Cell Signaling and Taste

Exploring the connection between our taste buds and the signal transduction pathway

Background information:

Chemoreception is the process by which organisms sense chemicals in their environment. This is often regarded as the oldest sense and is universal among animals; it is even found in bacteria and other microorganisms. Organisms use chemoreception to accomplish a number of different tasks, including identifying suitable habitats, determining the quality of a food source, finding a mate, finding places to lay eggs, and/or monitoring their internal environments.

Animals receive chemical information with special receptor neurons called **chemoreceptors**. Chemoreception can take a number of different forms, often depending on the environment in which an organism lives. In humans and most terrestrial animals, chemoreception has been refined into the senses of smell and taste. In contrast, for many organisms that have evolved living in water, there is not a big difference between the sense of smell and taste.

Gustation, the sense of taste, is closely related to the sense of smell. In fact, much of what we think of as taste is actually smell. In terrestrial vertebrates, taste is sensed through **taste buds** that are found in the mouth. Some fishes have taste buds in their skin, which enhances their ability to sense the environment in which they live. A taste bud is a cluster of several cells that contain: 1) chemoreceptor cells in the center of the bud that detect the tastant (i.e., a molecule that stimulates a taste), and a synapse with an afferent sensory neuron and 2) support cells that form the outer wall of the taste bud as well as some portions of the center.

In humans, approximately 10,000 taste buds are found on the tongue, many on the raised **papillae**. In contrast to smell, which is sensed by many different types of chemoreceptors, taste is sensed by only a few (4-5); it is the combination of these receptors that leads to the variety of tastes we can sense. These taste receptors detect tastants that signal **sweet, salty, sour, or bitter**. Recently, a fifth taste, **umami**, has been identified, which is the savory, meaty taste that originates from amino acids, commonly associated with MSG (monosodium glutamate), taken from the Japanese word for “delicious.” Similar to smell, taste is sensed by the diffusion of specific molecules into the taste buds. For example, saltiness results from the diffusion of sodium (Na^+), sourness from hydrogen ions (H^+), and the other tastes from a variety of organic molecules.

Contrary to a common misconception, the taste buds are not located on the tongue in regions for the primary taste, but rather all areas of the tongue are responsible for the primary tastes. Taste papillae can be seen on the tongue as little red dots, or raised bumps, particularly at the front. At the base of each bud, there is a sensory nerve that invades the taste bud and branches extensively. Each of these nerves typically joins with multiple other receptor cells within the taste bud.

receptor activation → intracellular signaling → neurotransmitter release → gustatory neuron activation
(Ca^{2+} entry)

Signal transduction of taste:

The transduction of taste signals involves ion channels bound in the membrane of taste nerve cells. These ion channels allow calcium (Ca^{2+}) and/or Na^+ to pass into the cell, which activates the nerve cell and taste is perceived.

Salt: Na^+ enter the receptor cells via channel proteins, causing depolarization, allowing Ca^{2+} to enter. The neurotransmitter is released, causing an action potential in the primary afferent nerve. Sodium chloride (NaCl), common table salt, tastes the saltiest.

Sour: Many sour foods are naturally acidic (e.g., lemons, oranges, tomatoes), so H^+ enter the cell through channel proteins. There are three possible transduction mechanisms, one of which is that H^+ ions block potassium (K^+) channels, which are responsible for maintaining hyperpolarization of the membrane. Blockage of the channels causes depolarization (see above for results).

Sweet: Receptors bind sugars and other carbohydrates, which activates adenylyl cyclase, thereby elevating cAMP. This causes a PKA-mediated phosphorylation of K^+ channels, inhibiting them, causing depolarization.

There are a number of different sweet receptors that respond to different organic compounds such as sugars, saccharin, alcohols, amino acids, and lead salts. These different receptors allow different artificial sweeteners to be effective.

Bitter: Bitter substances cause a second messenger (IP_3) to release Ca^{2+}, stimulating the release of neurotransmitters. Bitter taste is believed to have evolved as a protective mechanism to avoid poisonous plants and their toxic compounds, such as quinine, caffeine, nicotine, and strychnine.

Umami: MSG (main ingredient in soy sauce) binding to the receptor activates a G-protein, which may elevate intracellular Ca^{2+}, causing neurotransmitter release. Beef and aging cheese may also stimulate the umami taste.

Procedure:

To experience your taste buds in action, you will drink a tea made from the Indian herb, *Gymnema sylvestre*. Your task is to determine what effect *Gymnema* has on taste perceptions and develop an explanation for this mechanism.

1. Obtain a small package containing samples of the following: salt, Equal®, raw broccoli, sugar, M&Ms®, lemon wedge, Sweetarts®, and umami broth.
2. Taste the samples in the order listed above, rinsing your mouth with water in between each substance to avoid aftertaste mixing.
3. Rate each substance for the perception of sweet, sour, bitter, salty and umami on a scale of 0 to 10 in the table on your answer sheet. A rating of “0” represents no perceived taste, whereas a rating of “10” represents a very intense taste.
4. After your initial taste, get a sample of the *Gymnema* tea.
5. Swish one ounce of tea in your mouth for 30 seconds. Try to coat all areas of your mouth with the tea. Spit the tea into the sink, and briefly rinse your mouth with water.
6. Retaste each of the substances in the same order as before (rinsing with a small amount of water between each one). Rate and record your perceptions of each of the tastes for each substance in the table on your answer sheet.

Name ____

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Student Answer Sheet

	Taste Ratings (0-10 on perceived taste)					
Tastant		**Sweet**	**Sour**	**Bitter**	**Salty**	**Umami**
Salt	**Before tea:**					
	After tea:					
Equal®	**Before tea:**					
	After tea:					
Raw broccoli	**Before tea:**					
	After tea:					
Sugar	**Before tea:**					
	After tea:					
M&Ms®	**Before tea:**					
	After tea:					
Lemon wedge	**Before tea:**					
	After tea:					
Sweetarts®	**Before tea:**					
	After tea:					
Umami broth	**Before tea:**					
	After tea:					

Analysis Questions:

1. For each tastant, compare your before and after tea ratings.
   Which (if any) of the flavors were NOT affected by the tea?

   Which (if any) of the flavors were eliminated by the tea?

   Which (if any) of the flavors were changed by the tea? In what way?

2. What might be the possible mechanism for how the tea affects the perception of taste?