

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Mapping dominos and loops

The two mapping techniques illustrated above—one focusing on domino effects and the other on inter-systemic feedback loops—complement each other and together enable a distinctly network-based approach to crisis analysis. They help researchers identify those nodes (stresses, triggers, or crises) that are most *influential*—that affect many other nodes in the network—and those that are most *vulnerable*—that are most affected by other nodes (Low, 2021).[xii] In Figure 8, inflation is particularly vulnerable in this sense, while the pandemic is highly influential. Many of the feedback loops presented in Figure 9 travel through the nationalism and anti-globalization node, suggesting that people's ideological reactions to change will play a highly influential role in shaping future outcomes.

Network maps of global crises are not entirely new, of course. The World Economic Forum's (WEF) annual *Global Risk Report* has included similar diagrams since 2007 (WEF, 2007, p. 13). Most recently, the 2023 report (WEF, 2023) identifies "state collapse," "erosion of social cohesion," "collapse of a systemically important supply chain," "interstate conflict," and "cost-of-living crisis" as the most influential global risks (i.e., those most connected to other global risks).

Although WEF's diagrams provide useful insights into the architecture of the current global polycrisis, the Forum acknowledges their limitations. For one thing, the diagrams' links depict only positive correlations between risks—that is, about the likelihood that certain risks will appear together—not actual causal connections between them.[xiii] Neither do the diagrams convey information about negative correlations, where the occurrence of certain risks diminishes the likelihood of others (WEF, 2008, p. 25). Also, network maps like those presented by the WEF provide a static snapshot of risk connections at a particular moment; they do not reveal how risks and their connections change over time as crises occur and activate other risks. Finally, the data underlying the WEF diagrams are derived from surveys of leaders and experts in the business community. But when scientists were asked to appraise the same global risks, they generally judged them to be more likely and harmful than did the WEF's respondents (Future Earth, 2020; Future Earth et al., 2021; Garschagen et al., 2020).

To address these challenges, the emerging polycrisis research program should prioritize methodological innovation that uses valid and reliable measures of key variables to identify the actual casual mechanisms linking stresses, triggers, and crises.

5. Conclusion: A polycrisis research program and lessons for policy

[xii] In network analysis, the term "degree" refers to the number of links (connections) a given node has, which can be further divided into incoming and outgoing flows (in-degree and out-degree, respectively). High out-degree nodes have more influence on other nodes, while high in-degree nodes are more vulnerable to developments elsewhere in the network.

[xiii] We adopt a non-Humean ontology of causation that presumes causation is more than just observed patterns of correlation and requires real physical mechanisms linking cause and effect.

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We argue that the world is experiencing a worsening polycrisis and propose a conceptual framework for understanding how crises (and their precursor stresses and triggers) become entangled across global systems. This framework will help researchers identify and study the causal mechanisms that produce crisis amplification, acceleration, and synchronization.

We thus place the polycrisis concept at the centre of an urgent new research program. This program can draw on theories and methods in other fields to explain the dynamics of crisis interaction. Complexity science provides theories explaining critical transitions (Scheffer, 2009), path dependence (Pierson, 2004), stability landscapes (Folke et al., 2010; Walker et al., 2004), and the underlying sources of complexity (Arthur, 1993). Network science elucidates the structure of connectivity within global systems, including the interactions between networks (Buldyrev et al., 2010; Gao et al., 2015). And process tracing (a method of historical analysis in the social sciences) allows researchers to discern causal mechanisms in situations where controlled-case comparisons are impossible (George and Bennett, 2005, pp. 205-32), as when observed crisis interactions are historically unprecedented.

Targeted empirical research investigating specific crisis interactions can guide policymakers and other actors seeking to navigate the polycrisis. Our analysis points to three broad policy implications.

Focus on crisis interactions, not isolated crises: Governments tend to focus on individual and immediate threats, which often renders their management of systemic risks ineffective (ISC et al., 2022, p. 8). Because today's crises are causally entangled, they can be neither fully understood nor addressed in isolation from one another. A comprehensive approach is necessary—an "integrated assessment" of the full range of interlinked crises involved—especially when policies that address one crisis might worsen or undermine efforts to resolve others (Baum & Barrett, 2018).

Address system architecture, not just events: The polycrisis concept also highlights the role of densely interconnected global systems as the conduits that transmit the causes and effects of cascading crises. Policymakers must work to change system structures that generate such hazards. They can, for instance, strengthen negative (dampening) feedbacks that counteract pernicious positive feedbacks. In some cases, they might reduce connectivity or create buffers (or firebreaks) at sites of systemic vulnerability. Recent efforts to more heavily regulate financial institutions designated as systemically important show that governments and international agencies are starting to internalize this principle. But much more can be done to protect technological infrastructure (by increasing the resilience of vital communications systems to electrical grid and satellite failures, for instance), strengthen food systems (by buffering against the risk of simultaneous breadbasket failures (Gaupp et al., 2020)), and reduce pandemics arising from zoonotic spillover (by limiting wet markets, bushmeat consumption, and the illegal wildlife trade). Broadly speaking, policymakers should consider resilience alongside efficiency when evaluating policy outcomes, which means encouraging policy diversity, experimentation, and redundancy—all elements of adaptive management.

Exploit high-leverage intervention points: Many of the same features of complex systems that create polycrises also provide opportunities for systemic transformations toward more desirable futures. When systems are prone to non-linearities, positive feedbacks, and critical transitions, a relatively small action may have a profound effect, if it is tailored to the system's features (Meadows & Wright, 2008, pp. 145-

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65; Otto et al., 2020; Lenton et al., 2022). Network-based polycrisis visualization and analysis can help identify such intervention points.

The polycrisis concept—if effectively grounded in a scientific research program focused on practical steps to improve policy outcomes—can help us better address the world's interlinked crises. It can inform strategies to prevent the amplification, acceleration, and synchronization of crises and to respond when polycrises occur. But this research program needs to start now. "Business as usual," says United Nations Secretary-General António Guterres, "could result in breakdown of the global order, into a world of perpetual crisis and winner-takes-all" (Guterres, 2021).

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References:

Adelphi, & Potsdam Institute for Climate Impact Research [PIK]. (2020). *10 Insights on Climate Impacts and Peace: A Summary of What we Know*. Adelphi Research and Potsdam Institute for Climate Impact Research. Retrieved from Adelphi Research and Potsdam Institute for Climate Impact Research website: https://weatheringrisk.org/sites/default/files/document/10%20Insights%20on%20Climate%20Impacts%20and%20Peace%20Report_0.pdf

Allison, G. T. (2017). *Destined for war: Can America and China escape Thucydides's trap?* Melbourne London: Scribe Publications.

Araf, Y., Maliha, S. T., Zhai, J., & Zheng, C. (2023). Marburg virus outbreak in 2022: A public health concern. *The Lancet Microbe*, *4*(1), e9. https://doi.org/10.1016/S2666-5247(22)00258-0

Armstrong McKay, D. I., Staal, A., Abrams, J. F., Winkelmann, R., Sakschewski, B., Loriani, S., … Lenton, T. M. (2022). Exceeding 1.5°C global warming could trigger multiple climate tipping points. *Science*, *377*(6611), eabn7950. https://doi.org/10.1126/science.abn7950

Arthur, W. B. (1993). On the evolution of complexity. *Santa Fe Institute Working Paper 1993-11-070*. Santa Fe Institute.

Barnosky, A. D., Hadly, E. A., Bascompte, J., Berlow, E. L., Brown, J. H., Fortelius, M., … Smith, A. B. (2012). Approaching a state shift in Earth's biosphere. *Nature*, *486*(7401), 52–58. https://doi.org/10.1038/nature11018

Baum, S. D., & Barrett, A. M. (2018). Towards an Integrated Assessment of Global Catastrophic Risk. In *Proceedings of the First International Colloquium on Catastrophic and Existential Risk* (pp. 41–62). Garrick Institute for the Risk Sciences, University fo California, Los Angeles.

Beddoe, R., Costanza, R., Farley, J., Garza, E., Kent, J., Kubiszewski, I., … Woodward, J. (2009). Overcoming systemic roadblocks to sustainability: The evolutionary redesign of worldviews, institutions, and technologies. *Proceedings of the National Academy of Sciences*, *106*(8), 2483–2489. https://doi.org/10.1073/pnas.0812570106

Biggs, D., Biggs, R. (Oonsie), Dakos, V., Scholes, R. J., & Schoon, M. (2011). Are We Entering an Era of Concatenated Global Crises? *Ecology and Society*, *16*(2), art27. https://doi.org/10.5751/ES-04079-160227

Birdsall, N., & Fukuyama, F. (2011). The Post-Washington Consensus: Development After the Crisis. *Foreign Affairs*, *90*(2), 45–53.

Blom, P. (2019). *Nature's mutiny: How the little Ice Age of the long seventeenth century transformed the West and shaped the present*. New York: Liveright Publishing Corporation, a division of W.W. Norton & Company.

Buldyrev, S. V., Parshani, R., Paul, G., Stanley, H. E., & Havlin, S. (2010). Catastrophic cascade of failures in interdependent networks. *Nature*, *464*(7291), 1025–1028. https://doi.org/10.1038/nature08932

Buzan, B., Wæver, O., & Wilde, J. de. (1998). *Security: A new framework for analysis*. Boulder, Colo: Lynne Rienner Pub.

Carlson, C. J., Albery, G. F., Merow, C., Trisos, C. H., Zipfel, C. M., Eskew, E. A., … Bansal, S. (2022). Climate change increases cross-species viral transmission risk. *Nature*, *607*(7919), 555–562. https://doi.org/10.1038/s41586-022-04788-w

https://doi.org/10.1017/sus.2024.1 Published online by Cambridge University Press

Centeno, M. A., Nag, M., Patterson, T. S., Shaver, A., & Windawi, A. J. (2015). The Emergence of Global Systemic Risk. *Annual Review of Sociology*, *41*(1), 65–85. https://doi.org/10.1146/annurev-soc-073014-112317

Clapp, J. (2023). Concentration and crises: Exploring the deep roots of vulnerability in the global industrial food system. *The Journal of Peasant Studies*, *50*(1), 1–25. https://doi.org/10.1080/03066150.2022.2129013

Cline, E. H. (2014). *1177 B.C: The year civilization collapsed*. Princeton: Princeton University Press.

Council on Foreign Relations [CFR]. (2023). *Major Epidemics of the Modern Era, 1899-2022*. Retrieved from https://www.cfr.org/timeline/major-epidemics-modern-era

Dahl, R. A. (1957). The concept of power. *Behavioral Science*, *2*(3), 201–215. https://doi.org/10.1002/bs.3830020303

Davies, M., & Hobson, C. (2022). An embarrassment of changes: International Relations and the COVID-19 pandemic. *Australian Journal of International Affairs*, 1–19. https://doi.org/10.1080/10357718.2022.2095614

Drezner, D. (2023, January 28). Are we headed toward a 'Polycrisis'? The Buzzword of the Moment Explained. *Vox.Com*. Retrieved from https://www.vox.com/23572710/polycrisis-davos-history-climate-russia-ukraine-inflation

Folke, C., Carpenter, S. R., Walker, B., Scheffer, M., Chapin, T., & Rockström, J. (2010). Resilience Thinking: Integrating Resilience, Adaptability, and Transformability. *Ecology and Society*, *15*(4). Retrieved from https://www.ecologyandsociety.org/vol15/iss4/art20/

Future Earth. (2020). *Risk Perceptions Report 2020*. Future Earth. Retrieved from Future Earth website: https://futureearth.org/wp-content/uploads/2020/02/RPR_2020_Report.pdf

Future Earth, Sustainability In The Digital Age, & International Science Council. (2021). *Global Risks Perceptions Report 2021*. Zenodo. https://doi.org/10.5281/ZENODO.5764288

Gao, J., Liu, X., Li, D., & Havlin, S. (2015). Recent Progress on the Resilience of Complex Networks. *Energies*, *8*(10), 12187–12210. https://doi.org/10.3390/en81012187

Garschagen, M., Wood, S. L. R., Garard, J., Ivanova, M., & Luers, A. (2020). Too Big to Ignore: Global Risk Perception Gaps Between Scientists and Business Leaders. *Earth's Future*, *8*(3). https://doi.org/10.1029/2020EF001498

Gaupp, F., Hall, J., Hochrainer-Stigler, S., & Dadson, S. (2020). Changing risks of simultaneous global breadbasket failure. *Nature Climate Change*, *10*(1), 54–57. https://doi.org/10.1038/s41558-019-0600-z

George, A. L., & Bennett, A. (2005). *Case studies and theory development in the social sciences*. Cambridge, Mass: MIT Press.

Georgieva, K. (2022, April). *Facing crisis upon crisis: How the world can respond*. Presented at the Annual Meetings of the World Bank and International Monetary Fund, Washington, DC. Washington, DC. Retrieved from https://www.imf.org/en/News/Articles/2022/04/14/sp041422-curtain-raiser-sm2022

Gilpin, R. (1988). The Theory of Hegemonic War. *Journal of Interdisciplinary History*, *18*(4), 591. https://doi.org/10.2307/204816

Gilpin, R. (2002). *War and change in world politics* ([Repr.], transferred to digital print). Cambridge: Cambridge Univ. Press.

Global Catastrophic Risk Institute [GCRI]. (2023). *About*. Global Catastrophic Risk Institute. Retrieved from https://gcrinstitute.org/about/

Goldin, I., & Mariathasan, M. (2016). *The butterfly defect: How globalization creates systemic risks, and what to do about It* (Third printing and first paperback printing). Princeton Oxford: Princeton University Press.

Gunderson, L. H., & Holling, C. S. (Eds.). (2002). *Panarchy: Understanding transformations in human and natural systems*. Washington, DC: Island Press.

Guterres, A. (2021). *Global Crisis Response 'Too Little, Too Late', Secretary-General Tells Assembly 'Our Common Agenda' Event, Warning of Instability, Climate Chaos*. United Nations Meetings Coverage and Press Releases. Retrieved from https://press.un.org/en/2021/sgsm20891.doc.htm

Hall, C. A. S. (2018). *Energy return on investment: A unifying principle for biology, economics, and sustainability*. Cham, Switzerland: Springer.

Hansen, J. E., Sato, M., Simons, L., Nazarenko, L. S., Sangha, I., Kharecha, P., … Li, J. (2023). Global warming in the pipeline. *Oxford Open Climate Change*, *3*(1), kgad008. https://doi.org/10.1093/oxfclm/kgad008

Helbing, D. (2013). Globally networked risks and how to respond. *Nature*, *497*(7447), 51–59. https://doi.org/10.1038/nature12047

Holling, C. S. (2001). Understanding the Complexity of Economic, Ecological, and Social Systems. *Ecosystems*, *4*(5), 390–405. https://doi.org/10.1007/s10021-001-0101-5

Homer-Dixon, T. (2023, October 18). Why so much is going wrong at the same time. *Vox.Com*. Retrieved from https://www.vox.com/future-perfect/23920997/polycrisis-climate-pandemic-population-connectivity

Homer-Dixon, T. F. (2020). *Commanding hope: The power we have to renew a world in peril*. Toronto: Alfred A. Knopf Canada.

Homer-Dixon, T., Lawrence, M., & Janzwood, S. (2023, February 18). Dismissing the Term 'Polycrisis' has One Inevitable Consequence—Reality Always Bites. *The Globe and Mail*. Retrieved from https://www.theglobeandmail.com/opinion/article-dismissing-the-term-polycrisis-has-one-inevitable-consequence-reality/

Homer-Dixon, T., & Rockström, J. (2022, November 13). What Happens when a Cascade of Crises Collide? *The New York Times*. Retrieved from https://www.nytimes.com/2022/11/13/opinion/coronavirus-ukraine-climate-inflation.html

Homer-Dixon, T., Walker, B., Biggs, R., Crépin, A.-S., Folke, C., Lambin, E. F., … Troell, M. (2015). Synchronous failure: The emerging causal architecture of global crisis. *Ecology and Society*, *20*(3), art6. https://doi.org/10.5751/ES-07681-200306

Hoyer, D., Bennett, J. S., Reddish, J., Holder, S., Howard, R., Benam, M., … Turchin, P. (2023). *Navigating Polycrisis: Long-run socio-cultural factors shape response to changing climate* [Preprint]. SocArXiv. https://doi.org/10.31235/osf.io/h6kma

Ide, T., Brzoska, M., Donges, J. F., & Schleussner, C.-F. (2020). Multi-method evidence for when and how climate-related disasters contribute to armed conflict risk. *Global Environmental Change*, *62*, 102063. https://doi.org/10.1016/j.gloenvcha.2020.102063

Ikenberry, G. J. (Ed.). (2014). *Power, order, and change in world politics*. Cambridge ; New York: Cambridge University Press.

International Science Council [ISC], United Nations Office for Disaster Risk Reduction [UNDRR], & Risk Knowledge Action Network [RISK KAN]. (2022). *ISC-UNDRR-RISK KAN Briefing note on systemic risk*. International Science Council. https://doi.org/10.24948/2022.01

Janzwood, S. (2022). Confidence deficits and reducibility: Toward a coherent conceptualization of uncertainty level. *Risk Analysis*, risa.14008. https://doi.org/10.1111/risa.14008

Jervis, R. (1997). *System effects: Complexity in political and social life*. Princeton, N.J: Princeton University Press.

Juncker, J.-C. (2018, February). *Speech by President Jean-Claude Juncker at the Opening Plenary Session of the Ideas Lab 2018 'Europe—Back on Track' of the Centre for European Policy Studies*. Retrieved from https://ec.europa.eu/commission/presscorner/detail/en/SPEECH_18_1121

Kaufman, G. G., & Scott, K. E. (2003). What is systemic risk, and do bank regulators retard or contribute to it? *The Independent Review*, *7*(3), 371–391.

Kemp, L., Xu, C., Depledge, J., Ebi, K. L., Gibbins, G., Kohler, T. A., … Lenton, T. M. (2022). Climate Endgame: Exploring catastrophic climate change scenarios. *Proceedings of the National Academy of Sciences*, *119*(34), e2108146119. https://doi.org/10.1073/pnas.2108146119

Keys, P. W., Galaz, V., Dyer, M., Matthews, N., Folke, C., Nyström, M., & Cornell, S. E. (2019). Anthropocene risk. *Nature Sustainability*, *2*(8), 667–673. https://doi.org/10.1038/s41893-019-0327-x

Khoury, C. K., Bjorkman, A. D., Dempewolf, H., Ramirez-Villegas, J., Guarino, L., Jarvis, A., … Struik, P. C. (2014). Increasing homogeneity in global food supplies and the implications for food security. *Proceedings of the National Academy of Sciences*, *111*(11), 4001–4006. https://doi.org/10.1073/pnas.1313490111

Klose, A. K., Wunderling, N., Winkelmann, R., & Donges, J. F. (2021). What do we mean, 'tipping cascade'? *Environmental Research Letters*, *16*(12), 125011. https://doi.org/10.1088/1748-9326/ac3955

Kluth, A. (2023, January 21). So We're in a Polycrisis. Is that Even a Thing? *The Washington Post*. Retrieved from https://www.washingtonpost.com/business/so-were-in-a-polycrisis-is-that-even-a-thing/2023/01/21/cf05856e-9963-11ed-a173-61e055ec24ef_story.html

Koselleck, R. (2006). Crisis. *Journal of the History of Ideas*, *67*(2), 357–400.

Lähde, V. (2023). The Polycrisis. *Aeon*. Retrieved from https://aeon.co/essays/the-case-for-polycrisis-as-a-keyword-of-our-interconnected-times

Lakatos, I., & Musgrave, A. (Eds.). (1970). *Criticism and the Growth of Knowledge: Proceedings of the International Colloquium in the Philosophy of Science, London, 1965* (1st ed.). Cambridge University Press. https://doi.org/10.1017/CBO9781139171434

Lawrence, M., Janzwood, S., & Homer-Dixon, T. (2022). *What is a Global Polycrisis? And How is it Different from a Systemic Risk?* (No. Discussion Paper 2022-4. Version 2.0). Cascade Institute. Retrieved from Cascade Institute website: https://cascadeinstitute.org/technical-paper/what-is-a-global-polycrisis/

Lenton, T. M., Benson, S., Smith, T., Ewer, T., Lanel, V., Petykowski, E., … Sharpe, S. (2022). Operationalising positive tipping points towards global sustainability. *Global Sustainability*, *5*, e1. https://doi.org/10.1017/sus.2021.30

Low, I. (2021, June 11). Making Sense of Risk in an Interconnected World. *Business Times*. Retrieved from https://www.businesstimes.com.sg/hub/boardroom-matters/making-sense-of-risk-in-an-interconnected-world

Lustgarten, A. (2020, July 23). The Great Climate Migration. *The New York Times Magazine*. Retrieved from https://www.nytimes.com/interactive/2020/07/23/magazine/climate-migration.html

https://doi.org/10.1017/sus.2024.1 Published online by Cambridge University Press

Malpass, D. (2022, September). *The crisis facing development*. Stanford Institute for Economic Policy Research. Retrieved from https://www.worldbank.org/en/news/speech/2022/09/29/the-crisis-facing-development-speech-by-world-bank-group-president-david-malpass-before-the-2022-annual-meetings

Meadows, D. H., & Wright, D. (2008). *Thinking in systems: A primer*. White River Junction, Vt: Chelsea Green Pub.

Monbiot, G. (2016, April 15). Neoliberalism—The Ideology at the Root of All Our Problems. *The Guardian*. Retrieved from https://www.theguardian.com/books/2016/apr/15/neoliberalism-ideology-problem-george-monbiot

Morin, E., & Kern, A. B. (1999). *Homeland earth: A manifesto for the new millenium*. Cresskill, N.J: Hampton Press.

Nye, J. S. (2011). *The future of power* (1st ed). New York: PublicAffairs.

Nyström, M., Jouffray, J.-B., Norström, A. V., Crona, B., Søgaard Jørgensen, P., Carpenter, S. R., … Folke, C. (2019). Anatomy and resilience of the global production ecosystem. *Nature*, *575*(7781), 98–108. https://doi.org/10.1038/s41586-019-1712-3

Otto, I. M., Donges, J. F., Cremades, R., Bhowmik, A., Hewitt, R. J., Lucht, W., … Schellnhuber, H. J. (2020). Social tipping dynamics for stabilizing Earth's climate by 2050. *Proceedings of the National Academy of Sciences*, *117*(5), 2354–2365. https://doi.org/10.1073/pnas.1900577117

Perrow, C. (1999). *Normal accidents: Living with high-risk technologies*. Princeton, N.J: Princeton University Press.

Pierson, P. (2004). *Politics in time: History, institutions, and social analysis*. Princeton: Princeton University Press.

Pikovsky, A., Rosenblum, M., & Kurths, J. (2007). *Synchronization: A universal concept in nonlinear sciences* (Repr., transferred to digital printing). Cambridge: Cambridge Univ. Press.

Progressive International. (2023). *The New International Economic Order*. Progressive International. Retrieved from https://progressive.international/blueprint/1350647f-15c9-4f62-8b39-bddadc7046c3-the-new-international-economic-order/en

Renn, O. (2016). Systemic Risks: The New Kid on the Block. *Environment: Science and Policy for Sustainable Development*, *58*(2), 26–36. https://doi.org/10.1080/00139157.2016.1134019

Renn, O., Lucas, K., Haas, A., & Jaeger, C. (2019). Things are different today: The challenge of global systemic risks. *Journal of Risk Research*, *22*(4), 401–415. https://doi.org/10.1080/13669877.2017.1409252

Rocha, J. C., Peterson, G., Bodin, Ö., & Levin, S. (2018). Cascading regime shifts within and across scales. *Science*, *362*(6421), 1379–1383. https://doi.org/10.1126/science.aat7850

Rockström, J., Gupta, J., Lenton, T. M., Qin, D., Lade, S. J., Abrams, J. F., … Winkelmann, R. (2021). Identifying a Safe and Just Corridor for People and the Planet. *Earth's Future*, *9*(4). https://doi.org/10.1029/2020EF001866

Rodrik, D. (2011). *The globalization paradox: Democracy and the future of the world economy*. New York: W. W. Norton & Co.

Rodrik, D. (2019). Globalization's Wrong Turn: And How it Hurt America. *Foreign Affairs*, *98*(4), 26–33.

Roubini, N. (2022). *Megathreats: Ten dangerous trends that imperil our future, and how to survive them* (First edition). New York: Little, Brown and Company.

Scheffer, M. (2009). *Critical transitions in nature and society*. Princeton, N.J: Princeton University Press.

https://doi.org/10.1017/sus.2024.1 Published online by Cambridge University Press

Scheffer, M., Carpenter, S. R., Lenton, T. M., Bascompte, J., Brock, W., Dakos, V., … Vandermeer, J. (2012). Anticipating Critical Transitions. *Science*, *338*(6105), 344–348. https://doi.org/10.1126/science.1225244

Schleussner, C.-F., Donges, J. F., Donner, R. V., & Schellnhuber, H. J. (2016). Armed-conflict risks enhanced by climate-related disasters in ethnically fractionalized countries. *Proceedings of the National Academy of Sciences*, *113*(33), 9216–9221. https://doi.org/10.1073/pnas.1601611113

Schweizer, P.-J. (2021). Systemic risks – concepts and challenges for risk governance. *Journal of Risk Research*, *24*(1), 78–93. https://doi.org/10.1080/13669877.2019.1687574

Serhan, Y. (2023, January 17). Why 'Polycrisis' was the Buzzword of Day 1 in Davos. *Time*. Retrieved from https://time.com/6247799/polycrisis-in-davos-wef-2023/

Sial, F. (2023, January 27). Whose Polycrisis? Retrieved from Developing Economics website: https://developingeconomics.org/2023/01/27/whose-polycrisis/

Smil, V. (2016). *Power density: A key to understanding energy sources and uses* (First MIT Press paperback edition). Cambridge, Massachusetts London, England: The MIT Press.

Smil, V. (2022). *How the world really works: The science behind how we got here and where we're going* (First United States edition). New York: Viking.

Smith, K. F., Goldberg, M., Rosenthal, S., Carlson, L., Chen, J., Chen, C., & Ramachandran, S. (2014). Global rise in human infectious disease outbreaks. *Journal of The Royal Society Interface*, *11*(101), 20140950. https://doi.org/10.1098/rsif.2014.0950

Steffen, W., Rockström, J., Richardson, K., Lenton, T. M., Folke, C., Liverman, D., … Schellnhuber, H. J. (2018). Trajectories of the Earth System in the Anthropocene. *Proceedings of the National Academy of Sciences*, *115*(33), 8252–8259. https://doi.org/10.1073/pnas.1810141115

Strogatz, S. H. (2003). *Sync: The emerging science of spontaneous order* (1st ed). New York: Hyperion.

Summers, L. H., & Ahmed, M. (2022, October 5). World Bank-IMF Meetings are the Last Stop Before a Coming Economic Storm. *The Washington Post*. Retrieved from https://www.washingtonpost.com/opinions/2022/10/05/imf-world-bank-meetings-prepare-economic-downtown/

Swilling, M. (2013). Economic crisis, long waves and the sustainability transition: An African perspective. *Environmental Innovation and Societal Transitions*, *6*, 96–115. https://doi.org/10.1016/j.eist.2012.11.001

Swilling, M. (2020). *The age of sustainability: Just transitions in a complex world*. London ; New York: Routledge, Taylor & Francis Group.

Tooze, A. (2022, June 24). Defining polycrisis—From crisis pictures to the crisis matrix. Retrieved from Chartbook website: https://adamtooze.substack.com/p/chartbook-130-defining-polycrisis

Tooze, J. A. (2021). *Shutdown: How COVID shook the world's economy*. New York: Viking, an imprint of Penguin Random House LLC.

United Nations Children's Fund [UNICEF] Innocenti - Global Office of Research and Foresight. (2023). *Prospects for Children in the Polycrisis: A 2023 Global Outlook* (p. 53) [Global Outlook Report]. Florence, italy: UNICEF Innocenti - Global Office of Research and Foresight. Retrieved from UNICEF Innocenti - Global Office of Research and Foresight website: https://www.unicef.org/globalinsight/media/3001/file/UNICEF-Innocenti-Prospects-for-Children-Global-Outlook-2023.pdf

United Nations Development Programme Regional Bureau for Asia and the Pacific. (2022). *Polycrisis and Long-Term Thinking*. United Nations Development Programme. Retrieved from United Nations

Development Programme website: https://www.undp.org/asia-pacific/publications/polycrisis-and-long-term-thinking-reimagining-development-asia-and-pacific-foresight-brief

Walker, B., Crépin, A.-S., Nyström, M., Anderies, J. M., Andersson, E., Elmqvist, T., … Vincent, J. R. (2023). Response diversity as a sustainability strategy. *Nature Sustainability*, *6*(6), 621–629. https://doi.org/10.1038/s41893-022-01048-7

Walker, B., Holling, C. S., Carpenter, S. R., & Kinzig, A. (2004). Resilience, Adaptability and Transformability in Social-Ecological Systems. *Ecology and Society*, *9*(2). Retrieved from https://www.ecologyandsociety.org/vol9/iss2/art5/

Walker, W. E., Harremoës, P., Rotmans, J., van der Sluijs, J. P., van Asselt, M. B. A., Janssen, P. P. M., & Krayer von Kraus, M. P. (2003). Defining Uncertainty: A Conceptual Basis for Uncertainty Management in Model-Based Decision-Support. *Integrated Assessment*, *4*, 5–17.

Walt, S. (2022, October 24). How Many Shocks can the World Take? *Foreign Policy*. Retrieved from https://foreignpolicy.com/2022/10/24/how-many-shocks-can-the-world-take/

Wolf, M. (2022, November 29). How to Think about Policy in a Polycrisis. *Financial Times*.

World Economic Forum [WEF]. (2007). *Global Risks 2007: A Global Risk Network Report* (No. 150107; p. 34). Geneva: World Economic Forum. Retrieved from World Economic Forum website: https://www3.weforum.org/docs/WEF_Global_Risks_Report_2007.pdf

World Economic Forum [WEF]. (2008). *Global Risks 2008: A Global Risk Network Report*. Geneva: World Economic Forum. Retrieved from World Economic Forum website: https://www3.weforum.org/docs/WEF_Global_Risks_Report_2008.pdf

World Economic Forum (WEF). (2023). *The Global Risks Report 2023*. Geneva: World Economic Forum. Retrieved from World Economic Forum website: https://www3.weforum.org/docs/WEF_Global_Risks_Report_2023.pdf

Xu, C., Kohler, T. A., Lenton, T. M., Svenning, J.-C., & Scheffer, M. (2020). Future of the human climate niche. *Proceedings of the National Academy of Sciences*, *117*(21), 11350–11355. https://doi.org/10.1073/pnas.1910114117

Zeitlin, J., Nicoli, F., & Laffan, B. (2019). Introduction: The European Union beyond the polycrisis? Integration and politicization in an age of shifting cleavages. *Journal of European Public Policy*, *26*(7), 963–976. https://doi.org/10.1080/13501763.2019.1619803

https://doi.org/10.1017/sus.2024.1 Published online by Cambridge University Press

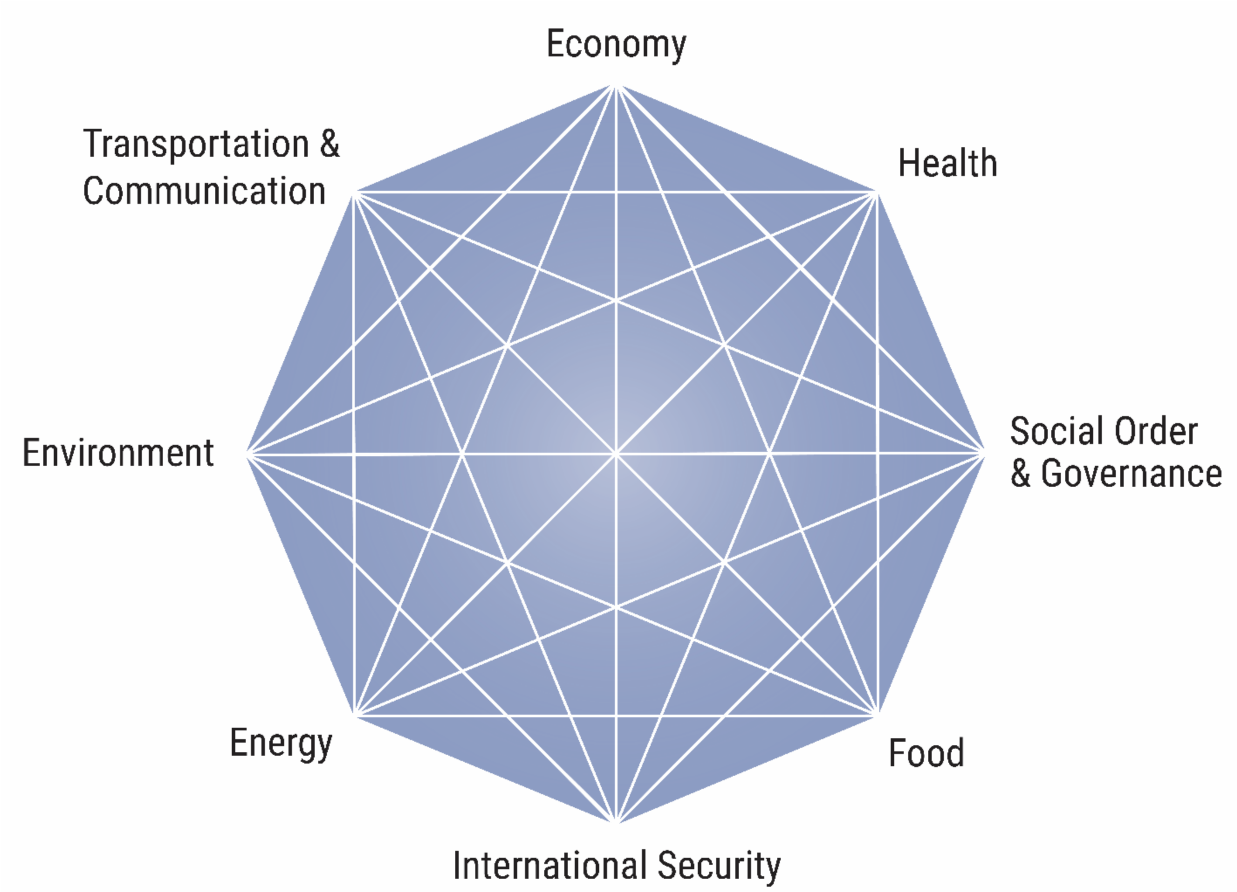

Figure 1: Global systems

Following Donella Meadows (2008), a system is a collection of *elements* whose *connections* create some sort of *whole* with its own qualities. In "global" systems, these three aspects extend over virtually all of humanity and/or the planet. The elements of global systems include agents (such as species, individuals, and organizations) and physical infrastructure (from server farms to ice sheets to cities). In human social systems, elements may also include such entities as worldviews (beliefs about how the world is and how it ought to be), institutions (rules of appropriate behavior), and technologies (procedures for directing physical phenomena to human purposes) (Beddoe et al., 2009). Connections between these elements are their circumplanetary exchanges of energy, material, information, and biota (the "vectors" discussed in Box 1) through the "conduits" outlined in Box 1.

The eight global systems presented here are defined, as "wholes," by the functions they perform in global life. We offer them as one plausible schema by which to disaggregate a messy reality for the purpose of polycrisis analysis. The notion that crises can travel across global systems presumes that we can identify distinct global systems, but discerning their boundaries remains a challenge, because complex systems are, by definition, open to exchanges with their environment; they change and co-

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evolve, which is (in part) what makes the concept of polycrisis so salient. Figure design by Jacob Buurma, Vibrant Content.

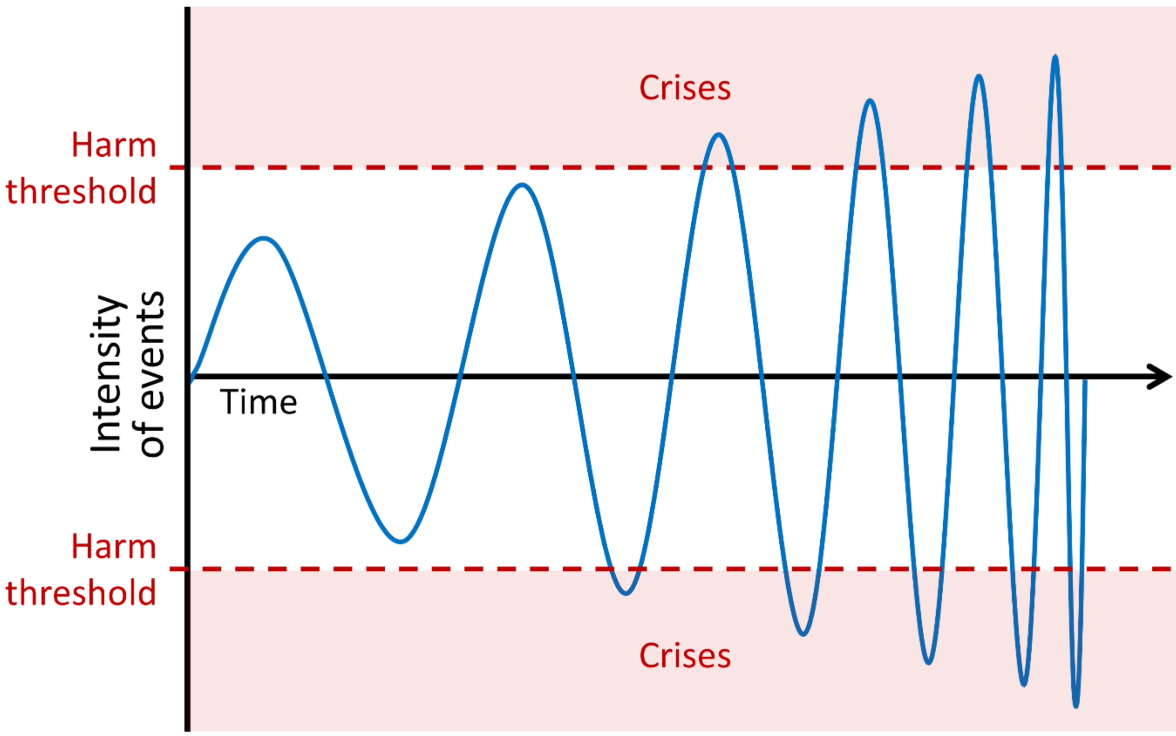

Figure 2: Crisis amplification and acceleration

This waveform diagram metaphorically illustrates the distinction between amplification and acceleration processes. The wave's increasing amplitude (increasing height and depth of peaks) and increasing frequency (decreasing space between peaks) represent, respectively, the amplification and acceleration of system perturbations. Event peaks that pass certain harm thresholds that are normatively defined by society (represented by the red dotted lines) constitute crises.

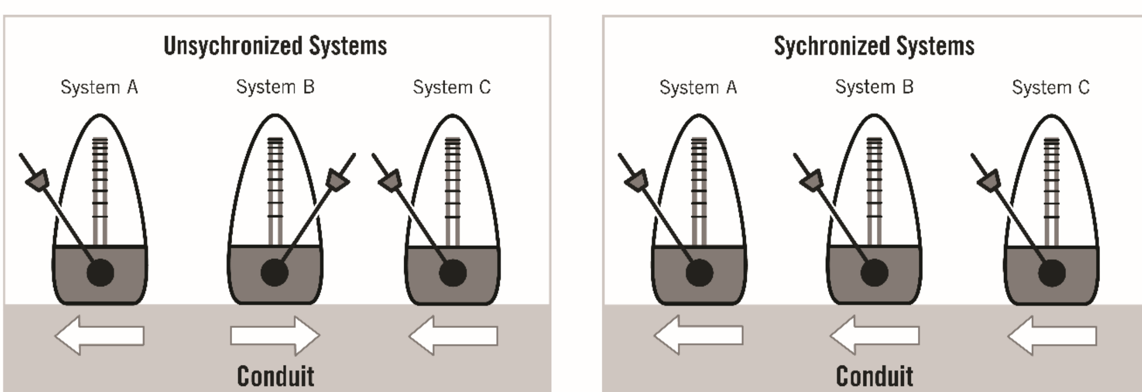

Figure 3: Crisis synchronization

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A real-world analogy demonstrates how a conduit can transmit a vector in a way that synchronizes systems. When several metronomes are placed on a sliding platform, each set to the same tempo but started out of rhythm with the others, they will quickly synchronize their oscillations—that is, fall into the same rhythm. The platform (conduit) transmits the kinetic energy (vector) generated by each metronome (a system) to the other metronomes. When two metronomes happen to align in rhythm, their combined force keeps them in time with one another, and the energy they jointly communicate through the platform increases, encouraging other metronomes to adopt the same rhythm, until all the metronomes on the platform swing in unison. The process constitutes a positive feedback that, though invisible to the untrained observer, produces a striking effect—inter-systemic synchronization.

Figure design by Jacob Buurma, Vibrant Content.

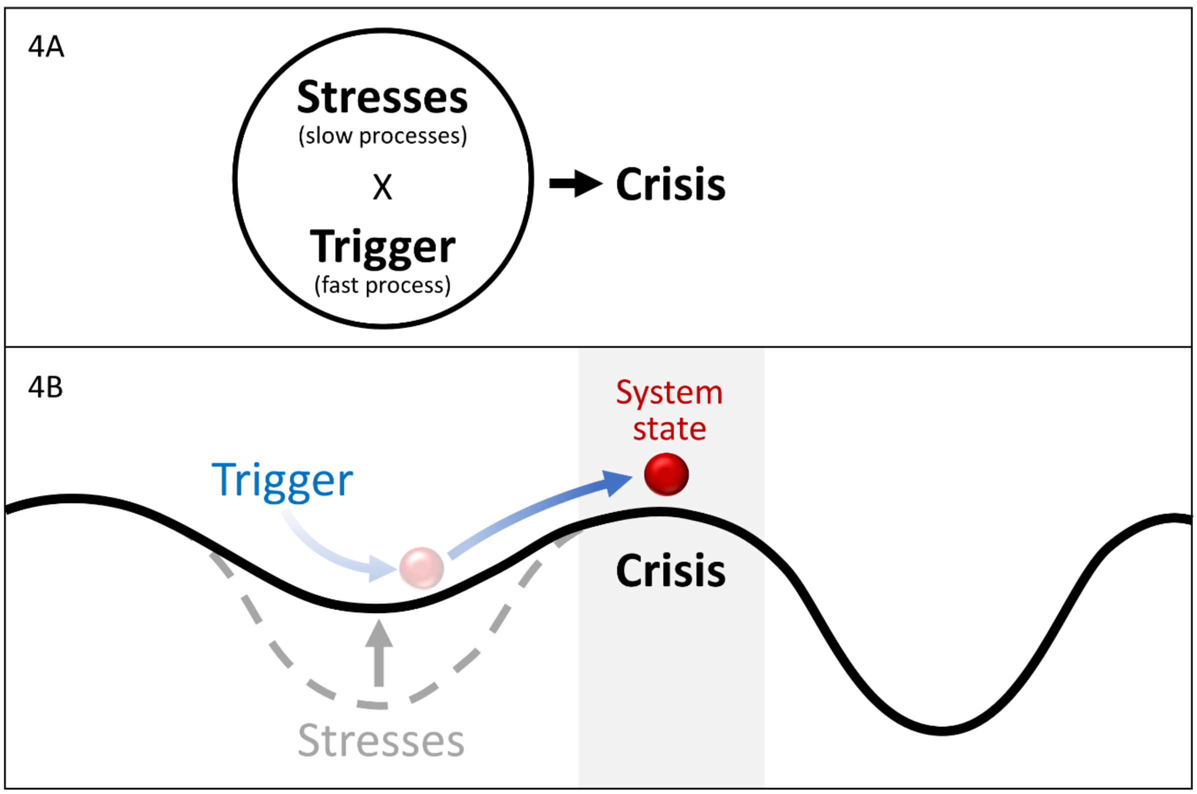

Figure 4: Basic model of systemic crisis

In **Figure 4A**, stresses interact with a trigger in a single system to generate a crisis. The multiplication sign indicates that stresses and trigger are both causally necessary for the crisis outcome and that the trigger multiplies the impact of the underlying stresses. **Figure 4B represents** the above process using a "stability landscape," which is a visual metaphor depicting stability and change in complex systems (Folke et al., 2010; Walker et al., 2004). The horizontal axis represents the range of possible system states defined by different values of the system's core state variables; it condenses (figuratively) an n-dimensional state space into one dimension. The vertical axis represents the degree of system stability; lower positions denote greater stability (and therefor greater probability) than higher ones. The ball represents the system's state—the values of its core state variables—at a particular moment in time.

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The ball tends to roll downwards—towards higher probability states—as if drawn by gravity towards greater stability into a "basin of attraction." But the ball never entirely settles at the bottom of its basin; instead, it is constantly jostled within the basin by the system's internal processes and by perturbations from its surrounding environment. Each basin represents a dynamic equilibrium—a set of feedbacks and relationships that constrain the system's behaviors and provide long-term stability amidst its short-term fluctuations; together the basins keep the system state in bounded regions of the full landscape.

A critical transition (also known as a "regime shift") occurs when a perturbation pushes the system from an established equilibrium into a different one that encompasses a different set of system states and behaviors. Once a system is forced out of equilibrium, it may move into a different basin and thereby complete a critical transition, it may return to its original equilibrium (if antecedent conditions are restored), or it may move around the landscape without settling. The latter situation constitutes a systemic crisis—an incomplete critical transition in which the system has left one basin of attraction but not yet settled into another, and thus remains in a highly unstable and potentially harmful state. Figure 4B illustrates how system stresses can act to make a basin of attraction shallower, so that a trigger event can more easily push the system out of equilibrium.

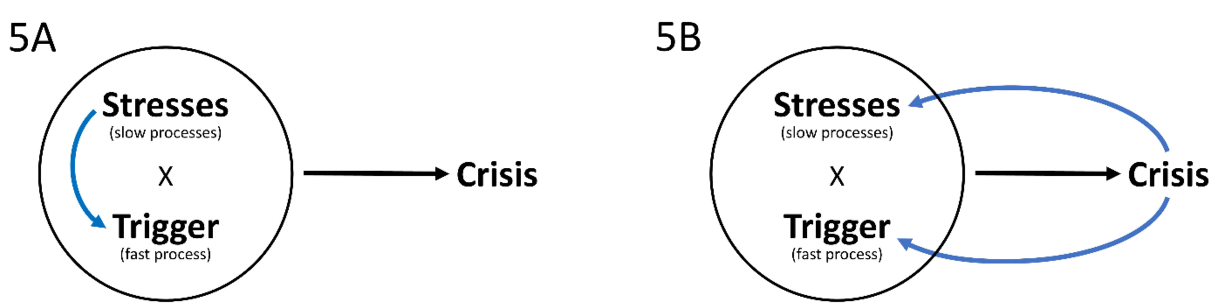

Figure 5: Crisis interactions within a single system

Figure 5A: In some cases, a trigger event is the final increment of a slowly-building stress that pushes the system past a critical threshold and out of its equilibrium, like the proverbial straw that broke the camel's back. In such cases, the stress and the trigger event both relate to the same accumulating pressure. Climate heating, for example, is a long-term stress, but the final increment of heating that "flips" a climate tipping element to a new regime constitutes the trigger event that pushes the climate system into crisis.

Figure 5B: A crisis may feed back upon the stresses and/or trigger event that produced it. A financial crisis, for example, could worsen the stress of massive public and private debt that, in part, enabled the crisis to emerge. A financial crisis could also intensify (or repeat) its own trigger event, by spurring further inflation or interest rate hikes, for instance.

[Suggestion: use the same table format/layout we use for this Figure in the document: "Responses to Reviewer Comments"]

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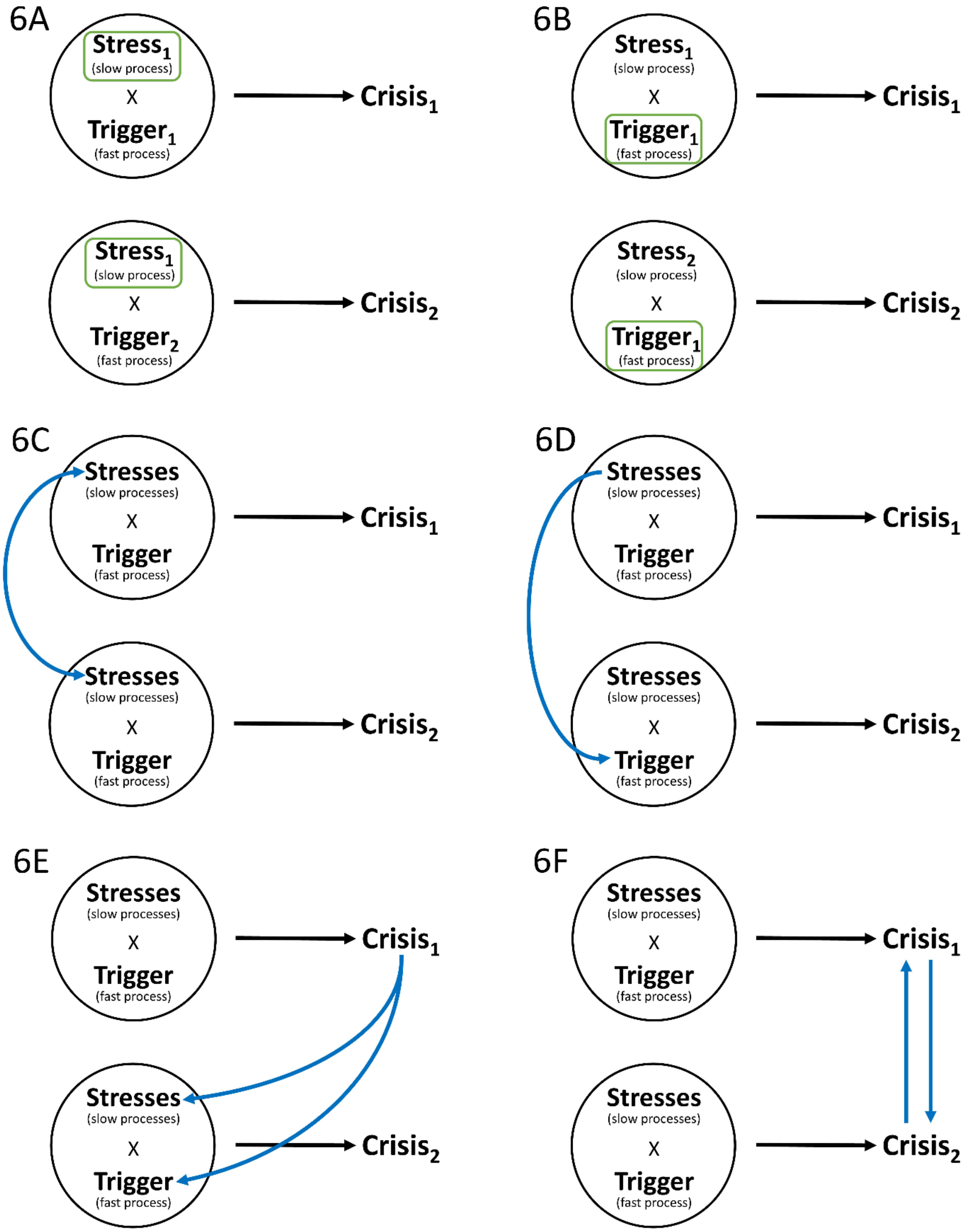

Figure 6: Crisis interactions between multiple systems

Figure 6A: Common stresses

The same stress (indicated by the green boxes) may affect two or more systems. An aging population, for example, places additional demands on healthcare systems. It also strains the economy by diminishing the workforce while increasing government spending on healthcare and social welfare.

Figure 6B: Common triggers

The same trigger (indicated by the green boxes) may interact with stresses in several systems to produce multiple crises. Russia's invasion of Ukraine and the sanctions imposed in response, for example, triggered a crisis in the energy system and in the food system.

Figure 6C: Interacting stresses

A stress in one system may causally interact with a stress in a second system, which could then affect the stress in the first system (as indicated by the blue arrow denoting a causal relationship). Food insecurity, for example, forces the poor to devote a major portion of their income to their alimentary needs rather than education, investment, and enterprise. The result is greater poverty and inequality in the economic system, which may then lower incomes and worsen food insecurity for the most vulnerable segments of society.

Figure 6D: Inter-systemic stress-trigger interactions

A stress in one system may generate a trigger event in another system. By disrupting habitats, for example, climate heating in the Earth system increases the zone of contact between humans and unfamiliar animal species, which increases the likelihood of a zoonotic (animal to human) viral transfer that triggers a pandemic.

Figure 6E: Crisis impacts on adjacent systems

A crisis in one system may causally affect the stresses and/or trigger event of another system. The Covid-19 pandemic, for example, deepened the stress of socio-economic inequality, while aggressive fiscal responses by governments triggered inflation.

Figure 6F: Inter-systemic crisis interactions

A crisis in one system may causally interact with a crisis in another system, altering the dynamics of each. An international security crisis, for example, can worsen the climate crisis by diverting urgently needed attention and resources from climate action, while the climate crisis can intensify an international security crisis by escalating conflict over resources and propelling mass migration.

[Suggestion: use the same table format/layout we use for this Figure in the document: "Responses to Reviewer Comments"]

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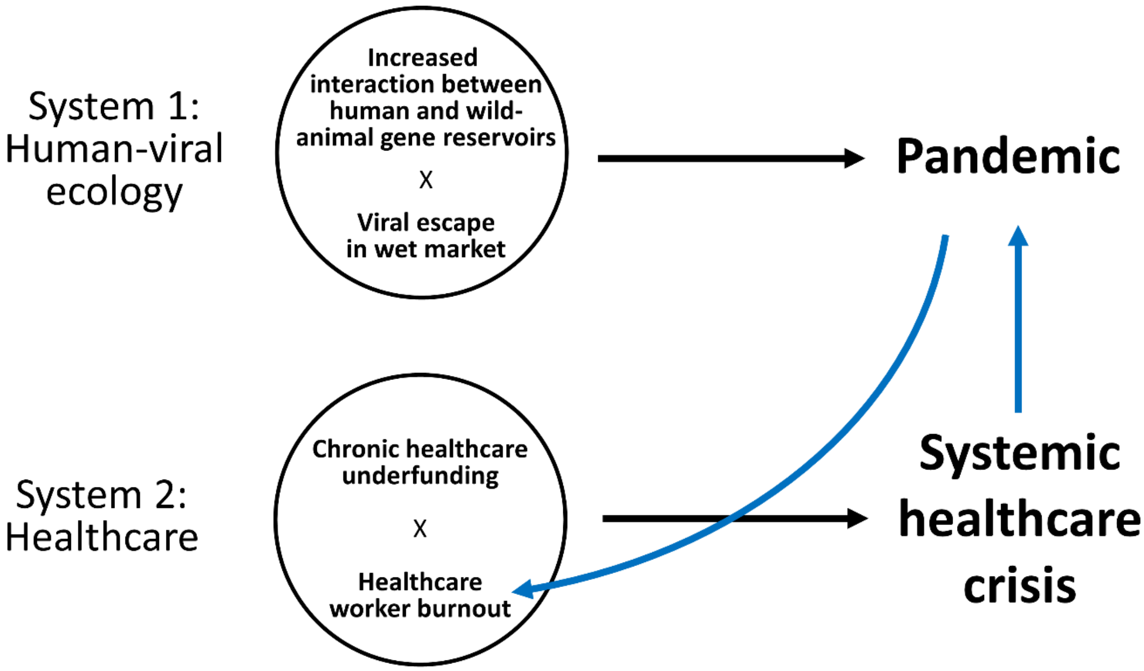

Figure 7: An example of interactions between multiple systems

A pandemic crisis arising from the human-viral ecological system triggers a crisis in the healthcare system, which then further amplifies the pandemic crisis. This example uses elements of the ideal types shown in Figures 6E and 6F.

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Figure 8: Domino effects in the global polycrisis

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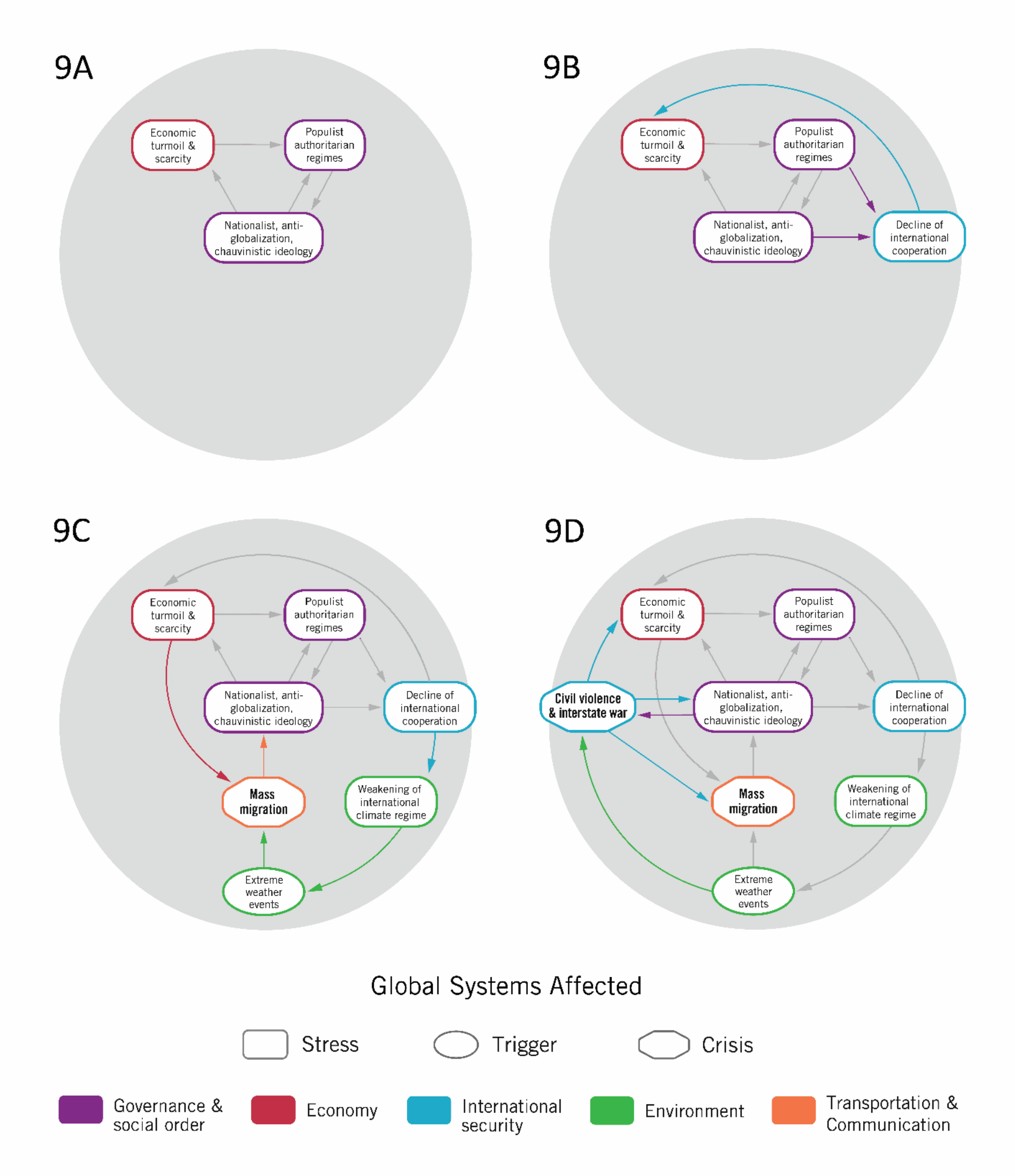

Figure 9: Inter-systemic feedback loops in the global polycrisis

Figure design by Jacob Buurma, Vibrant Content. [figure is explained in the body of the text]

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