



# Unhappy meal: How our need to detect stress may have shaped our preferences for taste

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**Summary** Conventional wisdom says that our preferences for particular tastes evolved to ensure an adequate instinctual intake of metabolic resources. Yet we discern scant taste in many vital dietary components, such as vitamins, minerals, co-factors, essential fatty acids and amino acids. We propose that taste preferences evolved to serve a secondary function—that of xenohormesis. Stress causes organisms to convert complex sugars to simple sugars, as seen during fruit ripening, and to increase the proportion of high-energy saturated fats relative to unsaturated fats, as seen among farmed livestock. The presence of dietary simple sugars, saturated fats, and salt within an organism may echo its stress experience—an experience assimilated by others when consumed. As each successive consumer in the food chain incorporates the stress phenotypes of its dietary components, cues for stress may accumulate in a game of “you-are-what-you-eat”. Detection of environmental stress embedded in diet may promote adaptive phenotype remodeling such as caloric hoarding to contend with potential ecologic challenges. The phenotype remodeling may be the result of direct stress signaling properties of fats, sugars, and salt. Since food ecosystems typically exhibit seasonality in composition, early detection of cues of ecologic stress during autumn, such as dehydration, lowered ambient temperatures, and impending resource scarcity, likely confers advantages in fitness. Taste preferences may represent a form of “Darwinian rubbernecking. Much like paying attention to vignettes of violence and trauma, recognizing proxies of ecologic stress and adapting accordingly may yield fitness advantages. Many aspects of agricultural modernization may increase the level of stress embedded in the food chain, catering to pre-existing taste preferences in a form of illegitimate signaling. Globalization and technology have transformed the dietary experience of autumn—when the food chain undergoes stress and therefore tastes the best—into a year-round bacchanal. Instead of experiencing ecologic stress through their diet in a seasonal pattern, modern humans have become creatures of chronic stress. Many human conditions related to stress dysfunctions may partly arise from maladaptive consumption of stressed foods. We anticipate that low-stress and stress-free food may have therapeutic potential in the treatment of diseases and the promotion of health.

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## Hypothesis

Taste preferences in humans correspond to dietary constituents such as simple sugars, fats, and salt.

Such tendencies are often thought to have evolved to ensure adequate instinctual intake of metabolic resources [1,2]. However, such prevailing wisdom does not explain why the palate fails to categorize other useful caloric sources such as complex carbohydrates and proteins in its palette of tastes. Many other vital dietary resources, such as vitamins,

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minerals, co-factors, essential fatty acids, amino acids, and starches, also elicit little or no taste. The teleologic explanation for the evolution of taste appears incomplete.

Xenohormesis refers to the adaptive remodeling of the body in response to ecologic signals embedded in the diet. Examples include aggressive life-history strategies associated with high dietary iodine intake, a signature of resource abundance [3], and lifespan lengthening associated with a high dietary intake of sirtuins, a signature of resource scarcity [4]. Emerging evidence suggests that organisms may assimilate the stress condition of their diet as a specific form of xenohormesis, using the stress signals embedded in flora and fauna as the basis of phenotype adaptation [5]. Successful integration of dietary cues with other cues of ecologic stress would confer obvious fitness advantages to an organism contending with both prevailing and impending environmental challenges.

We propose that taste preferences for sugars, fats, and salt evolved in part to detect stress, thereby augmenting our ability to adapt to ecologic challenges. Unfortunately, the modern context may have rendered maladaptive the previously valuable link between taste preferences and stress signals.

## Evidence

### Sweet taste as signatures of stress experience in the consumed organism

Many species exhibit a strong taste preference for simple sugars. Explanations for this phenomenon cite the higher energy density of simple sugars relative to complex sugars, and the greater digestive effort often needed to process the latter. Attraction to sweets would thus confer fitness advantage by improving the efficiency of energy intake.

However, the relative concentration of simple sugars among consumed fauna and flora notably tends to rise accordingly during circumstances of stress. Both plants and animals convert complex carbohydrates to simple sugars in order to increase energy availability in times of stress; ripening fruits exemplify this process. Emerging evidence suggests that simple sugars play direct mechanistic roles as mediators of the stress response [6,7], specifically with respect to enzyme activation and respiration rates [8–10]. Furthermore, consumption of simple sugars and high blood sugar levels have been implicated in increasing the risk of many human diseases associated with stress [11]. We speculate that simple sugars serve functions of signaling between

organisms, or xenohormesis, independent from that of caloric transfer.

### Fatty taste as signatures of stress experience in the consumed organism

Humans also demonstrate a preference for the taste of fats, especially that of saturated fats. Similar to the case for simple sugars, the conventional rationale typically invokes the higher energy density of saturated fats as compared to that of other caloric sources. Once again, particular fat profiles of a consumed organism appear to correlate with the degree of stress experienced. For instance, the relative concentrations of fats relative to body weight, as well as the relative concentration of saturated fats to unsaturated fats, tend to rise among consumed organisms as they experience chronic stress [12]. Furthermore, organisms that are farmed under stressful conditions tend to exhibit a lower ratio of (*n*-3) poly-unsaturated fatty acids relative to saturated fats and (*n*-6) poly-unsaturated fatty acids [13–15]. Emerging evidence also suggests that saturated fats play direct mechanistic roles as mediators of stress responses [16–18]. Consumption of fats, particularly saturated fats, has been implicated in the increased risk of many human diseases that are also associated with stress [19,20]. High blood levels of circulating fats are also associated with increased risk of human diseases linked to stress, such as cardiovascular disease. We speculate that fats serve signaling functions between organisms independent of their utility in caloric transfer.

### Salty taste as signatures of stress experience in the consumed organism

Increasing evidence suggests that salt may operate in a similar fashion as sugar and fat. Sodium is a mediator of cellular stress responses and plays a key role in the sympathetic nervous system, a major stress axis in humans [21]. The taste of salt triggers the sensation of thirst, which in turn compels the seeking and hoarding of water, a well-established stress response. The response of the distal convoluted tubules of the human kidney during chronic stress is to retain sodium [22]. The human attraction to salt may have as much to do with its relationship to stress as it does to conventional concepts of fluid and electrolyte homeostasis. As high concentrations of simple sugars, saturated fats, and salt may indicate the stress history of an organism, so too may attraction to cues of stress in the food chain reflect adaptive significance through taste preferences for certain fats, sugars, and salt.

## Perspectives

### Taste preference as a form of “Darwinian rubbernecking”

Why would evolution provide an emotional reward associated with taste preferences in order to attract organisms to sensory cues of stress? It is intuitively appealing to speculate that early detection of cues related to impending ecologic stress may afford fitness benefits in facilitating preemptive modification of behavior and remodeling of phenotype. In a pre-modern era when phenology indicates that environmental stress and food availability waxed and waned in seasonal patterns, selective pressures may have favored escalating sensitivity to detect any changes in ecologic stress. Across the spectrum of fauna and flora, from the Dutch crocus to the groundhog, mechanisms have evolved to detect the earliest signs of spring. When resources and opportunity become abundant, species remodel their phenotype accordingly by budding, blooming, blossoming, and breeding.

On the other hand, the coming of autumn brings progressive resource scarcity associated with declining temperatures. Stress can be detected through direct environmental cues; adaptive phenotype remodeling in response to temperature changes is well known [23]. Stress signals embedded in diet may provide additional information regarding ecologic stress independent of that provided by environmental cues. Taste preferences may have evolved to attract organisms to signals of stress in prey which functioned as proxies for stress in the environment. Stress related to chronic resource scarcity produces various adaptive responses in organisms. Examples include hibernation, during which conservation of energy compels the storage of fat and the lowering of metabolic rates, and defoliation of deciduous plants. Other behaviors along the lines of “fattening up for winter” may represent an adaptive response of organisms to contend with the challenges associated with this period of relative shortage. As with the detection of spring, one can infer a Darwinian arms race for mechanisms that enable the earliest and most accurate recognition of the signs of autumn. Refinement of taste preferences may enable success in this competition.

We believe that attraction to taste cues of stress represents part of a broader adaptive strategy that we term “Darwinian rubbernecking”. The term “rubbernecking” is a widely accepted colloquialism describing human sensory attraction to vehicular accidents. Despite the apparent time cost in

viewing accidents, humans remain deeply fascinated with environmental signatures of trauma and violence. Witness the commercial success of games and videos depicting gruesome violence—the modern incarnations of the gladiatorial and bullfighting spectacles of prior epochs. Emotional reward may similarly emerge from exposure to predetermined sequences of anxiety or fear, such as sports contests, public hangings, or amusement park rides. Commercial franchises that serve foods carrying high signals of stress, such as fast food restaurants, often utilize recognizable brand motifs that use reds and yellows, colors most associated with stress, as dominant colors [24].

The adaptive value of “rubbernecking” becomes apparent upon consideration of the fitness benefits of detecting ecologic stress. The presence of carnage implies a reasonable likelihood of threat in the local environment. Viewers of such mayhem would most benefit from activating their own stress responses. Evolution may favor a bias towards early detection and reaction to ecologic stress, if the fitness cost of a false negative detection of stress overrides that of a false positive detection of stress—a not altogether unreasonable assumption [25]. Indeed, “Darwinian rubbernecking” may constitute a specific form of a more general phenomenon. Humans concede an expensive attraction to cues that hold significant fitness value, and will crane their necks to ogle potential mates as well as scenes of carnage. The rise of sex and violence in media content may represent a pandering to evolutionarily-programmed rubbernecking behavior.

Unfortunately, the adaptive value of activating one’s own stress pathways in response to sensory detection of ecologic stress through “rubbernecking” has undergone maladaptive rendering in the modern world. Media distribution channels now exploit preexisting sensory preferences for signatures of ecologic stress by widening the scope and breadth of imported cues, by broadcasting geographically detached vignettes of sex and violence into our immediate fields of perception. The audience continues to pay attention to these stress cues even though they do not contain content of local significance. Technologies such as big screen television tend to amplify this effect, as we are generally programmed to equate size with significance. Darwinian forces that endowed “rubbernecking” failed to anticipate an era when communication technologies enable mass-scale “illegitimate signaling”. The proliferation of pornography is a similar exploitation of pre-existing rubbernecking tendencies that once held fitness value but now serves only to mislead.

## Modern agricultural practices render taste preferences maladaptive

Many aspects of agricultural modernization increase the level of stress embedded in the food chain [5], catering to taste preferences in a form of illegitimate signaling. The crowded and cramped conditions under which flora and fauna are bred suggests an unconscious acknowledgment of the potential benefits of cultivation under stress. Certainly the escalating economics of consumption suggests that taste has not suffered and may even undergo enhancement. Consumer preferences for tasty stressed foods provide economic incentives to manipulate food production, distribution, and preparation methods to best cater to these taste preferences. Not coincidentally, food production and distribution methods that promote business efficiency often tend to create stress in the underlying food being consumed.

Given the seasonal patterns of ecologic stress, our hypothesis suggests that foods should taste best in their autumnal state. Coincidentally, traditional celebratory feasts throughout human cultural evolution occur during the fall season. Aside from the obvious temporal link to harvest, the propensity to celebrate food at this time may also reflect the good taste of foods during this period. Notably, globalization and technology have enabled the autumn dietary experience—a time when the food chain undergoes heightened stress, thereby maximizing taste—to become a year-round experience. In addition, food grown out of season effectively undergoes stress throughout its growth. Thus, instead of perceiving ecologic stress through their diet in a seasonal pattern that conveys adaptive relevance, the diet of modern humans inflicts year-round stress, abetted by legacy taste preferences rendered maladaptive in the modern world.

Modern humans are becoming creatures of chronic stress, a multi-factorial phenomenon with many underlying causes. Our maladaptive attraction to signs of ecologic stress through our legacy taste preferences may constitute a newly considered component of this process. Chronic stress is being increasingly being implicated as a mechanistic culprit in virtually all categories of human ailments including cardiovascular, neurologic, psychiatric, reproductive, inflammatory, immunologic, renal, oncologic, pulmonary, dermatologic, and gastrointestinal disease [26]. By inference, the hypothesis described in this paper implicates stress embedded in our diet and the taste preferences that attract us to stressed foods as previously unrecognized contributors to the pathogenesis of a

wide variety of human diseases. We anticipate the therapeutic potential of low-stress and stress-free foods in the treatment of diseases and the promotion of health.

## Perspective on vegetables

The association of improved health found with consumption of vegetables rather than animals may relate to differences in stress content. This difference in stress content may relate to the differences in internal schemes of organization. Plants are largely structured as decentralized organizations—the notable exception being those components that constitute flowers and fruits—whereas animals typically adopt command–control hierarchies [27]. Command–control hierarchies must preserve the relationships amongst their constituents in particular configurations in order to effectively function, and as such, are vulnerable to stressors that may disrupt such relationships. The disruption or loss of a single constituent often proves catastrophic; for an animal, the loss of a single organ typically leads to expiration of the entire organism. The degree of stress experienced by organisms, and the responses evolved to address those stresses, may be proportional to the requirements to maintain order. In the case of animals, the entire body of the organism may harbor stress. Flowers and fruits likely harbor less stress than animals because of the less rigid constraints on their structure; note the vast spectrum of parameters ranging from size and shape to numbers of seeds that any particular fruit can assume. Yet they likely still experience greater stress than other aspects of the plant due to their retention of relatively specialized structures—stamen, pistil, ovary, ovule—in order to realize their function.

Decentralized organizations, on the other hand, are relatively impervious to external forces. Function continues even with disruption or loss of a portion of the organization. A plant can suffer injury to multiple trunks or stems, but the remainder of the organism persists, unrelenting. The stress incurred by any one aspect of the organism may not necessarily translate to the remainder. Consumption of what generally is classified as vegetable from a culinary standpoint—roots, stems, and leaves, i.e., the non-seed-bearing portion of the plant—likely conveys very little stress to the consumer and consequently does not promote stress-mediated diseases as would be evidenced by the absence of such mention in the literature. Indeed, stress typically results in allocation of resources to those structures which do contribute to

reproduction, that is, the flower and the fruit. So even under circumstances that may increase stress, non-flowering/fruitlet components of the plant may continue to signal an environment of low-stress; a signal that may have led the consumer astray in the past, but serve to allay and soothe given the constitutive stress present in our modern existence. Appropriate incorporation of properly harvested vegetables may constitute the first step in developing a low-stress diet for our modern times.

Curiously, vegetarians are often regarded as pacifists. Perhaps a low-stress diet represent the cause rather than the product of irenic attitudes. Speculating further, the emergence of pacifist philosophies such as Taosim could partly arise from a low-stress diet biased towards vegetables. Societal dietary bias may also influence culture through the consumption of phytoestrogens, which can alter human behavior through xenohormesis. High estrogen intake may neuter humans' aggressive tendencies; indeed, estrogen may serve as an antidote for the stress response, its effects curtailed in situations such as premenstrual syndrome and menopause. A high intake of soy, which contains abundant concentrations of phytoestrogens, appears to cosegregate with placid demeanors.

### Xenohormesis and stress reconsidered

Taste defines but one sensory channel through which fear and stress permeate throughout an ecosystem. Visual cues and auditory alarm cries can transmit fear and stress between and within species. Depending on the prevalence of Darwinian attitudes, an individual may exploit these cues to escape, hunt, dominate, or even deceive. Although a colloquialism exists that describes the "smell of fear," the ability of humans to sense fear through olfactory channels remains unknown. However, many other species may rely on chemosensory signals to detect stress and fear in the environment. For instance, ripening constitutes the stress response of fruits, thereby producing the delectable sweet tastes that please human palates. Ripening plants exude ethylene gas, a chemical mediator of the stress response. Nearby plant life that detects gaseous ethylene will themselves undergo ripening, essentially assimilating the stress characteristics of their neighbor. Communication of stress signals may thus explain the aphorism "one bad apple spoils the whole bushel."

Excrements also play a major role in signaling within ecosystems. Feces and urine are involved in territorial behavior, mating signals, tracking

prey, and avoiding predators. Goats that have never seen a tiger will still experience fear and stress when exposed to the feces of a tiger [28]. The stool of breast-fed infants possesses no odor, yet those babies fed commercial food immediately resort to producing foul stool. In order to cater to human tastes, most commercial foods, including infant formulas, contain components that carry signals of high stress [5]. Fecal stench may reflect the stress experience of the gut bacterial flora. While they may perceive breast milk as placid, they may interpret the content of commercial foods as stressed, invoking signals of fear throughout the flora, ultimately yielding foul stool as a broader stress signal to the greater ecologic environment.

### The duality of information and energy

In this paper we have explored the possibility that dietary components function not only as vehicles of caloric transfer within ecosystems, but also as signals between individual organisms. Certain dietary components such as simple sugars and saturated fats not only can drive stress responses within the consuming organism, but also can transfer these signals between organisms as part of predator-prey relationships within the food chain. In some cases, the informational value of fats and sugars may supersede their caloric value to the consuming organism.

Every entity in the universe may have two principal properties—its energetic potential and its information potential. Whereas energetic potential is realized when the entity undergoes combustion, information potential is realized when the entity is perceived by another. When light encounters the retina, the eye takes in both photonic energy and visual information. When acoustic waves mobilize the tympanic membrane, the ear absorbs both vibrational energy and auditory information. The consumption of food means not only the ingestion of caloric energy, but also the uploading of information. In the case of tasty foods, this information may be stress.

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