Sweet, Sour, Salty, Bitter and UMAMI

It's simply a matter of taste.

UMAMI
INFORMATION CENTER

Taste can be considered under three different headings:

In physical man it is the apparatus by which he distinguishes various flavors.

In moral man it is the sensation which stimulates that organ in the center of his feeling which is influenced by any savorous body.

Lastly, in its own material significance, taste is the property possessed by any given substance which can influence the organ and give birth to sensation.

—from Jean Anthelme Brillat-Savarin,
The Physiology of Taste, or Meditations on Transcendental Gastronomy.
Trans. M.F.K. Fisher, 1979.

Contents

a new word for an old taste

Nature's bounty is seemingly endless. And much of it contains umami. Along with the sweetness of cake, sourness of lemon, taste of salt and bitterness of beer, the umami of steak and many other foods is basic to our lives.

Taste can be as immediate as a glass of tingling lemonade–or as elusive as the famous madeleine in Proust's *Remembrance of Things Past.* But taste has long since gone beyond the boundaries of human subjectivity and emerged as one of the new frontiers of science. From the laboratories of major universities to the halls of international scientific congresses, taste is being analyzed, charted and even reconstituted.

In the process, some traditional notions are being discarded as research extends the frontiers of our knowledge. To describe the findings on those frontiers, we need an appropriate vocabulary. And the old Japanese word umami is an important new term in the growing lexicon.

As one of the basic tastes, umami is an abstraction, but we have become familiar with the nuances of its manifestations in a wide range of common dishes. Today, research has established its presence in more than forty compounds, and scientists understand umami as the characteristic taste represented by monosodium glutamate and 5′-ribonucleotides including disodium 5′-inosinate and disodium 5′-guanylate. Its link to monosodium glutamate is perhaps the reason why umami is generally known only as a flavor enhancer. It is that and more.

Naturally, any scientific discovery is of interest. But umami has special importance for the layman as well as the professional. Whether we acknowledge it or not, umami is an integral part of cuisines around the world. The fish sauces of Southeast Asia and the bouillon of Europe share it with the "dashi" and "tan" broths of Japan and China. Dishes as diverse as Italy's lasagna and China's braised mushrooms in oyster sauce have it in common. Like any of the basic tastes, umami is fundamental to the character of food itself. Moreover, its abundance in mother's milk is an indication of the role that umami plays in the nourishment that babies need during their formative months.

To recognize umami as one of the basic tastes can help us more clearly understand our dietary needs. A perspective on food that is as much psychological as it is culinary.

from broth to a breakthrough

"Der Mensch ist, was er isst"—*a man is what he eats—declared the German philosopher Ludwig Feuerbach. It is a recognition common to both the science of food chemistry and the art of food preparation. Each field stimulates the other. And offers insights into the intricacies and possibilities of our daily fare.*

"This distinctive quality."
Born in 1864, Kikunae Ikeda was among the leaders of the wave of scientists that propelled Japan's development around the turn of the century. After graduation from Tokyo Imperial University, he studied physical chemistry in Germany under Professor Friedrich Wilhelm Ostwald and went on to make a number of notable discoveries, accomplishments that led to the presidency of the Chemical Society of Japan. In a 1912 presentation at the 8th International Congress of Applied Chemistry held in Washington, D.C. and New York, he described umami this way, a summation that distills the essence of his experience and discovery.

"An attentive taster will find something common in the complicated tastes of asparagus, tomato, cheese and meat, which is quite distinctive and does not fall into any of the traditionai categories of taste. It is usually so faint and overshadowed by other stronger tastes that it is often difficult to recognize unless the attention is specially directed towards it. Had we nothing sweeter than carrots or milk, our idea of the quality 'sweet' would be just as indistinct as it is in the case of this distinctive quality. Just as honey and sugar gave us so clear a notion of what sweet is, the salt of glutamic acid is destined to give us an equally definite idea of this distinctive taste quality."

It was not until very recently that umami was recognized as a basic taste. For the most part, vague, even contradictory descriptions have had to suffice.

In Japan, however, researchers had a head start in formulating the concept and clearing up the confusion. With their traditional diet of simple, uncooked food, Japanese have been particularly attuned to the subtleties of flavor. Given this heritage, it was only natural that the words necessary to describe this culinary experience would evolve. And it was only natural that the nation's scientists would explore the roots of a description such as umami, merely a term of approbation for centuries.

A key step in understanding the chemical source of umami came around the turn of the century when it was isolated from "dashi," although its function remained unrecognized for decades to come. Taking a break from his research at Tokyo Imperial University, Professor Kikunae lkeda settled down to a bowl of tofu in a broth made with kelp. That traditional Japanese dish turned out to be momentous. For lkeda was struck by the way that the broth made the tofu particularly delicious.

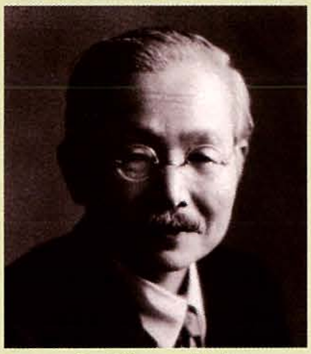
Bringing the work of others to bear, he went on to explore the origin of this taste and isolated glutamic acid as its basis. He named it umami, and the word moved from dining tables to scientific conference tables, If umami had gone unrecognized for so long, he noted, it was partially because this delicate taste tended to blend in so well with others.

lkeda's progeny followed up his findings with identification of umami substances and its independence. Even if all the results are not in yet, the evidence is telling. Reinforcement of the suggestion that umami was basic came partly from repeated failures to synthesize this taste from compounds of the traditional four. However, the idea that umami is a fundamental taste was not easily accepted internationally.

By 1979, Japanese scientists had introduced their results to the rest of the world in a paper on "The Umami Taste" at the Joint US - Japan Science Conference. The conclusion was inescapable. For too long, researchers had focused on only four tastes and, consequently, described only four - even though they had recognized that the matrix outlined by the German psychologist Hans Henning in 1916 was insufficient. Finally, here was an explanation that accounted for some of the question marks in taste physiology.

After 1982, many scientists of Japan, America and Europe joined in research on umami. Psychophysical and electrophysiological studies showed that umami is independent of the traditional four tastes. Furthermore, a specific receptor for glutamate representing umami substances was identified. Now it is widely accepted that umami is the fifth fundamental taste, and the word of umami is used internationally.


Photo by Akira Tateishi (Marine Art Center Co.,Ltd.)



Dr. Kikunae Ikeda

Free L-glutamate in natural foods (mg/100g)

Kelp	2240
Parmesan cheese	1200
Green tea	668
Seaweed	640
Sardine	280
Fresh tomato juice	260
Champignon	180
Cuttlefish	146
Tomato	140
Oyster	137
Potato	102
Chinese cabbage	100
Fresh shiitake mushroom	67
Soybean	66
Sweet potato	60
Dried sardine	50
Prawn	43
Clam	41
Chicken bones	40
Cabbage	37
Carrot	33
Bonito flakes	26
Pork fillet	23

the taste test: glutamate...

The first researcher to identify glutamic acid was the German scientist Dr. Karl H.L. Ritthausen during the course of his studies on wheat protein back in 1866. The name of this substance came naturally from its source, wheat protein or gluten.

It was not, however, until Professor Ikeda's research that this most abundant of all the amino acids was isolated as one of the chemical pillars of umami. In this 1908 study, he demonstrated that glutamate was a key to the robust taste of broth that led to his eventual coup. His investigations also showed that the same taste could be derived when glutamic acid was extracted from animal and vegetable protein hydrolysates and neutralized into sodium salt.

Following up on these findings, researchers confirmed that glutamate had an L-configuration–that is, one of those with nutritional significance as well as taste. It is a lesson that chefs and parents practice every day, consciously or not, as they cook for the palate and for health.

The waving kelp on the silent marine floor draws men as well as fish. For centuries, this seaweed's wealth of glutamate has been an important source of umami extract.

Shintaro Kodama

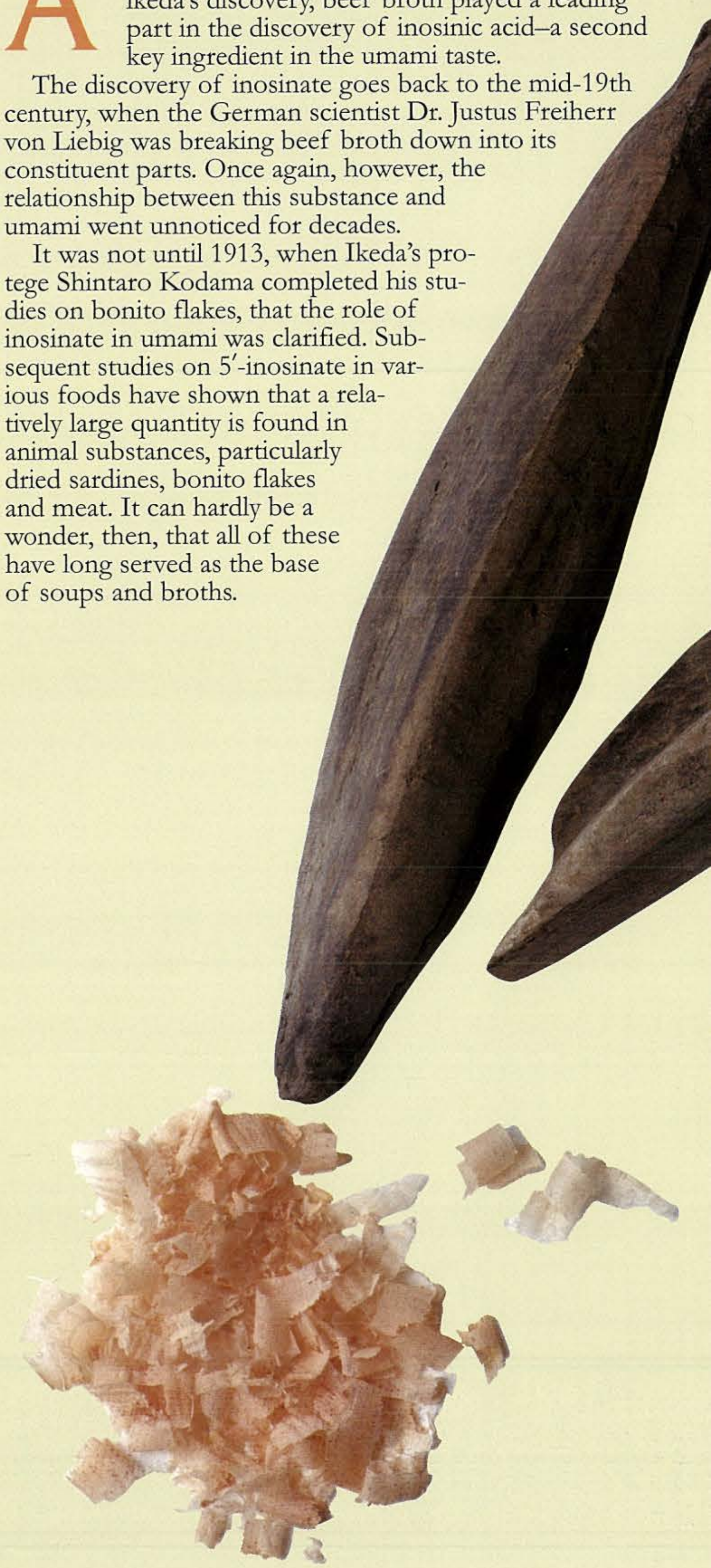
5′-inosinate in natural foods (mg/100g)	
Dried sardine	863
Bonito flakes	687
Bonito	285
Horse mackerel	265
Mackerel pike	242
Sea bream	215
Mackerel	215
Sardine	193
Tuna	188
Pork	122
Beef	107
Prawn	92
Chicken	76
Cod	44

...inosinate...

A Western counterpart to the source of Professor Ikeda's discovery, beef broth played a leading part in the discovery of inosinic acid–a second key ingredient in the umami taste.

The discovery of inosinate goes back to the mid-19th century, when the German scientist Dr. Justus Freiherr von Liebig was breaking beef broth down into its constituent parts. Once again, however, the relationship between this substance and umami went unnoticed for decades.

It was not until 1913, when Ikeda's protege Shintaro Kodama completed his studies on bonito flakes, that the role of inosinate in umami was clarified. Subsequent studies on 5′-inosinate in various foods have shown that a relatively large quantity is found in animal substances, particularly dried sardines, bonito flakes and meat. It can hardly be a wonder, then, that all of these have long served as the base of soups and broths.



The rich inosinate, delicate taste and intriguing texture of bonito flakes cannot help but prompt gratitude fcr the sea.

Dr. Akira Kuninaka

5′-guanylate in natural foods (mg/100g)	
Dried shiitake mushroom	156.5
Matsutake*	64.6
Enokitake mushroom	21.8
Fresh shiitake mushroom	16-45
Truffle mushroom	5.8
Pork	2.5
Beef	2.2
Chicken	1.5

*Armillaria matsutake Ito et Imei

… and guanylate

The identification of a third element in umami was as important as it was recent. With this discovery, the configuration was clear, freeing researchers to explore the intricacies and interaction of these substances.

Guanylic acid had been known to scientists since 1898, when the British researcher lvar Bang defined it in the course of his work on pancreatic nucleic acid. Identification of 5′-guanylate umami had to wait, however, until Dr. Akira Kuninaka's studies in 1960. The same year also saw it extracted from the broth of a very common mushroom, shiitake (Lentinus Edodes).

Though 5′-guanylate is found in other natural foods, it is especially abundant in shiitake mushrooms, while 5′-inosinate is generally associated with bonito.

Even the cool shade of the forest floor is abundant with nutritional delights. With their "woodsy-fruity" flavor and distinctive fragrance, dried shiitake mushrooms ate a delight to the senses. And a boon to the body.

when the time is ripe

When the time is ripe, so is the umami.

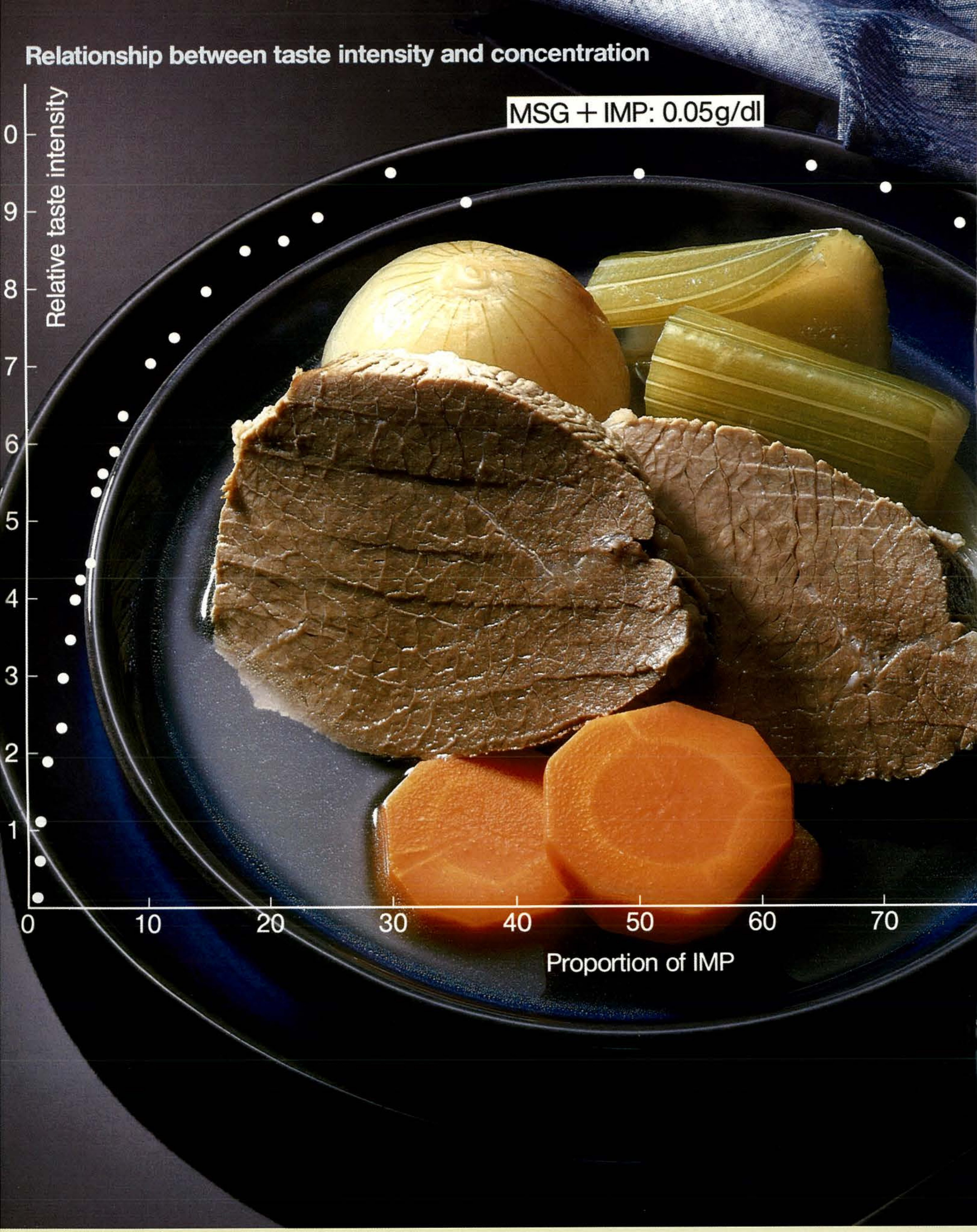
Following the discovery of glutamate, inosinate and guanylate as its core, we could define the presence of umami in our daily lives more precisely. Not only scientists and connoisseurs of cuisine but everyday people were keenly interested in the results. And for good reason: it is evident that umami is intimately linked to the essence of nature.

The foods with the highest percentages of umami are an expression of the fecundity of nature–the glutamate in most vegetables, the inosinate in fish and meat, the guanylate in mushrooms. But perhaps the clearest example of this close relationship to nature is the way umami follows the seasons.

Just as nature is vital and rhythmical, so is umami. When a food is in season, the amount and balance of its umami are optimum–in the rich flavor of the bonito of early summer, deep red tomatoes of midsummer and fragrant mushrooms of autumn.

Though people around the world have always prized the taste of a food at its prime, only recently have we recognized that umami is a key to this succulence.

Lush red tomatoes are one of nature's signposts for summer. And an invitation to enjoy umami at its prime.


Relationship between taste intensity and concentration
MSG + IMP: 0.05g/dl
Relative taste intensity
0
9
8
7
6
5
4
3
2
1
0
10
20
30
40
50
60
70
Proportion of IMP

1 + 1 = 8

The sum of umami can be more than the sum of its parts. It is not just its components that make the umami taste what it is. Rather, it is the synergistic effects of their interaction.

Although laymen may not understand the intricacies of synergism, they do know that a combination makes for a tastier soup or sauce. In Japan, for example, seaweed and bonito are typical ingredients in the stock for a meal. In Italy, tomatoes are cooked with cheese as a matter of course. And in other countries, meat and vegetables are found in many potages.

Such combinations have been repeated millions of times in millions of ways. For a world of cuisines demonstrates that it takes a combination of vegetable and animal elements to create the most flavorful dishes. While one ingredient alone may be delicious, it is their interaction that is the real secret of household chefs and the delight of their families.

Although testing on animals has confirmed these subjective impressions, scientists have yet to clear up all the questions about the process. Nevertheless, it is evident that the magnitude of this interplay is unparalleled–up to eight times the properties of the ingredients. The source of this multiplier effect is the combination of the glutamic acid with nucleotides–the basis of umami. As monosodium L-glutamate reacts with the inosinate, both their individual effects and the flavor increase geometrically.

Not only scientists but chefs recognize that quantity alone is not the issue here. The key lies in the ratio of the nucleotide to monosodium glutamate. That is the heart of the culinary art.

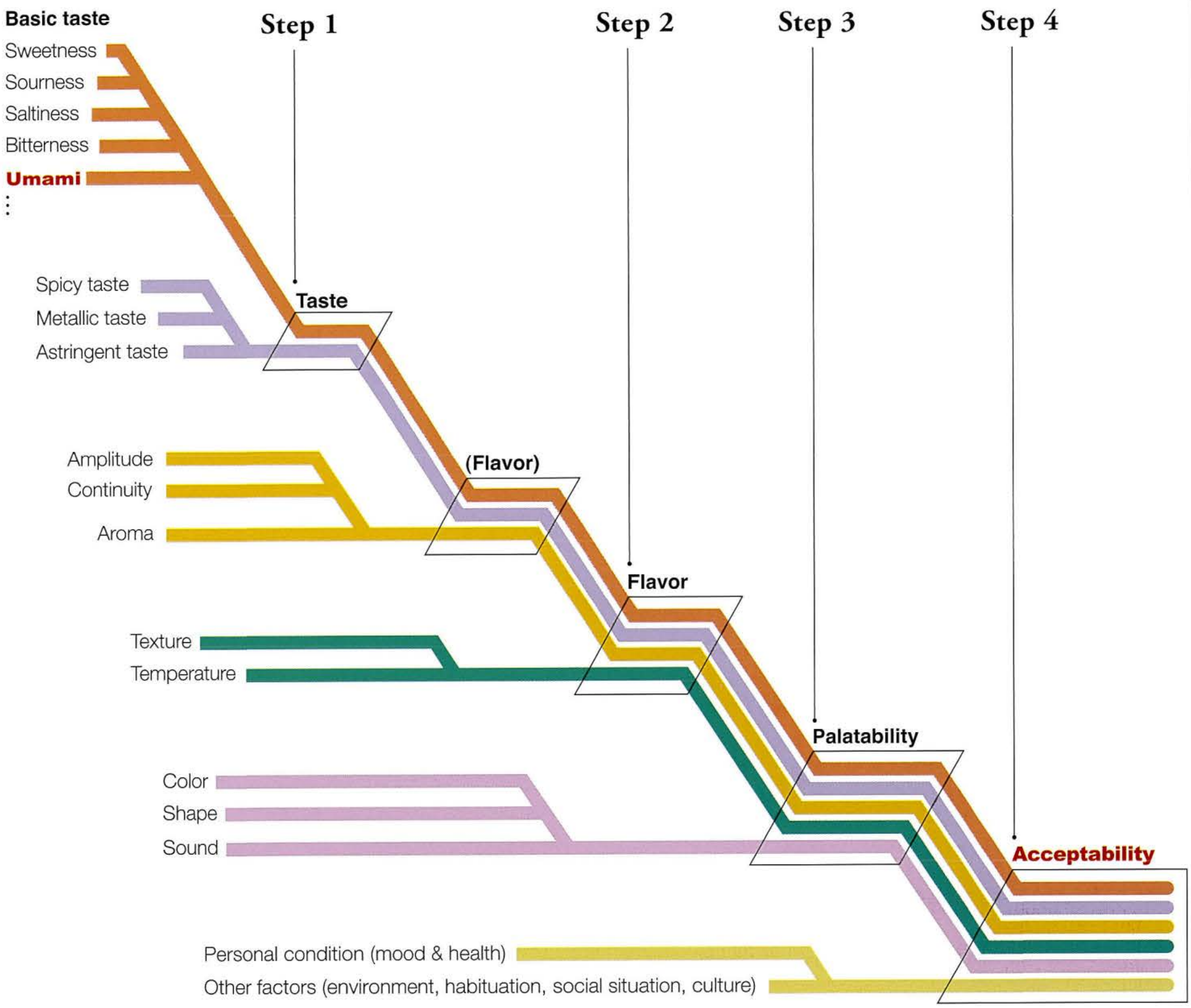
the ladder of success

While the makeup of umami is of special interest to scientists, the more immediate question for most of us is simply the part that umami plays in our enjoyment.

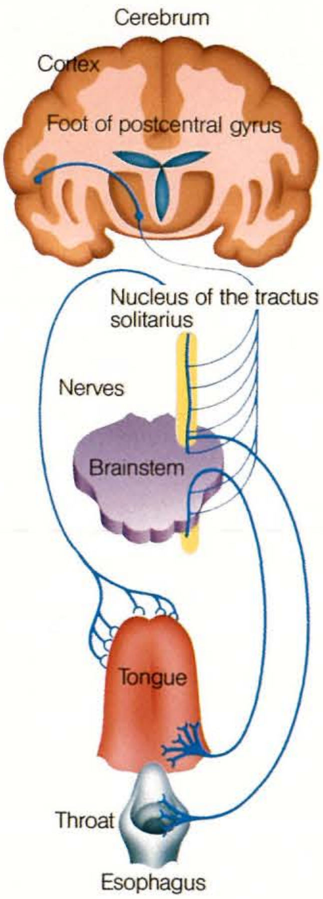
The question is simple. But the answer, as the chart suggests, is complex indeed. For umami is only one crucial part of a process that takes us from the taste buds and the brain to the other senses and the environment.

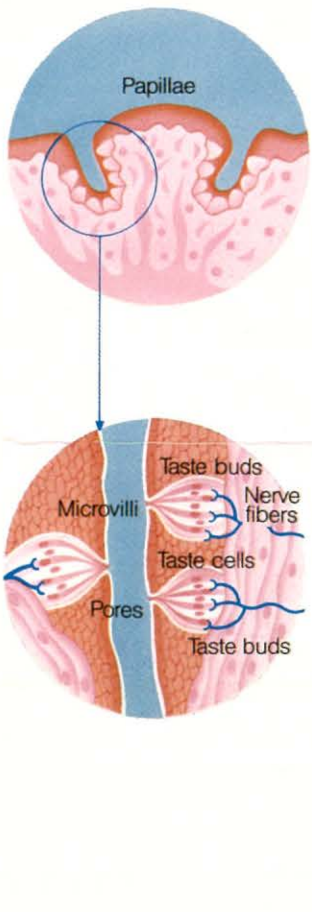
Essential to understanding the function of umami–or that of any other factor in this climb–is to look at each individual step.

Food acceptability



A map of taste





step 1: taste

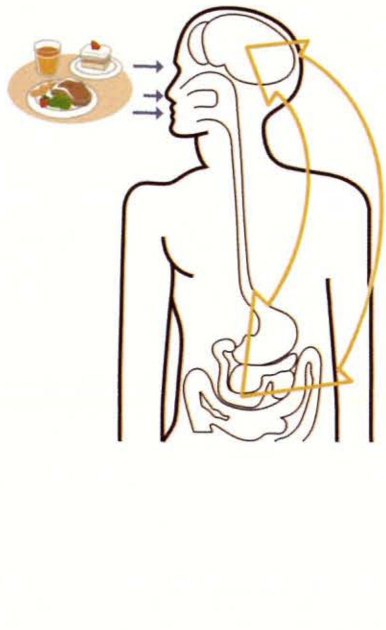
It can come as no surprise that appreciation starts with taste receptors on the tongue. Taste receptors are on microvilli of taste bud in papillae which are on the rough side of the tongue. Taste buds are small sensory organs composed of several taste cells which react to taste stimuli. An aqqueous stimulus reaches the microvilli of the taste cells within the taste buds through the pores on top of the buds. With the resluting activation of the cells, a message is transmitted to the brain via the nerves.

Recent studies on taste physiology has been providing us with new knowledge on the mechanisms for taste reception and transduction system. During eating, taste substances including glutamate are received by receptors on our tongue. There are separate system for receiving each basic taste. When receptors receive taste substances, such as glutmate, sucrose or caffeine, taste information is transferred to the brain through taste nerves. As a result we recognize different tastes.

In 2000, a research group in the US discovered a candidate receptor, metabotropic glutamate receptor type 4 variant(mGluR4), for glutamate on the tongues. Since then, many researchers around the world have found and identified new candidate receptors for umami or amino acids. Interdisciplinary research into umami, leading to an understanding of reception and transduction of basic tastes, and also cognitive mechanisms for umami inside the brain.

In 2006, a Japanese research team found that there were glutamate receptors, particularly metabotoropic glutamate receptor type 1 variant (mGluR1), in the stomach tissue. As umami taste sends signals to the brain through taste nerves after activation of its receptors on the tongue, umami receptors in the stomach also send signals to the brain via the vagus nerve through specialized fibers called afferents. The vagus nerve is the nerve that transfers sensory information of ingested foods from various alimentary organs, including the stomach, to the brain to regulate digestion of food. Upon receiving those signals, the brain responds by preparing the stomach for the digestion of food taken into the body via other nerve fibers of the vagus. They are called efferents because in this case information travels from the brain to the stomach. A similar response to umami occurs in the pancreas that also prepares for digestion in the small intestine under the central command of the brain. The complete elucidation for the physiological role of both oral and gastric chemoperception may lead to a better understanding of food digestion regulation and ingestive behavior control. Why is it important? The knowledge in the presence of specific regulatory receptors in the stomach will open the door for a new horizon in nutrition and new ways of intervention, which will answer the ultimate question 'why we eat.'

Basic taste	Stimulus	Threshold (%)
Sweetness	Sucrose	0.5
Sourness	Acetic acid	0.012
Saltiness	Sodium chloride	0.2
Bitterness	Quinine	0.00005
Umami	Monosodium glutamate (MSG)	0.03



step 2: flavor

Taste is one thing, flavor another.

It is only when the basic tastes work together with the sense of smell–and, most scientists maintain, the sense of touch as well–that the full flavor of a food emerges and it approaches palatability. That is, the whole oral cavity comes into play as our noses pick up the initial bouquet and add scents as we chew.

The importance of the sense of smell is readily apparent when we remember that many dishes would simply not be what they are if their aroma were to change–just the smell of bacon and eggs with coffee, cacchitore chicken smothered in tomato sauce, fresh papaya or corn tamales straight from the oven can whet our appetites. Not only a source of flavor, the sense of smell also functions as an early warning system that detects spoiled food.

Looking to all of the sensations of the mouth, the majority of reseachers in food chemistry include the sense of touch in an explanation of flavor–hence, the second designation of flavor on the preceding chart. As our tongues bring the sense of touch into play, the texture of a food–hard, smooth, sticky or crisp–and its temperature are integral to our delight or rejection. Many will attest to the pleasure of a cool drink on a warm day, iust as the crispness of an apple or water chestnut, the creamy smoothness of an avocado or the stickiness of tapioca have won devotees.

While it is easy to define the role that the senses play in creating flavor, amplitude is harder to pin down, even though we all succumb to the subtle allure of full-bodied flavor. Almost intangible, amplitude is the quality that accounts for the richness and complexity of a dish, the quality that separates the bland from the resonant.

And it is just at this point that research findings have demonstrated that umami is crucial. Not only a basic taste, umami is a flavor enhancer that brings out the essential character of the food itself. If the numerous factors in appreciation can be compared to all the instruments in an orchestra, then umami is the contrabass–the subtle but indispensable source of the rhythm that holds an arrangement together.

step 3: palatability

Building on the impressions of the other senses, vision and hearing establish a food's palatability.

Through our sense of sight, we take pleasure in form and color. Their distinctive shape and hue increase the delight we take in a range of vegetables and fruits–from those as common as cauliflower, eggplant, bell peppers and carrots to the tropical delights of mangostines, lichees, bananas and coconuts. Even if they may disagree on a particular aesthetic, there is universal agreement among gourmets that the eyes have it–that presentation is essential to the total effect of a preparation.

The sense of hearing also contributes to response–the cracking of a tortilla, the sizzling of a juicy steak over the fire. Just listening to comestibles being prepared or eaten is often enough to stimulate our appetites, and even the sound of chewing affects our experience.

If a dish is embroidered with a sprig of parsley, if a meal is served with chamber music in the background, it is a sign that the cook knows that appreciation calls on far more than taste.

Research readout

In "The Role of Extractive Components in Producing the Characteristic Flavor of Crab Meat," Dr. Shoji Konosu and his colleagues at the University of Tokyo bring hard scientific support to back up our subjective impressions of the importance of umami in amplitude.

After breaking the snow crab down into 44 chemical constituents, taste tests were conducted to establish the ten most striking aspects of its flavor. The results reveal the ways that glutamate and nucleotides contribute to the lingering, complex, full-bodied taste of crab as well as definition of its natural character.

While other ingredients also contribute to this trait, it is clear that crab just does not taste like crab if its umami is eliminated. The same conclusion was drawn in studies on other foods.

Extracted components in taste tests on crab (mg/100ml)

Glycine	600
Alanine	200
Arginine	600
Glutamate	30
Inosinate (IMP)	20
NaCl	500
K_2HPO_4	400
pH	6.80

step 4: acceptability

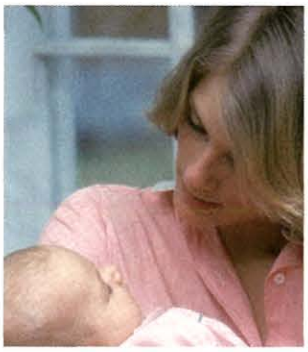
More than the physical senses come into play when we dine. Before we are finally ready to appreciate a food, our overall physical and emotional states must be attuned as well as our personal and cultural backgrounds. Any one of these factors can make or break enjoyment, even though the senses have been satisfied.

Of course, physical health is essential. Even if a person's appetite surmounts an illness, it is very unlikely that he or she will savor the repast. Flavor inevitably loses out to the software of mood as well. No one is apt to relish a feast after failing a test; a dreary day can frustrate the chef as well as diners. On the other hand, a table surrounded by convivial friends can be the beginning of a banquet to remember.

Habituation can also influence our preferences. Spaghetti sauce reminiscent of that grandmother used to make can prompt enthusiasm years after, while some adults wreak revenge on their parents by refusing to eat beets even decades after they have been on their own.

Not limited to personal influences, acceptability is also a function of the culture a person grows up in. Religious prohibitions, for example, may inhibit appreciation of beef, and some societies are aghast at the notion of eating monkey brains.

It is only when all of these factors–from the tongue to thousands of years of tradition–are satisfied that a gourmand can enjoy a delectable morsel. But everyone knows the result when all four steps are taken: nothing short of delicious.



Out of the mouths of babes
One of the most pointed examples of the way that we hunger for the tastes we need is apparent in studies on nutrition during infancy.

Scientists have found that during the period of their fastest growth babies not only can detect glutamate—in this case a 0.4% solution in vegetable soup—but also like it. Equally telling is the abundance of glutamate in mother's milk, the sole source of protein for most children in their early months. Particularly copious in the breast milk of the more intelligent animals, L-glutamate is another indication of how vital the umami taste is right from birth.

Free L-glutamate in breast milk (mg/100ml)

Human	21.6
Chimpanzee	38.9
Baboon	6.5
Rhesus monkey	4.6
Java monkey	4.3
Horse	8.4
Cow	1.9
Sheep	1.4
Rabbit	4.6
Cat	2.6
Mouse	2.2
Guinea pig	2.2
Rat	1.6

Although we may forget it as we enjoy a meal, taste is not just for the palate. At least most of the time, we eat what we need, even when we are full.

When we require energy, there is a natural craving for sugar. If the body is dehydrated, it cries out for water and the salt that replenishes minerals. A yearning for something sour reflects a need to boost the metabolism. Perhaps in much the same way, there is the possibility that in the future a similar link between umami and protein will be discovered.

Just as the basic tastes can feed the body, so they can protect it. A bitter taste, for example, is a warning that a substance is toxic, a defense mechanism that accounts for its very low threshold. Even if adults learn to appreciate the tang of lemon, a sour taste often complements this defense as it sets off an alarm that a food is spoiled.

The basic tastes are, then, not just a source of enjoyment but a complex semiotic system that directs us to satisfy the body's needs. It is these physiological functions that make any discovery in taste physiology an event of major significance.

When we group umami with the other four basic tastes, we are not just obliging the findings of science. We are also learning to interpret the signals that the body sends. It is a language that deserves attention.

The biological functions of tastes

Sweet	Signal for sucrose functions as a source of energy
Sour	Signal for organic acids accelerates the metabolism as well as warns that food is spoiled
Salty	Signal for minerals helps to maintain the balance of the body fluids
Bitter	Signal for alert protects the body from harmful substances
Umami	Signal for protein serves as a source of essential nutrients

Non-Profit Organization

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