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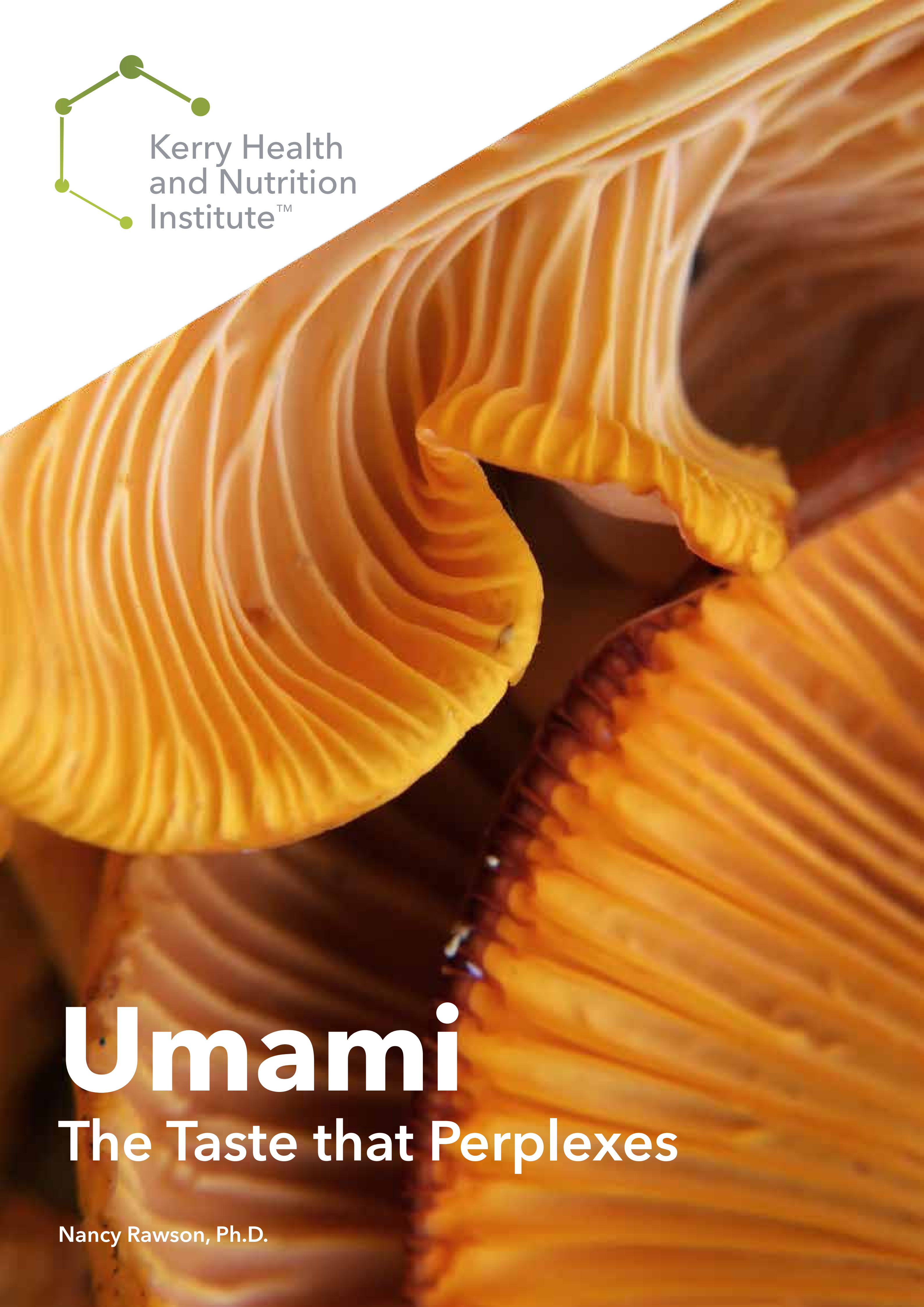

Umami
The Taste that Perplexes

Nancy Rawson, Ph.D.

Summary

Umami is one the primary tastes, but unfortunately the way many people have learned about umami is through the stigma of monosodium glutamate, the prototypical stimulus of umami taste. The questions ‘what does MSG do to your body?’ and ‘why is MSG bad for your health’ top the list of MSG-related google searches, and ‘MSG-free’ claims are becoming more common.

What many people don’t know is that MSG isn’t the only source of umami flavor. In fact, you can find umami flavor in foods we eat every day, like mushrooms, tomatoes, or aged cheese. Our bodies have developed complex machinery to sense umami flavor in food, but why?

In this white paper, we break down the complexities of what umami is and how our bodies sense it, which foods can contribute umami flavor without using MSG, and explore why our bodies have developed a taste for umami.

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Dr. Rawson holds multiple patents, has authored over 65 publications, and is an invited speaker and contributor on taste, olfaction and nutrition for conferences, organizations and media outlets around the world.

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Umami is a ‘basic taste’ that is anything other than basic

As a result, the biology of understanding how umami taste works is a complex challenge to solve

Originally referred to a century ago by the Japanese chemist Kikunae Ikeda as something ‘other than the 4 basic tastes’, the Japanese term ‘umami’ incorporates both a hedonic (“deliciousness”) and a qualitative (“savory” or “meaty”) character.

The subtlety of this description is reflected in the challenges that have been encountered in unraveling the biological mechanisms and functions of this important component of food flavor. Identification of a molecular receptor selectively responsive to the prototypical ‘umami’ stimuli monosodium glutamate (MSG) and enhanced by 5’-ribonucleotides such as inosine monophosphate, and demonstration of specific neural pathways highly sensitive to glutamate support the view that this sensory quality may properly be considered a primary ‘taste’. Nonetheless, it is a peculiarly complex one.

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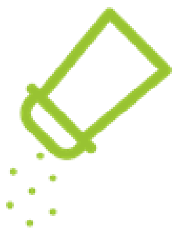
Take MSG, the prototypical ‘umami’ stimulator. It is made of a sodium component, which contributes a salty taste, but also a glutamic acid component, which contributes a sour taste.



SALTY

SOUR

JUICINESS

Due to its sodium component, MSG also elicits a salty taste, while glutamic acid, which is produced upon dissolution in saliva, is also sour. Thus, no stimulus elicits a pure “umami” taste, or perhaps put a different way, one might consider that while the receptor responsive to glutamate is an important component of ‘umami’ taste, true ‘umami’ taste as experienced in foods may be better viewed as an integrated sensation requiring multiple mechanisms resulting from the activity of the glutamate receptor(s) together with salt and sour detection pathways, as well as the secondary effects that each of these sensory pathways can have on other tastes. Further, umami substances in a food context enhance ‘mouthfullness’ or thickness – a quality likely involving a tactile sensation.

Thus, perhaps more so than any other simple compound, the sensation elicited by MSG may perhaps be best considered a basic “flavor” rather than a basic “taste”!

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Despite MSG's stigma, umami flavor is found naturally in many foods we eat daily

MSG with or without 5'ribonucleotides (such as inosine or guanosine monophosphate, IMP or GMP) has classically been used as the prototypical umami stimulus in sensory testing. However, the context in which MSG is consumed markedly alters the response, and MSG, with or without GMP/IMP is not necessarily liked when presented in water. The seaweed kombu dashi contains high levels of glutamate and aspartate, and is a characteristic umami stimulus.

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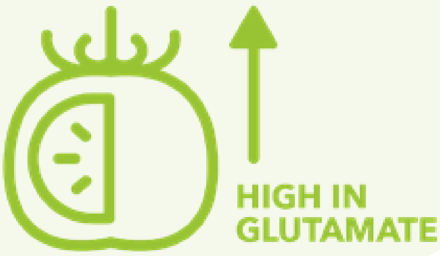


Umami stimulus can come from many different foods high in glutamate, like seaweed, mushrooms, tomatoes, aged cheeses, or even human breast milk

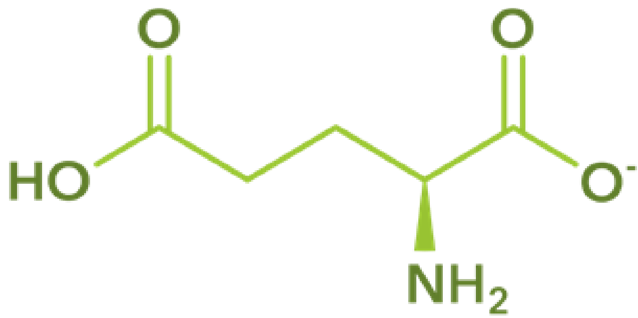
Interestingly, the amount of free glutamate in human breast milk is the highest of any free amino acid, and increases over the duration of lactation from colostrum through 3 months, suggesting an important role in the health of the neonate.

Other foods with inherent glutamate and ribonucleotides include mushrooms, fermented fish and fish broths, tomatoes and aged hard cheeses. Autolyzed yeast and hydrolyzed soy protein are used as a way to deliver umami flavor in many commercial food products due to their high intrinsic levels of amino acids and ribonucleotides.

As analytical methods have advanced, additional umami stimuli have been identified, including monosodium pyroglutamate, found in potatoes, and a number of di- and polypeptides.

These foods are able to provide the flavor enhancing effect of MSG without the added sodium that comes when adding MSG to foods

Glutamate compounds containing alternative anions such as calcium diglutamate provide potential avenues to substitute for the flavor enhancing effect of MSG without adding sodium. The search for umami taste compounds has become a very active area of research as food scientists seek ways to achieve the sensory impact with compounds that are naturally present in foods and without added sodium.



Calcium diglutamate

In Asia, dried seafood like shrimp and meat bones are used in traditional cooking to bring the umami taste and mouthfeel. For example, in China and Japan, meat bones are boiled for hours to prepare meat stock.

Fermented food in Asia is also very high in glutamate. In South East Asia, fermented fish sauce or shrimp paste is commonly used in cooking to create a more balanced taste.

In North Asia, fermented miso and soy bean paste is commonly used in different types of soups for a natural and longer lingering taste and mouthfeel.

Veronica Dong
Kerry's Strategic Marketing Manager
for Taste in the Asia-Pacific,
Middle East, and Africa

Our brains perceive umami as taste, smell, and even physical sensation

Human infants as young as two months old have taste responses umami similar to those of adults – MSG in water is less preferred than water, while MSG in broth is more preferred. This further suggests that a unique olfactory interaction plays a key role in the interpretation of MSG taste.

This is consistent with the observation that the presence of a congruent odor such as a meat odor substantively enhances the central neural response to glutamate.

Umami is different from the other 4 basic tastes in the way it's perceived by our nervous system

In general, perception of umami is less robust than other tastes – even at maximal concentrations, the perceived intensity is generally rated lower on a visual analog scale and subjects are less likely to correctly identify the quality than other taste modalities.

However, sensitivity may be enhanced through repeated exposure. Centrally, tastes are detected in a part of the brain called the insular cortex. Brain areas responding to umami taste overlap partially with those responding to sour and salty taste in the anterior insula (Prinster et al., 2017) but were distinct from those showing the largest responses to sweet, bitter or carbonation. Importantly, in the brain area responsible for the integration of odor and taste information, responses to glutamate/IMP are enhanced by savory aromas, and the sensory perception and pleasantness of umami stimuli are intimately linked to the presence of consonant odors (Rolls). Thus, the neurophysiological evidence also suggests that, as noted above, "umami" is not so much a unique taste but is actually a unique flavor requiring a combination of odor + taste + somatosensation for its full positive hedonic appeal to be experienced!

This complexity can be seen even in infants, who have been shown to prefer the flavor of MSG in broth more than MSG in water, which means odor likely plays a large role in how umami is perceived

The umami receptor: a complex taste relies on complex biological machinery to sense it

Two receptors for detection of MSG have been reported, but additional mechanisms for detection of amino acids is likely. The T1R1/T1R3 receptor is a dimer selective for MSG and other amino acids in humans, and is modulated by 5′-ribonucleotides (FIGURE 1). The breadth of tuning varies among species, as well as the modulation by 5′-ribonucleotides such as IMP and GMP. The T1R3 component of the receptor is also a component of the sweet receptor, when paired with T1R2. Removing either T1R1 or T1R3 substantially reduces, but does not wholly eliminate the response to umami taste stimuli in mice. Sequence variations in both T1R1 and T1R3 have been identified which may influence responses, and there is substantial variation in the ability to detect umami taste stimuli.

The human form of this receptor (FIGURE 1), is a protein dimer which exhibits a binding site narrowly selective to glutamate and a second, modulatory, site for 5′ribonucleotides. Sequence variations occur among individuals in both protein elements, but those in the T1R3 influence sensitivity (Breslin, 2009), in which several single nucleotide polymorphisms were found to result in a doubling of umami intensity ratings.

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Our body's receptor for umami relies on sensing multiple molecules at once

The human TAS1R1 protein can bind two amino acids, L-glutamate and L-aspartate which can be enhanced with IMP (Li et al. 2002) to elicit the umami signal. In contrast, the mouse TAS1R1 protein can bind additional L-amino acids including cysteine, alanine, methionine and glycine, yet in the presence of IMP all amino acids can stimulate the receptor (Nelson et al. 2002).

While the dog responds similarly to humans, with a strong synergy between MSG and GMP or IMP (Kurihara and Kashiwayanagi, 2000), the homologous receptor in cats responds to IMP alone, along with multiple amino acids; is more responsive to L-arginine than glutamate, and exhibits little synergism between IMP or GMP and MSG (Belloir et al., 2017; Kurihara & Kashiwayangi, 2000). Thus, both species and individual variations in this receptor likely play important roles in differences in umami perception. Additional mechanisms for glutamate detection have been documented in rodents, including a truncated form of the metabotropic glutamate receptor (mGluR1) but their role in human umami perception has yet to be demonstrated. (Chaudhari et al; San Gabriel et al., 2009).

FIGURE 1

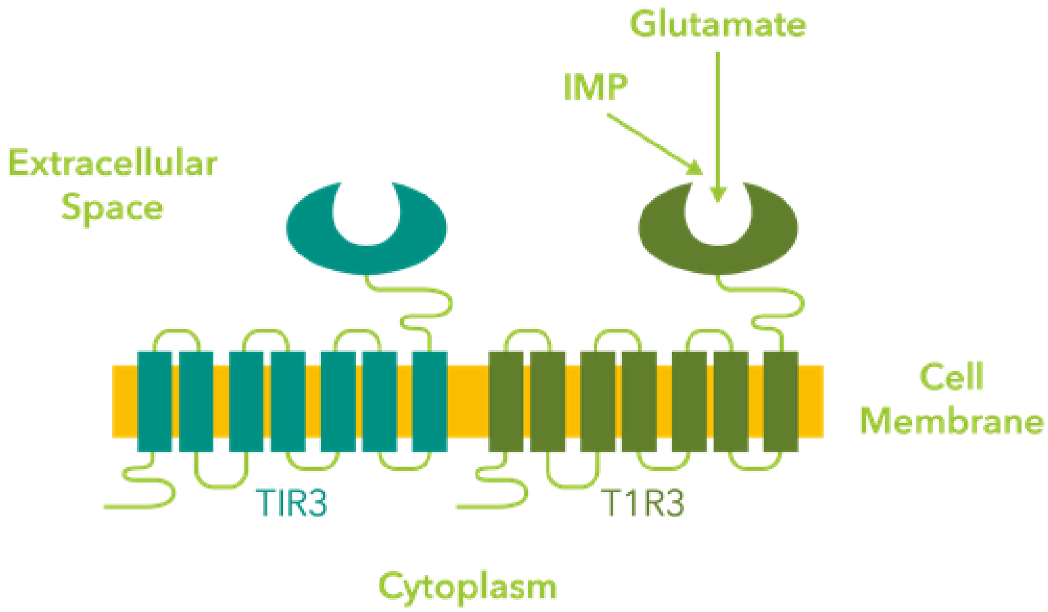

FIGURE 1

The human umami taste receptor is composed as a heterodimer of T1R1 and T1R3 proteins. T1R1 and T1R3 are G protein-coupled receptors. Each consists of ~850 amino acids, and has seven transmembrane helices forming a heptahelical domain. The large extracellular N-terminus is composed of a "Venus flytrap" (VFT) domain and a cysteine-rich domain connected to the heptahelical domain.1 Both glutamate and IMP interact with the VFT domain of T1R1, but at different binding sites. Glutamate induces the closure of the VFT domain, whereas IMP further stabilizes the closed conformation, which determines the synergistic effect between glutamate and purine 5'-ribonucleotides.9 In rodents (mice and rats), the T1R1+T1R3 heterodimer functions as a broadly tuned L-amino acid receptor. Some scientists proposed that in addition to T1R1+T1R3, several other molecules could function as mammalian taste receptors for umami or glutamate taste. These additional candidate receptors include splice variants of metabotropic glutamate receptors mGluR4 and mGluR1, and the ionotropic N-methyl-D-aspartate (NMDA)-type glutamate receptor; all of these are involved in glutamatergic synaptic transmission in the brain. There is also evidence that glutamate and purine 5'-nucleotides may activate different taste receptors.

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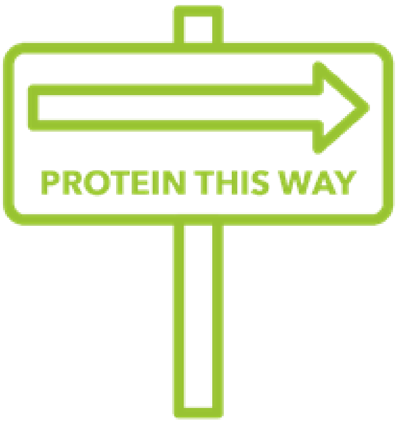
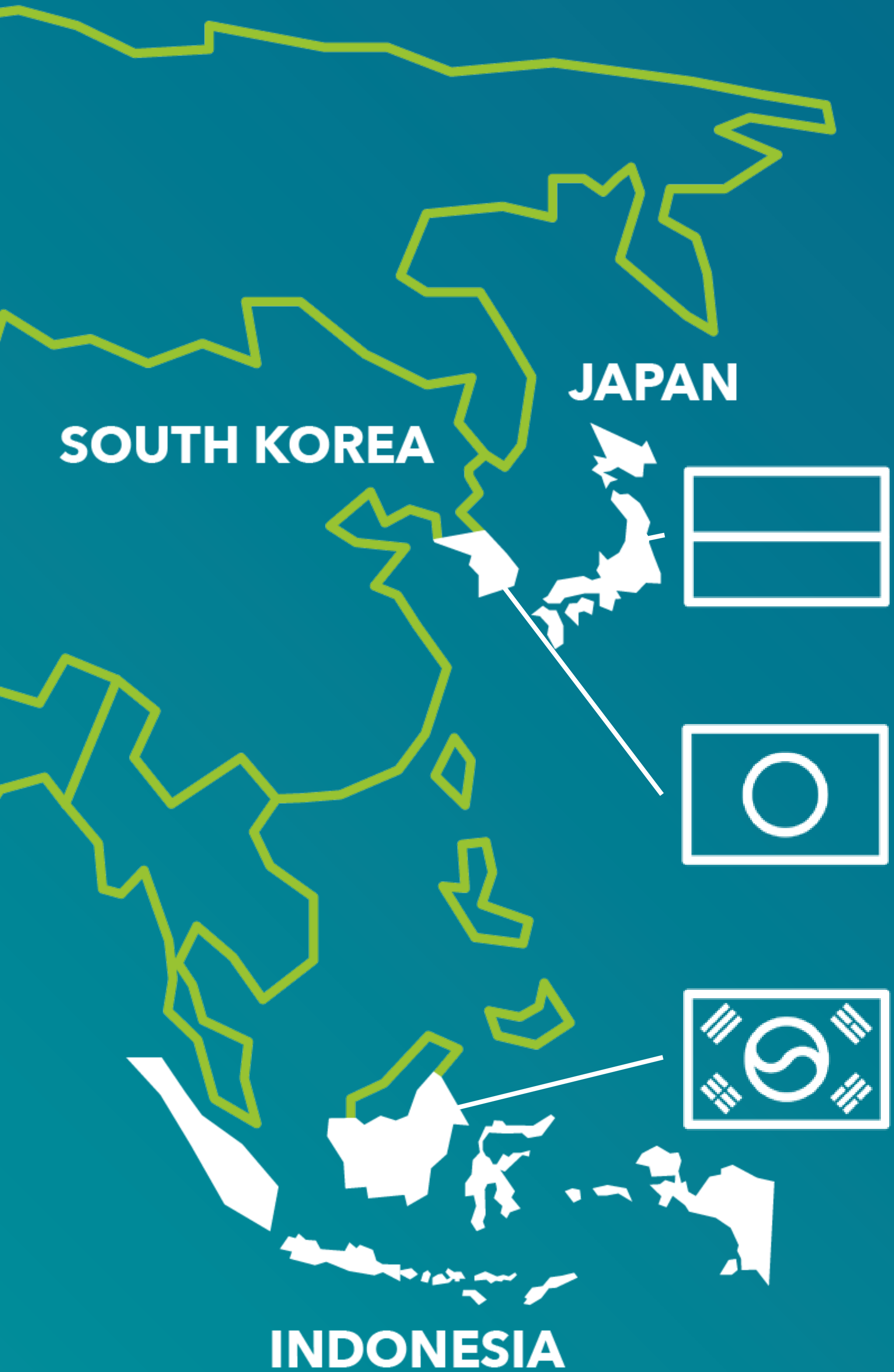
Could umami taste be a driver of protein appetite?



Taste is a critical sensory characteristic used by animals to learn what foods to consume and what to avoid, as well as which foods best serve specific nutritional needs. Sweet and fattiness signal energy density, while bitter signals potential toxins. Umami has been proposed as the signal for 'protein'.

While it seems logical that the taste pathway responsive to amino acids evolved to enable us to recognize protein-containing foods, hard evidence for this remains limited. The role of umami as a driver of protein appetite has been considered from a nutritional and an evolutionary perspective. Enforced protein deficiency did not enhance MSG preference in rats, although it does enhance preference for a number of essential amino acids.

"Many consumers in Asia perceive MSG to have negative health effects, but they still see it as the ultimate flavor enhancer."



"In Japan, there is no exact term for MSG in Japanese."

"In South Korea, consumers perceive MSG as a positive image of conveniently making food delicious – adding umami to food boosts its flavor."

"Indonesian consumers use chicken or beef bouillion, coconut milk and mixed seasonings to replace MSG."

Veronica Dong
Kerry's Strategic Marketing Manager for Taste in the Asia-Pacific, Middle East, and Africa

Tastes help the body know what to eat and avoid – bitter helps signify potential toxins, while the salty taste of sodium or the sweet taste of sugar lead us to eating nutrients our body needs

A recent report showed that subjects habitually consuming a high protein diet rated MSG more as more pleasant when protein deprived. This was not observed among those consuming a lower protein diet, suggesting the possibility that the palatability of MSG may be related to protein need at least among some consumers.

From an evolutionary perspective, one might propose that a functional MSG receptor should persist among carnivores and omnivores, but be lost in herbivores. The T1R1/T1R3 receptor in cats and dogs is similar to that of humans, and responds to both glutamate and aspartate, as well as to IMP alone. However, while the receptor is nonfunctional in a number of herbivores, it remains intact in some herbivores such as cows and deer.

Thus it is difficult to draw firm conclusions regarding the evolutionary pressure driving persistence of this receptor as a functional component of the taste system across phyla. It is also worth noting that the nutritional significance of glutamate goes beyond its signal as a potential source of protein. Glutamate is the major amino acid in maternal milk; is used as an energy source in the gut; converted into nonessential amino acids, and is the building block for the synthesis of glutathione – an important regulator of oxidative status. Finally, the presence of the receptors outside the oral cavity, including in gut cells involved in regulation of metabolism, introduces the possibility that a metabolic role may serve as a driving force for the evolution of this receptor.

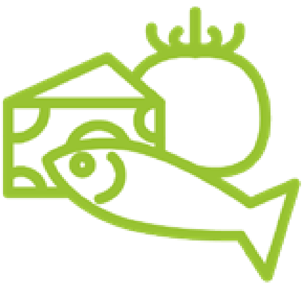
The role of amino acids, the building blocks of protein, in umami taste has led to the idea that **umami may drive us to desire protein-rich foods,** but science hasn't shown this relationship to be true yet

While scientists may not yet be able to fully explain the evolutionary or nutritional drive for umami perception or even the full molecular mechanisms underlying it, the special character it contributes to food flavor clearly plays an important role in our enjoyment of food, and food scientists will continue to search for ways to evoke this sensation in new and more impactful ways.

Conclusions

One of our basic tastes

MSG is actually one of the many sources of 'umami' flavor. "Umami flavor" is one of our basic tastes, like sweet or salty, and is often thought of as the 'savory' taste. It is also able to enhance our sensation of many flavors.



Glutamate is found naturally in many foods

Glutamate is found naturally in many foods – it is even the most common amino acid in breast milk. It's also found in mushrooms, fermented fish, tomatoes, and aged hard cheeses, which explains why some of these foods are so good at enhancing other flavor when they are used in cooking dishes.

Alternatives to MSG can create an umami flavour

Even though we're exposed to many sources of umami flavor naturally in our diets, one concern with using MSG as a source of umami flavor in food is the sodium content. This creates opportunities for other ingredients to be used for umami flavor to keep foods tasty and healthy at the same time.

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