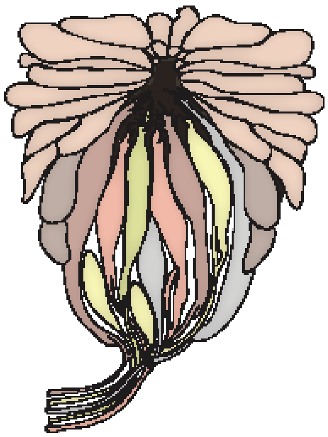
What exactly is taste, and why is it important?

Well into the modern age, taste was regarded as something subjective over which housewives and chefs held sway. It was not until about the 1920s that it became the object of rigorous scientific studies. So it should come as no surprise that it is only within the past few decades that we have started to gain a better understanding of its actual physiological basis. This allows us to explain, in detail, how taste is detected in the mouth by certain receptors and converted into nerve impulses that are then forwarded to specific centers in the brain. The neural cells in these centers carry out the final calculation and convey a message about the food—for example, sweet! or salty!

THE BASIC TASTES: FROM SEVEN TO FOUR TO FIVE AND POSSIBLY MANY MORE

For many centuries, it was customary in the Western world to accept the ancient Greek view, originating with Aristotle, that there were seven basic tastes: sour, sweet, salty, bitter, astringent (causing dryness), pungent (or spicy), and harsh. Over time, people came to the conclusion that there were actually no more than four true basic tastes; namely, the first four on this list. But it was only in the course of the twentieth century that a clear distinction was drawn between sour, sweet, salty, and bitter as genuine tastes and the other three as mechanical or chemical effects caused by substances in the food that damage the cells on the tongue or in the mouth.

In many countries in Asia, however, people have thought that in addition to these four basic tastes, there is a fifth one—pungent or spicy, for example, as in chile peppers. Complicating matters, according to classical Indian philosophy, astringent is also a separate taste. On the other hand,



Schematic illustration of a taste bud. The taste bud is covered by some epithelial cells that form a little pore, through which the taste substance can enter the taste bud. The taste bud consists of a bundle of taste receptor cells, which are individually responsive to one basic taste: sour, sweet, salty, bitter, or umami. Cells that detect the same tastes transmit the information through a single nerve fiber that forwards the collective signal to the brain, which then registers the taste sensation.

A number of models have been proposed to explain how the various taste receptor cells transmit their signals from the taste buds. There now appears to be a consensus around a model in which each taste receptor cell is primarily adapted to detect one particular taste. The various cells that are sensitive to the same taste collect the signals in a single nerve fiber that sends the total signal onward through the cranial nerves to the taste center in the brain. The picture is complicated by the presence in the taste buds of another type of cells, known as the presynaptic cells, which have no taste receptors but still participate in the transmission of the nerve signals. In contrast to the taste receptor cells, the presynaptic cells can respond to several different types of taste, given that they receive signals from a number of taste receptor cells.

There are two principal types of taste receptors. One type, called the G-protein-coupled receptors, which are sensitive to sweet, bitter, and umami tastes, traverse the membrane of the sensory cell. When such a receptor on the surface of the cell has identified a taste molecule for which it is adapted and has bound it, a signal is passed through the protein that a certain other protein (known as the G-protein), located on the other side of the membrane, is also to be bound. This binding sets in motion a cascade of biochemical processes that eventually cause particular sodium channels in the cell membrane to open. Sodium ions flow through the channels, resulting in a drop in the electrical potential across the membrane. This generates an electrical signal that passes through the nerve and ends up in the brain.

The other type of taste receptors is sensitive to sour and salty tastes; that is to say, especially hydrogen ions (H^+) and sodium ions (Na^+), but also potassium ions (K^+). These receptors are ion channels that cut across the cell membrane. A change in the concentration of these ions is registered by the taste receptors, which leads to a change in the electrical potential across the membrane, and an electrical impulse can be sent to the brain.

THE INTERPLAY BETWEEN SWEET AND BITTER

In contrast to umami, which in its pure form is brought out by only a small number of substances, an incredible range of very diverse substances brings out sweetness and bitterness. For a long time, it was thought that the receptors for sweet and bitter tastes were very closely related. This is due to the fact that many sweet substances, such as the artificial sweetener saccharine, can have a bitter aftertaste. In addition, only very minor chemical modifications can change a molecule from

There is still another quality,
which is quite distinct from all these
[sweet, sour, bitter, briny] and which must
be considered primary, because it cannot be
produced by any combination of other qualities.
… It is usually so faint and overshadowed by
other stronger tastes that it is often difficult
to recognize it unless the attention is
specially directed towards it….
For this taste quality the name
'glutamic taste' [umami]
is proposed.

これらの味とは全く別の、そして他の味を如何に組合わせても作ることができないことから、本源的とみなければならない別の味がある。その味は通常非常に弱く、他の強い味によってボカされるので特に注意をそれに向けないと識別することがむずかしい。私はこの味に「グルタミン酸の味」という名称をつけようと思う。

Kikunae Ikeda (1864–1936)

The fifth taste: What is umami?

Even though the word *umai* had been used in Japan for hundreds of years to signify the concept of something delicious, people only became truly conscious of it thanks to the efforts of a single individual—Japanese professor and chemist Kikunae Ikeda (1864–1936), who set himself the challenge of identifying the substance in Japanese soups that was responsible for their fantastically good taste. He found the answer in 1908.

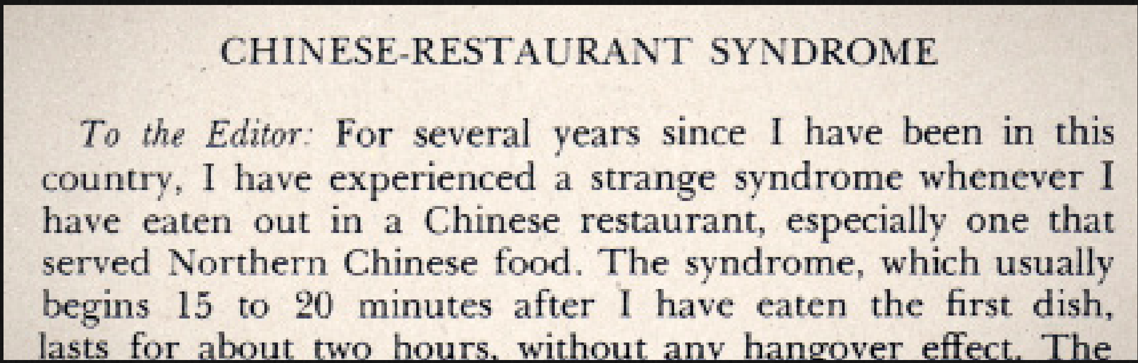
In 1908, Professor Kikunae Ikeda (1864–1936), a Japanese chemist, discovered that monosodium glutamate (MSG) is the substance that is responsible for the delicious taste of the soup stock dashi. He was the first person to investigate this taste in a scientific manner and introduced the term by which it is now known: umami.

SCIENCE, SOUP, AND THE SEARCH FOR THE FIFTH TASTE

Japanese soups are based on a stock called *dashi*, which is a very simple, clear broth. It is made by extracting the taste substances from a particular species of brown macroalgae, konbu, and flakes of fish that have been cooked, salted, dried, fermented, and smoked, known as *katsuobushi*. Dashi is rich in umami and is a ubiquitous, indispensable element that is central to all traditional Japanese cuisine.

Professor Ikeda's hypothesis was that the soup must contain a substance that imparted a taste that could not be explained away as a combination of the four common basic tastes. So he set to work on the very labor-intensive, and at times probably very tedious, process of making a chemical analysis of all the ingredients found in an aqueous extract of konbu (*Saccharina japonica*), a species of kelp. He started with 12 kilograms of the seaweed, basically working on his own with a single laboratory assistant.

First, Ikeda discovered that the extract from the seaweed contained an abundance of a particular carbohydrate, mannitol, a sugar alcohol present in the slime that is exuded onto the surface of many brown algae. Mannitol tastes somewhat sweet. He also noted the presence of a number of inorganic salts. Finally, he isolated a component that he identified as a salt of


CHINESE-RESTAURANT SYNDROME

To the Editor: For several years since I have been in this country, I have experienced a strange syndrome whenever I have eaten out in a Chinese restaurant, especially one that served Northern Chinese food. The syndrome, which usually begins 15 to 20 minutes after I have eaten the first dish, lasts for about two hours, without any hangover effect. The

A little letter with a huge impact: The ‘Chinese restaurant syndrome’

In 1968, *The New England Journal of Medicine* published a short communication, which was not a scientific article but a letter to the editor, from Dr. Robert Ho Man Kwok. In this little letter, which is only about forty lines long, Dr. Kwok describes his personal observations about what he characterized as a “strange syndrome” that he and others experienced after eating at Chinese restaurants. The syndrome resembled a mild version of the hypersensitivity some individuals have to the acetylsalicylic acid found in aspirin. The somewhat vaguely defined symptoms associated with the syndrome included numbness at the back of the neck that gradually radiated to the arms and the back, general weakness, heart palpitations, and thirst. They set in 15 to 20 minutes after the meal had started and lasted for a few hours, but they had no lasting effect.

Dr. Kwok writes that the underlying cause of this reaction is obscure and speculates on a range of different possibilities. He specifically mentions a number of ingredients that were all, at that time, used liberally in Chinese restaurants: soy sauce, cooking wine, MSG, and salt. Any of these in excess could trigger a reaction, which might be more acute when several of them are combined. He is very cautious in his allegations and suggests that it might possibly be that the sodium from the large quantities of table salt, together with that from the MSG, creates an imbalance between potassium and sodium in the body. At the conclusion of the letter, he makes a plea for more information on the subject.

It is noteworthy that the expression ‘Chinese restaurant syndrome’ and the more recently adopted ‘MSG-symptom complex’ are not to be found in Dr. Kwok’s letter. Rather, it was used as a heading for the letter and was chosen by the editor.

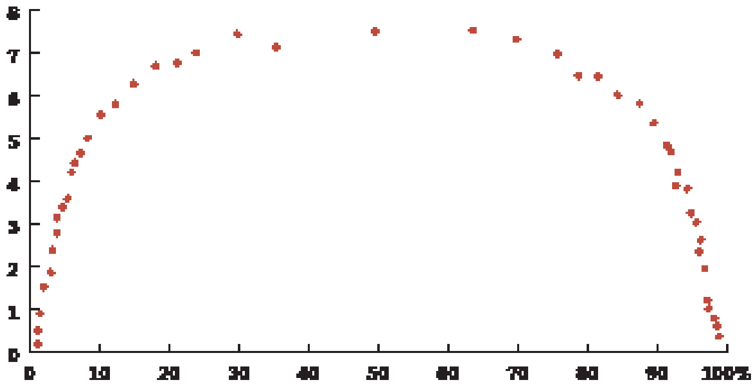
This short letter was to have a huge impact, which is felt even now.

Dr. Kwok’s letter attracted much attention and caused an uproar, not least because government authorities had declared that MSG was safe for human consumption. MSG was vocally proclaimed to be a fiendish invention of the food manufacturers and its consequences cited as an example of the dangers of using chemicals in foods. Experiments come closer to an understanding of this mechanism. Paradoxically, the synergistic effect makes it much harder to evaluate the taste of pure inosinate, because human saliva normally contains a miniscule amount of glutamate, about 0.00015 percent.

The culinary arts can be said to be a study of how to maximize umami by taking advantage of the gustatory synergy produced by combining different ingredients. In the preparation of a dish, one will typically

DETECTING UMAMI SYNERGY ON THE TONGUE AND IN THE BRAIN

The Japanese researcher Shizuko Yamaguchi carried out a seminal study based on psychophysical observations, which resulted in an actual formula for the synergy in umami. As shown in the following illustration, the subjective experience of taste intensity increases when glutamate and inosinate are present at the same time. In the experiment, the total concentration of the two substances remains constant (50 mg/100 g), but the proportion of each varies. At this concentration, both pure glutamate and pure inosinate result in very weak taste intensity, but when they are mixed together, the intensity increases and is strongest when there are equal amounts of each. The bell curve derived from these measurements has given rise to the popular saying about synergy in umami: 1 + 1 = 8.



Curve showing the subjective perceptions of the taste intensity of umami produced by a mixture of MSG and IMP, where the proportion of the two components in the mixture varies but the combined amount is constant and lies below the detection threshold of each of the two components. The curve shows that when small quantities of one are added to the other, the taste intensity rises dramatically. Taste intensity is strongest when there are approximately equal amounts of the two components.

seaweed and mix in the extract from the mushrooms. The *shōjin* dashi is now ready for use, for instance, in a consommé with vegetables and tofu.

1 L (4¼ c) soft water • 100 g (3½ oz) dried shiitake mushrooms
1 L (4¼ c) soft water • 10 g (⅓ oz) dried konbu

INSTANT DASHI

If you do not have time to make dashi from scratch, a dry soup powder, e.g., Hon-dashi, consisting of dehydrated dashi containing *katsuobushi*, often with some MSG added to it, can come to the rescue. Packaged preparations for Japanese consommé or miso soup are generally based on dashi powder. Pure konbu dashi powder is also commercially available.

Three types of dashi, from top to bottom: konbu dashi, first dashi, and dashi made with the red alga dulse.

NORDIC DASHI

Once one has realized that it takes two components, namely, glutamate and one or more ribonucleotides, to make a clear dashi with good umami, there is nothing to stop one from improvising with local ingredients. These can be chosen by consulting the tables at the back of the book. And then, armed with knowledge of the synergistic properties of umami, all that remains is to experiment with different combinations and methods of preparation until the desired taste is achieved. It becomes an exciting venture into the realm of molecular gastronomy.

Practitioners of the New Nordic Cuisine have a dogma that all ingredients must be from the region. One can remain faithful to the idea of the traditional Japanese dashi while using local seaweeds, such as sugar kelp, winged kelp, or dulse, as a source of glutamate. The problem, however, is that there is nothing that is truly equivalent to *katsuobushi*. But it could be replaced by dried Nordic mushrooms, cured pork, or prepared chicken. Even though the Nordic varieties of seaweeds have much less free glutamate than konbu, and even though neither mushrooms, pork, nor chicken have as much guanylate or inosinate as *katsuobushi*, experimentation has shown that one can make a reasonably tasty dashi by using another alga such as dulse or winged kelp. The finished stock is mild, with a slightly floral taste.

It is, however, possible to go one step further and create another type of dashi, resembling a vegetarian *shōjin* dashi, using ingredients that are available practically anywhere in the world. It calls for only two things—

Umami-rich 'foie gras from the sea'

Only a few decades ago, monkfish was disdained as a relatively uninteresting bycatch when trawling for groundfish or dredging for scallops. There is little question that its appearance worked against it, as it was considered to be one of the ugliest creatures in the sea. With its huge head and enormous mouth, a peculiar sort of antenna used to lure prey toward it, and clumsy mitten-like dorsal fins, it was unlikely to make an appearance on any dinner table as a grilled whole fish.

Monkfish liver.

In the past few years, though, monkfish has come to be appreciated for its taste, and it is now such a sought-after delicacy that there is no longer any justification for calling it 'poor man's lobster.' The flesh from the tail and the cheeks costs a small fortune at the fish store. But there is yet another delicious part of the fish, namely its liver, which has not made many inroads in Western cuisine. This is puzzling, as monkfish liver is held in high esteem in Japan, and some, who have come to know it elsewhere, call it 'foie gras from the sea,' putting it on a par with goose liver.

Monkfish liver certainly deserves to take a place alongside the much more common cod liver, which is already a familiar item in some cuisines. It can be prepared so that it is soft and creamy, with good mouthfeel. It has tastes of the sea, but these are mingled with its fattiness and inherent slightly sweet and partly bitter and nutty tastes. In contrast to liver from poultry, or for that matter from cod, which is brownish, it is pale orange, providing a beautiful color contrast in a dish.

A fatty goose or duck liver can have a fat content of 50–60 percent. The fat, which is overwhelmingly made up of unsaturated fatty acids, is distributed throughout in small droplets, which results in a pleasing, delicate mouthfeel. Monkfish liver has only about half as much fat as goose liver, but it is also primarily made up of unsaturated fatty acids. The liver of a fully grown monkfish can be quite large, weighing as much as half a kilogram. Small livers from younger fish are much finer than the large ones, which have a more bitter taste and a coarser texture. Monkfish liver contains only about one tenth as much iron as goose liver, and it is consequently less characterized by the taste of iron than poultry liver is. But it is rich in umami, which can be enhanced by the way it is prepared.

In Japan, monkfish liver, or *ankimo*, is a major winter delicacy. According to the classical recipe, cleaning the fresh liver involves placing it in a 3 percent salt brine, to which sake has been added, for about half an hour. Then the large veins are removed. One or more livers, placed in cheesecloth or aluminum foil, are rolled tightly using a bamboo rolling mat to form a thick sausage, which is then steamed for 30–40 minutes. It must be cooled before serving and has the best consistency after being left in the refrigerator for about a day. *Ankimo* is served with a dressing made from soy sauce, *yuzu* juice (or *ponzu* sauce in place of both), dashi, and possibly a bit of sake.

MONKFISH LIVER AU GRATIN WITH CRABMEAT AND VEGETABLES

It is best to presoak the liver under refrigeration for 12–30 hours to remove some of its bitter taste. This can be done in a 3 percent salt brine or, even better, in milk, which seems to be more effective. Next, the liver needs to be tidied up by removing the blood vessels.

Serves 4

250 g (½ lb) monkfish liver, presoaked in milk for 12 hours
500 g (about 1 lb) vegetables, as follows:
100 g (3¼ oz) ripe tomatoes
100 g (3¼ oz) porcini mushrooms
100 g (3¼ oz) red bell peppers
100 g (3¼ oz) eggplant
100 g (3¼ oz) celery
1 large clove garlic, puréed
2 shallots
¼ tsp fennel seeds
olive oil
1 Tbsp puréed tomato
1 small chile pepper
150 g (5¼ oz) crabmeat
2 egg yolks
1 small sprig fresh dill, chopped
salt and freshly ground black pepper
8 small pieces grilled bread or brioche
salsa verde from basil, sage, parsley, anchovies, capers, and olive oil
baked tomatoes and dried olives, for garnish

1. Finely dice the monkfish liver together with the vegetables, puréed garlic, chile pepper, shallots, fennel seeds, puréed tomato, and chile pepper to make a coarse *brunoise*. Heat some olive oil in a large skillet over medium heat and cook the mixture, stirring constantly, until it has a uniform consistency.
2. Remove from the heat, allow to cool, and put through a food processor to make a coarse mince. Fold in the crabmeat, egg yolks, and dill. Season well with salt and black pepper.
3. Make a *salsa verde* from basil, sage, parsley, anchovies, capers, and olive oil according to taste.
4. Spread the liver mixture on grilled toast or pieces of brioche and grill in the oven for a couple of minutes.
5. Serve on a bed of *salsa verde* and garnish with baked tomatoes and dried olives.

Tip: Count on using a little less than 1 kg (2.2 lb) of crab claws, of which about one-fifth is actual crabmeat.

▸ Monkfish liver au gratin with crabmeat and vegetables.

Katsuobushi for sale at a Japanese market.

Unfortunately, we were not able to see how *karebushi* is made in the course of our visit to Yaizu. This is a description of the process. First the tar-covered outer layer of the *arabushi* is planed or scraped off and the fillets are sprayed with a mold culture (*Aspergillus glaucus*) at a temperature of 28°C. In the course of the following weeks, the mold spores sprout on the fillet and the fungal mycelia bore into the fillet. Once it is covered with mold, the fillet is brought out into the sun to dry, and all the mold is scraped off. This alternation between taking the fillet into the mold chamber and bringing it outside to dry in the sun continues for one to two months. The quality of the fish is thought to improve with each successive cycle.

The longer and more meticulous process used to make *karebushi* leads to a dried product that has fewer cracks. As a result, it is possible to make shavings that stay together instead of crumbling. When it is to be used, the hard fillet is placed on top of special box, which is like an inverted plane, so that ultrathin shavings can be cut from it. The *karebushi* yields the best taste when it is freshly shaved. Because they are so thin, it is technically possible to get 98 percent of the taste substance inosinate to seep out into a dashi. One can buy ready-cut shavings in airtight packages containing nitrogen to prevent the shavings from oxidizing. The shavings come in several varieties, according to the thickness of the shavings. Naturally, the thinner the shavings, the more quickly one can extract umami to make dashi.

Katsuobushi flakes are also sprinkled on soups, vegetables, and rice. When the dried flakes encounter the steam from the hot food, they contract and move as if dancing. That is why the Japanese call them 'dancing' fish flakes.

How does *katsuobushi* taste? First and foremost, there is a mild smoky taste, then a little saltiness, and then umami. Apart from inosinate, *katsuobushi* has at least forty other substances that contribute to its complex and distinctive taste, which combines saltiness, bitterness, and umami. Bitterness from an amino acid, histidine, is particularly prominent. The umami taste really comes to the forefront when *katsuobushi* is combined with other ingredients that contain glutamate, such as konbu.

▸ *Katsuobushi* production in Japan. Here the fillets are simmering in a special kettle.

Brewing Japanese *shōyu* in the traditional manner takes time. Due to a shortage of soybeans in Japan after World War II, it was necessary to import them from the United States. Furthermore, because of the difficult economic situation at the end of the 1940s, the slow fermentation process, which breaks down the proteins in the beans to free amino acids, was displaced by a faster enzymatically controlled method. Later, there was a return to the classical methods, but in more efficient, modern breweries.

Commercially produced soy sauce.

PRODUCTION OF *SHŌYU*

Brewing Japanese *shōyu* using the traditional process starts with a Chinese invention, a fermentation medium called *kōji*, which is the secret behind the whole process. Without it, it is not possible to make authentic soy sauce. For soy sauce, the *kōji* consists of a solid mass of cooked soybeans and roasted crushed wheat, which has been seeded with the spores of the fungi *Aspergillus oryzae* and *Aspergillus sojae*. The spores sprout to form a mycelium that grows in it for about three days at a temperature of 30°C. The resulting *kōji* contains a large quantity of hydrolytic enzymes that are able to break down proteins.

The *kōji* is then placed in a saline solution (22–25 percent w/v NaCl) for six to eight months. The salt causes the fungus to die off, but its enzymes remain active. A yeast culture and lactic acid bacteria, which thrive in a salty environment, either start to grow spontaneously in the solution or are introduced into it. The combined activity of the enzymes and the microorganisms breaks down the proteins and fats, giving rise to a wide range of taste and aromatic substances, among them free amino acids and large quantities of glutamate. The resulting solid, called *moromi*, is placed in large, open cedar barrels, where it is allowed to cure for two summers. At the completion of this aging process, the *moromi* is transferred to canvas sacks that are pressed to separate out both soy sauce and soy oil. The latter floats to the top and is removed. The soy sauce is then pasteurized and bottled. Using this process, it takes two years to produce top-quality Japanese *shōyu*.

Shōyu was one of the few Japanese food products that the Dutch were allowed to take back to Europe during the 250-year Edo period, when Japan was isolated from the rest of the world by the shogunate. It was exported from their trading station at Dejima, near Nagasaki, and shipped to Europe, where it found favor in the kitchens of the royal French court.

Cutaway of a tomato showing the variations in the glutamate (MSG) and adenylate (AMP) content across the inside of the tomato.

As we learned from the experiment with making a Nordic dashi, sun-ripened tomatoes can be used as a source of glutamate for the stock, for example, in combination with smoked shrimp heads or dried fungi.

The wealth of umami in tomato juice can also be used to advantage in cocktails made with an alcohol that has little taste on its own, such as vodka. A classic example is the Bloody Mary. An even better example is a cocktail inspired by the sauce for a Venetian version of *spaghetti alle vongole*, made with clams and tomatoes. This is the Bloody Caesar, which combines vodka, tomato juice, clam broth, Worcestershire sauce, and a drop of Tabasco sauce. It is Canada's most popular mixed drink. But it is, possibly, also its best-kept secret and deserves a much wider following elsewhere.

Mackerel contains large quantities of inosinate, 215 mg per 100 g. When combined with tomato, the synergy between the two ingredients turns the dish into a veritable umami bomb. So it is little wonder that even a simple tin of mackerel in tomato sauce can give so much pleasure. And who has not experienced the fantastically good taste that the traditional Italian Bolognese sauce, combining tomatoes and meat, can add to a simple bowl of pasta?

Because tomato sauce enhances umami, it provides a convenient way to round out the taste impressions in a dish, both by increasing saltiness and sweetness and by masking any bitter nuances. ··> *Baked monkfish liver with raspberries and peanuts (page 128).* The best way to gain the most concentrated umami taste from tomatoes is to oven-roast cooked whole tomatoes and herbs at low heat. If the tomatoes and herbs are chopped coarsely, the roasted tomato paste will end up with a texture that is similar to that of Bolognese sauce, but without the meat. The

Umami from land animals: Meat, eggs, and dairy products

In general, there are more free amino acids in the foodstuffs that are made from the organisms that grow in the earth than there are in those derived from the animals that live on it. On the other hand, animal-based foods are good sources of inosinate, which interacts synergistically to signal the presence of proteins. The umami content of meat and dairy products can be strengthened dramatically by preparing them in certain ways or by fermentation and curing. In particular, both simmering meat and bones over long periods of time and fermenting milk result in an abundance of umami.

THE ANIMAL KINGDOM DELIVERS UMAMI IN SPADES

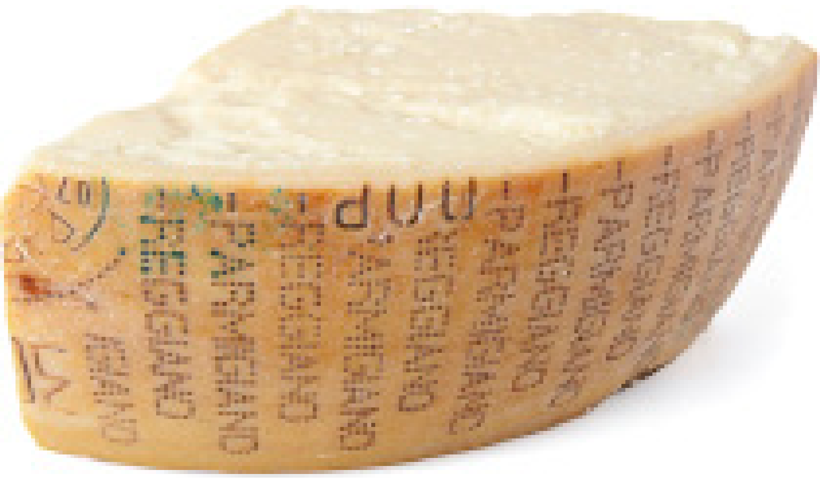
Meat and dairy products are excellent sources of protein. The art of turning them into tasty food is, therefore, to a great extent a question of breaking down the proteins present in the raw ingredients. Animal innards generally contain more umami substances than meat from the animal muscles. A piece of liver, for example, foie gras, can also have a large quantity of glutathione, a compound that elicits *kokumi* and, thereby, also enhances umami. ··> *Mushrooms, foie gras, and mushroom essence (page 138)*

In order to release the umami, we employ a whole range of techniques: cooking, ripening, curing, drying, salting, smoking, and fermenting. These processes allow us to draw out free amino acids in greater or lesser quantities. Many researchers in the field of evolution posit that our distant ancestors began to cook their food, especially the meat, a few million years ago. Their early culinary efforts were a determining made up of ordinary salt, which is what many people think, but rather of calcium lactate and the bitter-tasting amino acid tyrosine.

Parmesan cheese is unrivalled in its ability to add depth to the taste of an otherwise insipid pasta or rice dish. Because it is so rich in umami, Parmesan can help to attenuate the bitterness in some dishes, especially if they also have a little sweetness that can be enhanced by the glutamate from the cheese. For example, in pesto sauce the cheese helps to soften some of the bitterness inherent in basil. Moreover, the dry rind, which can be saved and stored for a long time, is a good source for adding umami to soups and sauces.

Another use of Parmesan is in baking, for example, to add umami to breads or biscuits. A real umami treat can be created by mixing in some bacon at the same time, because it contributes inosinate, which interacts synergistically with the glutamate. To enrich the taste even more, one can add a few flakes of nutritional yeast to the dough. ···> *Parmesan biscuits with bacon and yeast flakes (page 150)*

It is possible to make a vegetarian version of the Parmesan biscuits by substituting the red alga dulse for the bacon. Dulse has a characteristic slightly smoky and meaty taste. No doubt that is why toasted dulse was once a popular snack in Scottish pubs. ···> *Parmesan biscuits with dulse (page 150)*



Parmesan cheese (Parmigiano-Reggiano).

KNORR AND MAGGI: EUROPEAN UMAMI PIONEERS

Carl Heinrich Theodor Knorr (1800–1875) was a German food products manufacturer, who started out by producing coffee substitutes and marketing grains. About 1870, with the collaboration of his sons, he introduced a line of soup powders made from finely milled dried legumes and dried vegetables. The company is now owned by Unilever, which has the rights to the Knorr brand in all countries except Japan, where it is marketed by Ajinomoto.

Knorr's soup powders and bouillon cubes were the first successful commercially produced soup concentrates in Europe. Among industrially prepared stocks, they are the ones that most closely resemble Japanese dashi powder.

The Swiss miller and industrial food pioneer Julius Maggi also came up with the idea of producing soup powders for the European market. They contain dehydrated, concentrated bouillon based on hydrolyzed plant protein, which is rich in glutamate—in other words, concentrated umami. His most famous, and ingenious, invention is the little bouillon cube, which was first sold in 1908. This inexpensive cube was used by those who could not afford meat, in order to impart a meaty taste to soups and sauces.

Even though Maggi's company was swallowed up many decades ago by the giant conglomerate Nestlé, the Maggi cube is still synonymous with a quick, cheap way to make a delicious bowl of soup.

A related product is a thin sauce, also called Maggi, which is popular in both the East and the West as a condiment or as a seasoning for soups and stews. Its taste is very similar to that of the herb lovage, which is not actually a component of the product. Ironically, however, lovage is referred to in a number of languages as the Maggi herb.

Bass Brewery, and a source of large quantities of yeast, a by-product of the beer-making process. The famous German chemist Justus von Liebig (1803–1873) had earlier discovered that brewer's yeast could be converted into a useful, nutritious substance. Based on his findings, the Gilmour family set up a factory to take advantage of the excess brewer's yeast that would otherwise have been discarded. The yeast is hydrolyzed to release its free glutamate content, which is then mixed with salt, vegetable extracts, and other ingredients to produce a dark brown, sticky paste with a strong, salty taste.

About 2 percent of Marmite (1,960 mg/100 g) is made up of free glutamate, giving it an intense umami taste. In addition, as it has significant quantities of vitamin B, including folic acid (B_9) and B_{12}, the paste is a good source of this vital nutrient. After vitamins were first discovered and described scientifically in the early 1900s, Marmite quickly gained popularity. Beriberi, a disease caused by vitamin B deficiency, had been common in Britain during World War I, and Marmite was embraced as a way to prevent it. Its nutritional content was the very justifiable basis for a later marketing campaign that promoted the spread as a source of sufficient vitamin B to keep nerves, brain, and digestion in proper working order.

Marmite is used more or less in the same way as Bovril, often spread thinly on toasted, buttered bread or made into a drink. Whatever the nutritional merits of Marmite, its palatability evokes strong opinions one way or another, and it is definitely an acquired taste. Its fans defend it passionately, while others think that it is disgusting and inedible. The manufacturer capitalized on these reactions a number of years ago, launching a marketing campaign with the slogan "Love It or Hate It."

Another similar product, Vegemite, which has gained the status of a national icon in its home country of Australia, followed a couple of decades later. The name draws attention to its vegetable content, to which autolyzed brewer's yeast is added. In 2009 the parent company, Kraft Foods, attempted to increase the appeal of this traditional product to the younger generation by rebranding it iSnack. The experiment was met with great resistance by the customer base and was quickly abandoned.

There are, naturally, other related pastes that are more locally based, among these Promite and AussieMite in Australia and Cenovis in Switzerland. True connoisseurs are aware of the subtle taste and texture differences that set them apart from each other.

Bovril, Marmite, and Vegemite, protein-rich products with tons of umami.

EGGPLANT GRATINÉE WITH GARLIC, ANCHOVIES, AND NUTRITIONAL YEAST

neutral-tasting oil, for deep-frying
eggplants, preferably the firm, long, and thin Japanese variety
cloves garlic, crushed
anchovy paste
nutritional yeast
panko bread crumbs

1. Heat the oil in a large, deep pot over medium-high heat until hot. Preheat the oven broiler.
2. Slice the eggplants in half lengthwise and deep-fry them in the hot oil until they are done through. Allow to cool.
3. Score a diamond pattern into the cut sides of the eggplants and rub them with the crushed garlic. Then spread the anchovy paste on them. Make a half-and-half mixture of nutritional yeast and *panko* bread crumbs and sprinkle that on top.
4. Broil until the surface is golden.

An American classic: Heinz tomato ketchup.

KETCHUP

Ketchup is a purée made from sun-ripened tomatoes. Many households in the Western world have a bottle of ketchup in the kitchen, where it is one of the most frequently used umami enhancers. Although ketchup is often associated with American fast food, such as hamburgers and fries, its roots are actually to be found in the Far East and Indonesia, where it was first fermented as a special type of salty, spicy fish sauce. The origin of the name is unknown, but a variant of it is the name of the original Chinese fish sauce, *koe-chiap*, which refers to the brine in which fish and shellfish were marinated in China.

English sailors brought this Chinese fish sauce back to Europe, where over time the recipe evolved to incorporate fungi, anchovies, tomatoes, vinegar, walnuts, pickled vegetables, and a number of spices. The tomatoes were included to lend umami to what was otherwise a blend of salty, bitter, and sour tastes. Along the way, an increasing amount of sugar was added, rounding out the full complement of all five basic tastes.

Tomato ketchup in its more or less present form dates back to the beginning of the 1800s. The best-known version is Heinz ketchup, which was put on the market in 1876 and is still made according to the same recipe.

Twelve easy ways to add umami

Mushroom salt

Cut shiitake or other dark mushrooms into slices and dry them in an oven on low heat. Crush them into a powder and mix it with Maldon sea salt flakes.

Use to season fish, soups, vegetables, and pasta dishes.

Highly concentrated chicken bouillon

1 L (4¼ c) chicken stock reduced to 1 dL (½ c) or less.

Use as an essence in gravies that are a little flat or to add depth to a dressing, or drizzle on pasta or salads.

Marinated mushrooms

Marinate mushrooms in a little soy sauce or garum.

Can be fried or used raw in salads.

Miso paste

Light or dark paste made from fermented soybeans; available where Asian foods are sold.

Adds a nutty, savory taste to dressings, sauces, marinades, and soups (especially those with shellfish); or use it like butter to coat warm vegetables just before serving.

Essence of Worcestershire sauce

Concentrated reduction of the sauce kept at the ready in a small bottle with an eyedropper.

Just add a couple of drops to meat that is being fried or to a sauce or a dressing. Rounds out the taste of a pâté or an egg dish.

Anchovy paste

Available in a squeezable tube to keep in the refrigerator.

For all types of vinaigrettes, dressings, marinades, pesto, and pâtés.

BEEF *ESTOFADO*

For the red wine marinade

Serves 4

500–600 g (17½–21 oz) root vegetables, such as celery, carrots, onions, and leeks
olive oil
1 bottle (750 ml) dry red wine
1 dL (⅔ c) red wine vinegar
fresh parsley stalks, sprigs of fresh thyme, bay leaves, black peppercorns, and peeled garlic cloves
300 g (10½ oz) bacon
1½ kg (3⅓ lb) beef chuck roast, bone-in

For braising and serving

root vegetables, such as celery, carrots, and celeriac
generous dash of brandy
a little more red wine, if needed
crushed tomatoes
mashed potatoes

1. Cut the first lot of root vegetables into large pieces and toast them in a pot in a little olive oil. Add the red wine, red wine vinegar, and the herbs and spices. Allow to simmer, covered, for 15–20 minutes; then cool.
2. Divide the bacon into two pieces, cut the meat into 8 pieces. Immerse the pieces completely in the cooled marinade and let sit in a cool place for 24 hours, turning them once.
3. Preheat the oven to 130°C (260°F). Allow the bacon and meat to drain thoroughly and then brown it well in a large skillet. Transfer to an ovenproof baking dish. Cut the second batch of root vegetables into large pieces and add to the dish. Pour in the marinade and add a generous dash of the distilled spirits and possibly a little more red wine. As the meat should be covered with liquid, it might be necessary to add a little beef bouillon or even a bit of water.
4. Braise in the oven for about 3 hours until the meat come off the bone easily.
5. Strain the liquid into a pot and skim off the fat carefully with a spoon. Reduce the liquid a little over high heat. The gravy can be thickened *en roux* using the fat, or by blending some of the vegetables and adding them to the gravy. What the gravy loses in appearance will be compensated for by what it gains by way of taste.
6. *To serve:* Prepare a large portion of crushed tomatoes as follows: Blanch the tomatoes in boiling water for 1 minute and peel them. Remove the seeds and chop the pulp into small cubes. Mix the tomatoes into the *estofado* and serve it with mashed potatoes, preferably mixed with puréed root vegetables.

▸ Beef *estofado*.

RATATOUILLE AND *BRANDADE*

The traditional Provençal ratatouille made with a variety of vegetables, typically eggplants, tomatoes, onions, and celery simmered in olive oil, can be a little on the heavy side. There is a Sicilian variation, however, which is lighter in color and less filling. ··> *Sicilian ratatouille*

Sicilian ratatouille can be served as an accompaniment to a *brandade*, which is made with salt cod. ··> *Brandade with air-dried ham and green peas*. The combination of these two dishes hits all the right notes, with umami from tomatoes, dried ham, and green peas.

SICILIAN RATATOUILLE

Serves 4

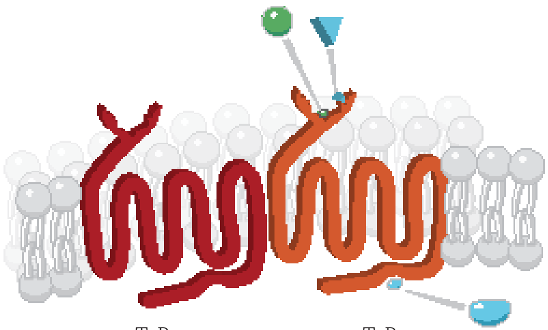
400 g (14 oz) eggplants
2–4 fresh artichokes
200 g (7 oz) zucchini
5 stalks celery
salt
olive oil
200 g (7 oz) shallots, finely chopped
2 cloves garlic, crushed
400 g (14 oz) very ripe tomatoes
2 Tbsp tomato purée
2 Tbsp drained capers
chopped fresh oregano
white wine vinegar
sugar
freshly ground black pepper
2 tsp shelled pistachios

1. Cut the eggplants, artichokes, zucchini, and celery into cubes. If fresh artichokes are not available, oil-preserved artichokes in a jar can be substituted.
2. Salt the eggplant cubes lightly and place them in a colander to drain for about 20 minutes. Rinse and pat them dry.
3. Sauté the eggplant cubes in a pot with olive oil until browned, and then remove them. Next sauté briefly the shallots, garlic, zucchini, celery, and artichoke cubes in the pot. Add the tomatoes and the tomato purée to the pot. Cover and allow to simmer for about 10 minutes.
4. Add the eggplant cubes, capers, and oregano to the pot. Season with a little white wine vinegar, sugar, salt, and pepper.
5. Toast the pistachios in a dry skillet and sprinkle over the ratatouille. It tastes even better if it has been allowed to sit for a day before eating.

More recently, yet another mGlu glutamate receptor, which is related to *taste*-mGluR4, has been discovered. This brings the total number of receptors for umami to at least three, the two mGlu receptors and T1R1/T1R3. Although it is not known for sure, there is some indication that the signaling pathways for the three types of receptors are different, even though they may involve the same G-proteins (possibly gustducin). It has been suggested that mGluRs and the T1R1/T1R3 pair have different functions in the perception of umami. According to this theory, T1R1/T1R3 plays a major role on the front part of the tongue in the preferential selection of food that has umami, whereas the mGlu receptors are important on the back part of the tongue with regard to discriminating between umami and other tastes.

UMAMI SYNERGY: IT FUNCTIONS LIKE A VENUS FLYTRAP

The discovery of how the taste receptors T1R1 and T1R3 work in tandem in the combination T1R1/T1R3, which can be activated by the substances that synergistically induce umami, paved the way for further research. The scientists were at last on the way to finding out what cooks the world over have known for a very long time, namely, that meat soup with vegetables tastes good. The meat contributes inosinate and the vegetables have glutamate. Or what the Japanese have also known for centuries: Dashi is best when konbu, containing glutamate, is combined with *katsuobushi*, which contributes inosinate.



Schematic illustration of the umami receptor T1R1/T1R3 embedded in the cell membrane of a sensory cell. The T1R1 part binds a glutamate ion (the green sphere) and a nucleotide (the blue triangle). This triggers a signal through the receptor that a G-protein (the blue 'jelly bean' shape) is to be bound on the other side of the membrane.

Inosinate and guanylate do not activate T1R1/T1R3 by themselves, but can do so in conjunction with glutamate. Conversely, other ribonucleotides that do not bring out umami have no effect on the receptor. From recent research it is possible to explain this synergy with the help of a mechanism that resembles the trapping mechanism in the Venus flytrap, an unusual carnivorous plant.

TABLE 5: FREE GLUTAMATE IN RAW INGREDIENTS

Food category	Free glutamate (mg/100 g)	Food category	Free glutamate (mg/100 g)
Meat and poultry		**Vegetables**	
Ham (air-dried)	337	Tomato (sun-dried)	648
Duck	69	Tomato	200
Chicken	44	Potato (cooked)	180
Beef	33	Potato	102
Pork	23	Corn	130
Eggs	23	Broccoli	115
Lamb	8	Green peas	106
		Lotus root	103
Fish and shellfish		Garlic	99
Anchovies (marinated)	1,200	Chinese cabbage	94
		Soybeans	66
Sardines	280	Onion	51
Squid	146	Cabbage	50
Scallops	140	Green asparagus	49
Sea urchin	140	Spinach	48
Oysters	130	Lettuce	46
Mussels	105	Cauliflower	46
Caviar	80	White asparagus	36
Alaska crab	72	Carrot	20
Sardines (dried, *niboshi*)	50	Marrow	11
		Green bell pepper	8
Shrimp	40	Cucumber	1
Mackerel	36		
Dried bonito	36	**Milk**	
Dried tuna	31	Human breast milk	19
Salmon roe	22	Goat's milk	4
Salmon	20	Cow's milk	1
Crab	19		
Cod	9	**Fungi**	
Lobster	9	Shiitake (dried)	1,060
Herring	9	Shiitake	71
		Button mushroom	42
Tea		Truffle	9
Green tea	450		
Green tea (roasted)	22		

Food category	Free glutamate (mg/100 g)
Fruits and nuts	
Walnuts	658
Strawberries	45
Apple juice	21
Pear	20
Avocado	18
Kiwifruit	5
Red wine grapes	5
Grapefruit	5
Apple	4
Dried seaweeds	
Konbu (*Saccharina japonica*)	1,400–3,200
Nori (*Porphyra yezoensis*)	1,378
Wakame (*Undaria pinnatifida*)	9

Food category	Free glutamate (mg/100 g)
Cheese	
Parmigiano-Reggiano	1,000–2,700
Roquefort	1,280
Gruyère de Comté	1,050
Stilton	820
Cabrales (goat's milk blue cheese)	760
Danish blue	670
Gouda	460
Camembert	390
Emmenthal	308
Cheddar	182

Sources: Ninomiya, K. Umami: a universal taste. *Food Rev. Int.* **18**, 23–38, 2002; Ninomiya, K. Natural occurrence. *Food Rev. Int.* **14**, 177–211, 1998; http://www.umami-info.com; http://www.msgfacts.com; Özden, Ö. Changes in amino acid and fatty acid composition during shelf-life of marinated fish. *J. Sci. Food Agric.* **85**, 2015–2020, 2005; Löliger, J. Function and importance of glutamate for savory foods. *Amer. Soc. Nutr. Sci.* **130**, 915S-920S, 2000; Giacometti, T. Free and bound glutamate in natural products. *Glutamic Acid: Advances in Biochemistry and Physiology* (L. J. Filer, Jr. et al., eds.) Raven Press, New York, s. 25–34, 1979; Komata, Y. Umami taste of seafoods. *Food Rev. Int.* **6**, 457–487, 1990; Maga, J. A. Flavor potentiators. *Crit. Rev. Food Sci. Nutr.* **18**, 231–312, 1983.

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Glossary

acetic acid organic acid formed by bacterial and fungal fermentation of sugars. Vinegar contains diluted acetic acid.

adenosine triphosphate (adenosine-5'-triphosphate, ATP) polynucleotide that is the biochemical source of energy production in living cells. Among other substances, it can be transformed into the 5'-ribonucleotides inosinate, adenylate, and guanylate, which are associated with synergistic umami.

adenylate adenosine-5'-monophosphate (AMP), a salt of the nucleic acid adenylic acid; synergizes with glutamate to enhance umami; found especially in fish, shellfish, squid, and tomatoes.

adenylic acid nucleic acid; its salts, adenylates, are a source of umami synergy.

Ajinomoto international Japanese company that was founded in 1908 by the Japanese chemist who identified umami, Kikunae Ikeda, together with the entrepreneur Saburosuke Suzuki. Its primary product is MSG, which is used worldwide as a taste enhancer.

alanine amino acid with a sweetish taste.

alapyridaine tasteless chemical substance found in beef stock; enhances umami.

alkaloid one of a group of basic chemical compounds that are rich in nitrogen. The bitter-tasting substances caffeine and quinine are alkaloids.

allec type of fermented fish paste; made from the dregs left over from the production of the classic fish sauce *garum*.

allostery biochemical expression for the condition in which a substance can regulate the function of a protein by binding to it on a site different from the main active site. Simultaneous binding of glutamate and 5'-ribonucleotides to the umami receptor and the resulting synergy in stimulating the receptor is an example of allostery.

amino acid small molecule made up of between ten and forty atoms; in addition to carbon, hydrogen, and oxygen, it always contains an amino group. Amino acids are the fundamental building blocks of proteins. Examples include glycine, glutamic acid, alanine, proline, and arginine. Nature makes use of twenty different specific amino acids to construct proteins, which are chains of amino acids bound together with peptide bonds. Short chains are called polypeptides and long ones proteins. In food, amino acids are often found bound together in proteins and also as free amino acids that can have an effect on taste. An example is glutamic acid, which is the basis of umami. Of the twenty natural amino acids, there are nine, known as the essential amino acids, that cannot be produced by the human body and that we must therefore obtain from our food (valine, leucine, lysine, histidine, isoleucine, methionine, phenylalanine, threonine, and tryptophan). Amino acids are chiral molecules, meaning that they are found in two versions that are chemically identical but are mirror images of each other. They are referred to as left-turning (L-amino acids) and right-turning (D-amino acids). Their tastes can vary depending on which way they turn.

AMP see adenylate.

ankimo Japanese expression for liver from monkfish (*ankō*, *Lophius piscatorius*).

ao-nori species of green alga that is similar to sea lettuce.

Apicius, Marcus Gavius legendary Roman gourmet who lived in the first century CE, to whom authorship of the comprehensive ancient work on the culinary arts *De re coquinaria* is popularly attributed. The extensive use of an umami-rich ingredient, *garum* (q.v.), in this collection of

Index