# The Grammar of Mindset

*Alia Crum's Mindset Science and the Closure Framework: How Cognitive Grammars Reach Into Biology*

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> *Mindsets are the lenses through which information is perceived, organized, and interpreted. They alter objective reality through behavioral, psychological, and physiological mechanisms.*
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> *Every finite closure generates remainder. The remainder is not noise. It is the proof that the grammar is finite.*
> CF Dietz, Consciousness, Closure, and the Cosmos, 2026


## Abstract

Alia Crum is Associate Professor at Stanford University and Director of the Stanford Mind and Body Lab. Her research demonstrates, across multiple domains and with experimental rigor, that cognitive mindsets, the frameworks through which information is perceived and organized, produce measurable physiological changes in hormone levels, metabolic activity, immune response, and stress physiology. The same milkshake consumed as indulgent suppresses the hunger hormone ghrelin three times more powerfully than the same milkshake consumed as sensible. Hotel workers who reframe their daily labor as exercise achieve measurable improvements in fitness markers without changing their activity level. Participants who view stress as enhancing rather than debilitating show different cortisol profiles and better downstream outcomes. These findings are not placebo effects in the dismissive sense. They are demonstrations of a fundamental fact about biological systems: the cognitive frame through which an organism engages with its situation is not separate from the biological situation itself. It constitutes it. This paper argues that Crum's mindset science is the most broadly applicable empirical demonstration available of the closure framework's central claim: that cognitive closure reaches into biological closure and reconfigures it. Crum demonstrates this across domains, timescales, and populations where Kaptchuk demonstrates it in medicine and Benedetti demonstrates it in the neuroscience of pain. Together they constitute a convergent body of evidence for the same structural claim: what you think you are doing is part of what you are doing, biologically.


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## 1. Two Identical Milkshakes

In a study that should trouble everyone who assumes that biology and cognition operate independently, Alia Crum and her colleagues at Yale brought participants into a laboratory and gave them milkshakes. The milkshakes were described in two ways to two groups of participants. One group was told they were drinking a rich, indulgent milkshake containing 620 calories and substantial fat. The other group was told they were drinking a sensible, nutritious shake containing 140 calories and no fat. After drinking, blood was drawn at regular intervals and analyzed for ghrelin, the hormone that signals hunger to the brain. When ghrelin drops sharply after eating, the brain receives a strong satiety signal and hunger is suppressed. When it drops gradually, the brain receives a weaker signal and hunger returns sooner.

The milkshakes were identical. Both groups drank the same 380-calorie beverage. The only difference was the cognitive frame: the information each group had about what they were consuming. The results were striking. Participants who believed they had consumed the indulgent shake showed a ghrelin decline three times steeper than participants who believed they had consumed the sensible shake. Their bodies responded as if they had eaten much more, because they believed they had.

This is not the placebo effect in the narrow clinical sense of a sugar pill producing drug-like responses. It is something broader and more fundamental. The cognitive frame through which a person engages with food is not merely a representation of what they are eating layered on top of the metabolic reality. It is part of the metabolic reality. What you think you are consuming constitutes, in part, what your body processes it as. The frame is not separate from the physiology. It reaches into the physiology and shapes it.

Alia Crum has spent two decades demonstrating this principle across domains far beyond food. Stress, exercise, illness, the clinical encounter: in each domain, the cognitive frame through which a person engages with their situation produces measurable biological differences from the frame alone, holding everything else constant. The closure framework calls this downward causation from cognitive closure to biological closure. Crum calls it mindset science. They are describing the same structural fact about how organized biological systems work.

## 2. Crum's Four Claims

Crum's research program has four interconnected findings, each demonstrating the same structural principle in a different domain.

### 2.1 Mindsets About Food Change Metabolism

The milkshake study established that beliefs about food composition alter hormonal responses to that food independent of its actual nutritional content. Ghrelin is not controlled by conscious cognition in any direct sense: it is a hormone produced by cells in the stomach lining in response to the nutritional and digestive state of the body. Yet the cognitive frame that participants held about what they were eating produced a threefold difference in ghrelin suppression from the same physical substance.

The mechanism Crum proposes is that cognitive frames, mindsets about food, activate anticipatory physiological responses that the body has learned to associate with the anticipated nutritional content. The body prepares for what the mind expects. When the expectation is of high caloric density, the digestive and hormonal systems activate the stronger satiety response associated with high caloric intake, even before the actual caloric content has been metabolically processed. The frame shapes the metabolic context within which the food is processed. Cognition and metabolism are not independent systems where one perceives and the other processes. They are nested levels of a single integrated system where the cognitive level sets boundary conditions for the metabolic level.

## 2.2 Mindsets About Exercise Change Physiology

In a study with hotel room attendants, Crum and Ellen Langer demonstrated that the cognitive frame through which workers understand their physical activity produces physiological changes without changing the activity itself. Hotel attendants perform considerable physical labor: making beds, carrying linens, pushing carts, scrubbing surfaces. Objectively, this activity meets or exceeds public health recommendations for daily exercise. But most attendants did not perceive their work as exercise: they understood it as labor, distinct from the category of health-promoting activity.

In the experimental group, attendants were informed that their daily work constituted substantial physical exercise and met health guidelines. No other change was made: the same work, the same schedule, the same diet, the same everything except the cognitive frame through which they understood their activity. Four weeks later, this group showed measurable improvements in weight, blood pressure, body fat, and waist-to-hip ratio compared to the control group, whose frame about their work remained unchanged.

The frame produced the physiological benefit. Not because it changed the work, but because the cognitive closure through which the workers engaged with their activity changed how the body metabolically processed that activity. When the nervous system understands physical activity as exercise, it activates the physiological responses associated with exercise. When it understands the same activity as labor, those responses are attenuated. The biological difference is real and measurable. The only cause was cognitive.

## 2.3 Mindsets About Stress Change the Stress Response

Crum's stress mindset research addresses one of the most pervasive and consequential framings in modern health: the assumption that stress is inherently harmful and should be avoided or minimized. Her research shows that the frame through which a person understands their stress response produces different physiological and psychological outcomes from the same objective stressor.

Participants who view stress as enhancing, who understand the stress response as a useful mobilization of resources in service of goals they care about, show a different cortisol profile from those who view stress as debilitating. They also show higher levels of dehydroepiandrosterone, a hormone associated with neural growth and stress recovery, and report better downstream

performance and wellbeing. The stressor is identical. The frame is different. The biology is different.

The mechanism is not denial or suppression. Crum explicitly distinguishes the stress-is-enhancing mindset from the avoidance or minimization of stress. Acknowledging the stress fully while framing it as a resource rather than a threat produces a different neuroendocrine response from acknowledging it while framing it as damage. The cognitive closure through which a person engages with stress sets boundary conditions for the physiological stress response. Different closures produce different boundary conditions. Different boundary conditions produce different biology.

### 2.4 Mindsets in the Clinical Encounter Shape Treatment Outcomes

Crum's most recent applied work, the Medicine Plus Mindset program developed with Stanford Medicine, addresses the therapeutic encounter directly. The program trains clinicians and healthcare teams in how patient mindsets about illness, treatment, and the body shape clinical outcomes, and how practitioners can deliberately shape those mindsets to improve outcomes.

The evidence behind the program draws on a body of research showing that patient expectations about treatment efficacy, beliefs about the nature of their illness, and frames about the body's capacity for recovery all produce physiological differences measurable in immune function, pain response, treatment adherence, and clinical outcomes. A patient who enters a treatment believing that their body has significant capacity for recovery responds differently, biologically, to the same treatment as a patient who enters believing that their condition is progressively worsening. The frame is not merely a psychological overlay on the biological reality. It is a constitutive part of the biological reality. The cognitive closure the patient holds shapes the boundary conditions within which the treatment acts.

## 3. What Crum Needs

Crum's research program is among the most carefully designed and rigorously executed in the field of mind-body science. Her experimental designs control for everything that can be controlled, isolating the cognitive frame as the only variable that differs between conditions. Her findings replicate across domains and populations. Her mechanistic proposals are grounded in the neuroscience and endocrinology of how cognitive states affect hormonal and immune systems.

What the research has not yet provided is a structural account of why cognitive frames produce physiological effects: what it is about the relationship between cognitive and biological systems that makes the cognitive frame constitutive of the biological response rather than merely correlated with it. Crum describes the phenomenon with precision and proposes mechanisms at the level of specific hormonal and neural pathways. She does not have a philosophical account of what organized biological systems are such that cognitive framing necessarily reaches into biological processing.

The closure framework provides this account. Cognitive and biological processes are not two independent systems where one influences the other through some special mind-body channel. They are nested closure regimes in a single organizational hierarchy. The cognitive closure regime

sets boundary conditions for the biological closure regime below it, not through any mysterious connection but through the same structural mechanism by which any higher-level closure sets boundary conditions for any lower-level closure in a nested hierarchy: by determining the initial and boundary conditions within which the lower-level dynamics operate. What the cognitive frame does is set the organizational context within which the body's metabolic, hormonal, and immune processes run. Different contexts produce different boundary conditions. Different boundary conditions produce different biological outcomes. This is not mind over matter. It is nested closure all the way through.

## 4. The Framework in Crum's Terms

The closure framework is introduced here in the minimum terms needed to ground Crum's findings and show why they demonstrate exactly what the framework predicts.

### 4.1 A Mindset Is a Cognitive Closure

A closure regime is a system that stabilizes some content by drawing distinctions, establishing identity criteria, and maintaining lawful relationships among its elements. A mindset, in Crum's precise definition, is a core assumption or belief about a domain that shapes how information in that domain is perceived, organized, and interpreted. These are the same thing in different vocabularies.

A stress-is-enhancing mindset is a cognitive closure that draws specific distinctions within the domain of stress experience: distinguishing the stress response as a resource from the stress response as damage, distinguishing activation as mobilization from activation as threat. It establishes identity criteria for stress encounters: these are occasions for deploying resources in service of something that matters, rather than occasions for harm to be minimized. And it maintains lawful relationships among the elements of the stress encounter: the physiological activation, the cognitive challenge, and the goal-oriented response are constituted as parts of a coherent action rather than as disconnected threats.

The food mindset in the milkshake study is a cognitive closure that draws distinctions between nutritional categories: high caloric density versus low, indulgent versus sensible. These distinctions are not merely descriptive. They activate the identity criteria that the body has learned to associate with each category: the anticipatory metabolic responses that evolved to prepare the digestive system for the type of food it expects to process. The cognitive closure constitutes the nutritional fact, and the constituted fact sets boundary conditions for the metabolic response.

### 4.2 Mindsets Reach Biology Through Nested Closure

The mechanistic question Crum's research raises, how a cognitive frame produces a hormonal response, is answered by the structural account of nested closure regimes. The cognitive closure regime, the mindset about food or stress or exercise, is a higher-level closure that contains the biological closure regimes below it as its elements. Higher-level closures set boundary conditions for lower-level closures: this is the same structural principle that Benedetti's prefrontal damage dissociation established anatomically for placebo analgesia, that Noble's biological

relativity demonstrated for multi-level biological causation, and that Friston formalized mathematically as the active inference account of hierarchical generative models.

In Crum's milkshake study, the cognitive closure that constitutes the food as indulgent sets boundary conditions for the digestive and hormonal systems that process it. Those boundary conditions are the anticipatory metabolic context: the nervous system's expectation of high caloric intake, which activates the hormonal response associated with substantial feeding. The ghrelin response is not produced by the conscious belief about the caloric content. It is produced by the boundary conditions that the cognitive closure sets for the hormonal system operating below it. The belief is the closure. The hormonal response is what the lower-level biological closure does within the boundary conditions that the higher-level cognitive closure establishes.

This is why Crum is right that mindsets alter objective reality through physiological mechanisms. They do not alter it through any mysterious channel. They alter it through the same structural mechanism by which any higher-level organizational closure alters what happens at lower levels: by setting the boundary conditions within which lower-level processes operate. The cognitive frame is not separate from the biology. It is organized around the biology, at a higher level of organizational closure, and it reaches down through the standard mechanisms of nested closure to shape what the biology does.

## 5. Four Claims, One Structure

The vocabulary correspondence between Crum's mindset science and the closure framework is the most directly experimental in the series. What Crum calls a mindset, the closure framework calls a cognitive closure regime. What Crum calls the domains through which mindsets operate, food, stress, exercise, clinical encounter, the framework calls the specific organizational contexts within which cognitive closures set boundary conditions for biological closures. What Crum calls the physiological mechanisms through which mindsets alter biology, hormonal cascades, immune activation, metabolic processing, the framework calls the outputs of biological closures operating within the boundary conditions that cognitive closures set. And what Crum calls the bidirectional relationship between mind and body, the feedback loop in which biological state informs mindset and mindset shapes biological state, the framework calls the circular causation of nested closure regimes.

### 5.1 The Milkshake Study Is Downward Causation

The milkshake study demonstrates downward causation from cognitive closure to biological closure with experimental precision. The cognitive closure about food composition is the independent variable. The ghrelin response is the dependent variable. All other variables are held constant: same calories, same nutrients, same participants across conditions, same time of consumption, same measurement protocol. The threefold difference in ghrelin suppression is produced by the cognitive frame alone.

This is the structural claim the Grammar of Healing established from the neuroscience of placebo: cognitive closure reaching into biological closure and reconfiguring it. The Grammar of Healing demonstrated it in the context of pain and healing. Kaptchuk demonstrated it in the context

of the clinical encounter. Crum demonstrates it in the context of ordinary food consumption. The structural mechanism is the same across all three demonstrations. The cognitive closure sets boundary conditions for the biological closure below it. The biological closure operates within those conditions and produces outputs that differ depending on which boundary conditions have been established. This is not a special phenomenon restricted to clinical settings or suggestive laboratory conditions. It is how organized biological systems with cognitive levels work, all the time, in every interaction with food, stress, exercise, and experience.

## 5.2 The Housekeeper Study Is Grammar-Constituted Exercise

The hotel housekeeper study demonstrates something subtler and more philosophically striking than the milkshake study. The attendants' physiological health improvements came not from any change in their actual physical activity but from a change in the cognitive closure through which they understood that activity. The body's processing of physical work as exercise rather than labor is not merely a different labeling of the same process. It is a different process, biologically, because the cognitive closure that frames the activity as exercise activates the physiological responses associated with health-promoting physical exertion in ways that the cognitive closure that frames the same activity as labor does not.

In closure framework terms, the cognitive closure that frames physical activity as exercise constitutes a fact: this is exercise. That constituted fact sets boundary conditions for the metabolic and hormonal systems that process the physical work: activate the responses associated with health-promoting exertion. Those systems operate within those boundary conditions and produce the metabolic adaptations associated with exercise. The physical activity is the same. The biological processing of it is different because the cognitive closure that frames it is different. The grammar constitutes the fact. The constituted fact shapes the biology.

## 5.3 Stress Mindsets Are Closure Identity Criteria

Crum's stress mindset research demonstrates that the identity criteria a cognitive closure establishes for its domain produce different boundary conditions for the stress response system. The stress-is-enhancing mindset and the stress-is-debilitating mindset are different closures over the same domain of stress experience. They draw different distinctions: one constitutes the stress response as resource, the other constitutes it as damage. They establish different identity criteria: one frames stress encounters as occasions for deployment of resources, the other frames them as occasions for harm to be minimized. And they produce different boundary conditions for the neuroendocrine system: different cortisol profiles, different DHEA levels, different downstream outcomes.

This is the closure framework's account of why mindsets matter not just psychologically but biologically: they are not mental additions to a biological reality that operates independently. They are cognitive closures that set the boundary conditions within which the biological reality operates. The identity criteria of the cognitive closure determine the organizational context for the biology below it. Different closures, different contexts, different biology.

### 5.4 The Clinical Encounter Is Shared Cognitive Closure

Crum's Medicine Plus Mindset program, training clinicians to shape patient mindsets about illness and treatment, is an application of the same structural principle that Kaptchuk's therapeutic encounter research established. The practitioner's manner, the information conveyed, the frame established for the illness and the treatment: these are not decorative additions to the pharmaceutical or procedural intervention. They constitute the cognitive closure within which the patient engages with the treatment. Different closures, different boundary conditions for the biology of treatment response, different outcomes.

The Grammar of Healing established this theoretically using Benedetti's neuroanatomical evidence. Kaptchuk established it clinically through thirty years of placebo research. Crum establishes it in everyday medical encounters through the Medicine Plus Mindset program and its supporting evidence base. Three independent lines of research, three different methods, three different researchers, same structural conclusion: the cognitive closure that frames the therapeutic encounter is constitutive of the therapeutic biology.

## 6. The Convergence With the Suite

The Crum paper is the tenth in the living thinkers series, and it is the paper that most fully completes the convergence between the suite's biological papers and its philosophical papers. The series began with Noble establishing that biological causation flows in both directions between levels of organization. It progressed through Friston's mathematical account of how higher-level closures minimize prediction error at lower levels, Maturana's autopoietic account of living systems as self-producing closures, Deacon's thermodynamic account of absence as causally efficacious, and Jablonka's evolutionary account of how nested closures at different timescales built the organizational hierarchy that eventually became conscious. Kaptchuk's clinical research then demonstrated that cognitive closure reaches into biological closure in the specific context of medicine. Crum demonstrates the same principle across the full range of ordinary human experience.

The significance of this completion is that it moves the claim from a clinical or laboratory curiosity to a universal structural feature of how cognitively organized biological systems work. Placebo effects in clinical trials are real and important. But Crum's research shows that the same mechanism operates when a hotel worker picks up a towel, when a student drinks a milkshake, when an executive walks into a high-stakes meeting. The cognitive frame through which any cognitively organized organism engages with any situation is part of the biological situation, because the organism is a nested closure hierarchy in which the cognitive level sets boundary conditions for the biological levels below it. This is not a special effect triggered by specific ritual conditions. It is the standard operation of any organism that has a cognitive closure level.

For the closure framework, Crum's research provides the broadest empirical base in the series: evidence from everyday food consumption, ordinary physical activity, common stress experiences, and routine clinical encounters that cognitive closure systematically shapes biological closure across the full range of human experience. The framework is not describing a rare phenomenon that requires special conditions to observe. It is describing how every cognitively organized biological system operates all the time.

## 7. The Grammar of Mindset

Two identical milkshakes. One consumed as indulgent, one consumed as sensible. Different bodies. Not metaphorically different. Measurably different, in the hormone that signals hunger to the brain, at a threefold magnitude, from the same liquid.

Alia Crum has spent two decades mapping the territory that observation opens onto. Stress that is framed as enhancing produces different biology from stress that is framed as debilitating. Work that is understood as exercise produces different physiological outcomes from work that is understood as labor. A clinical encounter framed by warmth and expressed confidence in the body's capacity for recovery produces different treatment outcomes from the same intervention delivered in a context of detachment. The cognitive frame constitutes, in part, the biological reality.

The closure framework names the structure underlying all of these observations. Cognitive closures are higher-level organizational regimes that set boundary conditions for the biological closures they contain. Different cognitive closures establish different boundary conditions. Different boundary conditions produce different biological outputs. This is not a special mechanism. It is the standard operation of any nested closure hierarchy: higher levels set conditions for lower levels, and the outputs of lower levels depend on the conditions that higher levels establish.

Crum's research is, in structural terms, an extended experimental demonstration of the Grammar of Healing's central claim: what you think you are doing is part of what you are doing, biologically. Not because the mind has magical powers over matter. Because the cognitive level and the biological level are not separate systems where one influences the other through an unexplained channel. They are nested closure regimes in a single organizational hierarchy, and that hierarchy works the way all nested closure hierarchies work: from the top down as well as from the bottom up, with each level setting conditions for the levels below it. The grammar of mindset is not the grammar of belief alone. It is the grammar of organized biological systems whose cognitive level is part of their biological reality. Crum has been demonstrating this for twenty years. The closure framework names what she has been demonstrating.

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**Author's Note**

*This paper is the tenth in a series engaging thinkers whose work converges with the closure framework developed in Consciousness, Closure, and the Cosmos. Alia Crum is Associate Professor at Stanford University and Director of the Stanford Mind and Body Lab. Her research has demonstrated across multiple domains and with rigorous experimental design that cognitive mindsets produce measurable physiological changes through behavioral, psychological, and biological mechanisms. Her work is among the most broadly applicable body of evidence in the series because it moves the demonstration of cognitive closure reaching into biological closure from specialized clinical settings into the full range of ordinary human experience: food, exercise, stress, and the clinical encounter. The connection between Crum's mindset science and the Grammar of Healing is the central convergence of this paper: both arrived at the same structural claim from different directions, the Grammar of Healing from the neuroscience of downward causation and Crum from the experimental psychology of mindset effects on physiology. Together with Kaptchuk's clinical research and Benedetti's neuroanatomical work, Crum's mindset science constitutes a three-part empirical confirmation of the Grammar of Healing's central claim across laboratory, clinical, and everyday settings. The author welcomes engagement from Crum directly and from researchers in health psychology, behavioral medicine, and mind-body science who find the structural account of why mindsets change physiology either clarifying or contestable.*