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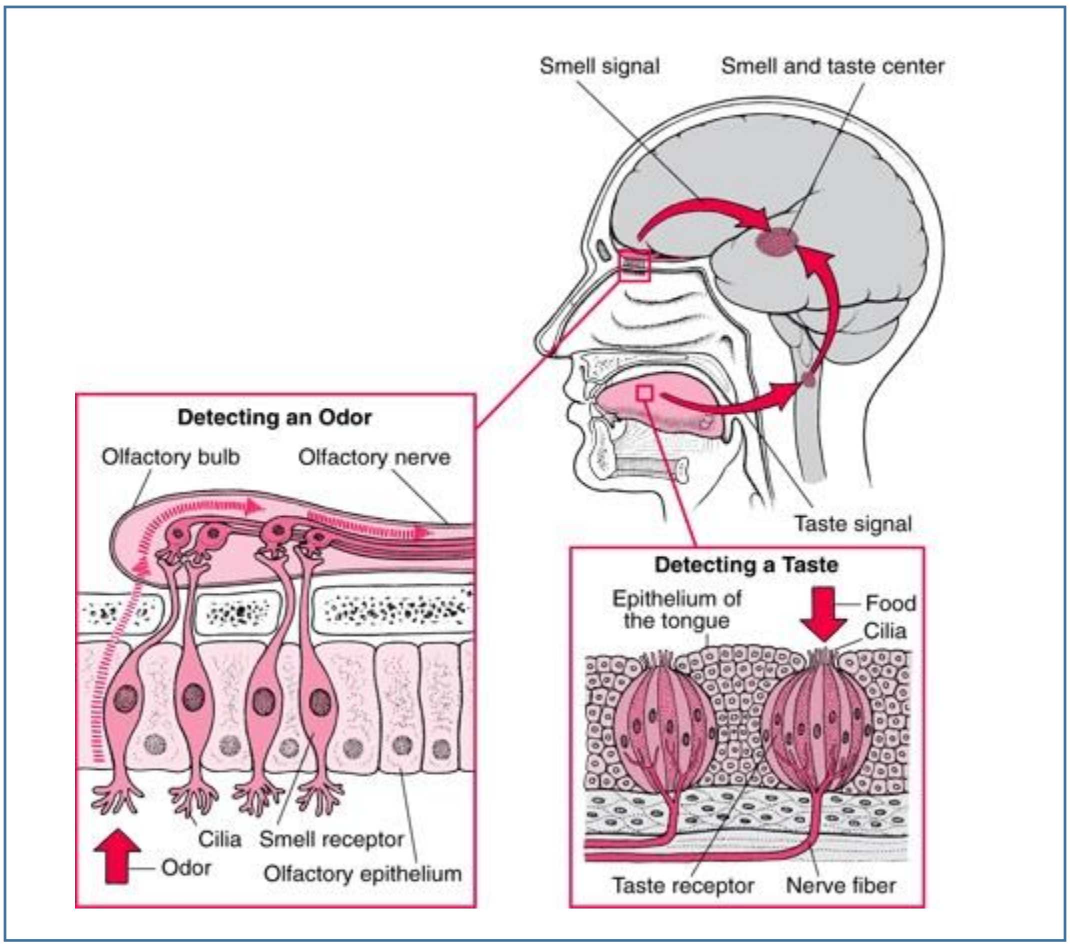
The Psychology of Flavor and Why it Matters



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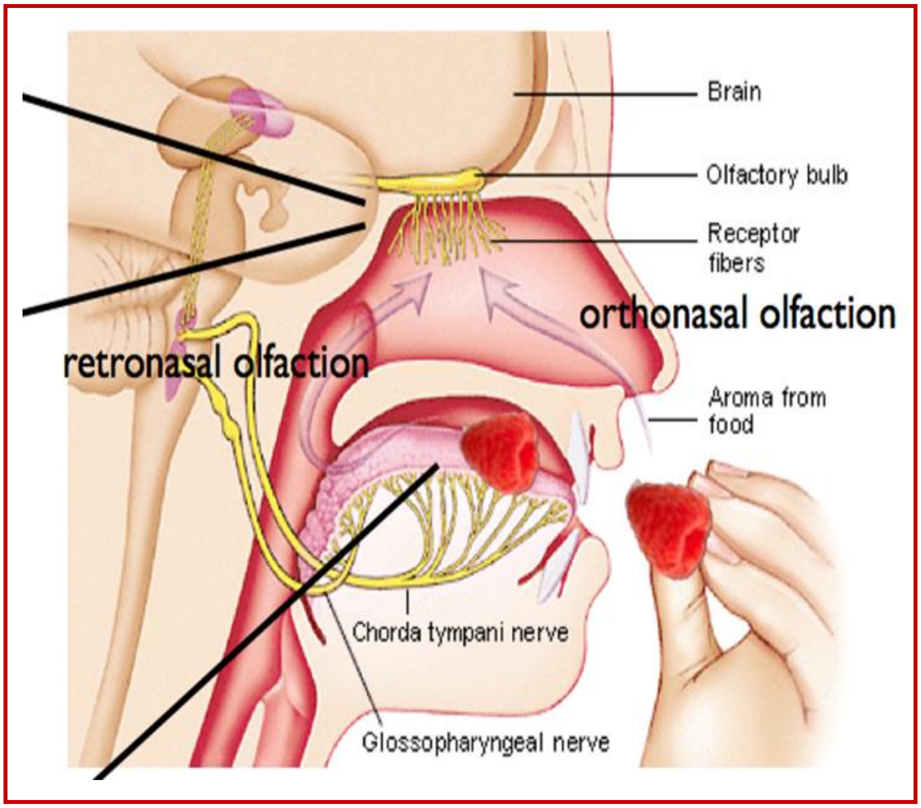
"Flavor is among the most complex of our perceptions created in the brain."
~ Gordon M. Shepherd, Professor of Neurobiology, Yale School of Medicine

The Psychology of Flavor
and
Why it Matters

From our earliest years we learn about our body's traditional five senses: sight, hearing, touch, smell and taste. Until recently, the latter two senses have been the underdogs, unimportant underachievers even; the first three seemingly much more important to our survival. If the choice were given, who's going to choose taste over sight, or smell over hearing (except perhaps a chef!)? Yet increased attention in the past decade has made clear just how important olfaction (smell) and gustation (taste) are to our health and well-being. A malfunction of either can lead to mood disorders, obesity, diabetes, hypertension, malnutrition, Parkinson's disease, Alzheimer's disease, and Korsakoff's syndrome (Harnett, E. 2007).

A brief look at how these two systems work. Smell is a distal chemical sense (energy emitted by or reflected by some object) detected by sensory cells called chemoreceptors and perceived in the temporal cortex of the brain. When an odorant (smell) stimulates the chemoreceptors in the nose that detect smell, an electrical impulse is sent to the brain. The temporal cortex interprets the pattern of electrical impulse as specific odors and olfactory sensation becomes perception – something we can then recognize as smell (Dowdy, S. 2014, Sekular, R. 1999). The sense of smell is a dual system comprised of orthonasal (odor compounds traveling through the nose) and retronasal (odor compounds traveling primarily through the inside of the mouth), and is never sensed by itself but always together, along with virtually every sense in the mouth (Shepherd, G.M. 2012, pg. 117). Jean Anthelme Brillat-Savarin, French lawyer, politician, famed epicure and gastronome, described the retronasal route this way, “The back of the throat is the chimney of taste” (Shepherd, G.M. 2012, Introduction). This is why even if you pinch your nose tightly closed while taking your cold medicine, you will be able to taste it as soon as you unplug your nose.



STUDYBLUE (Chemical Senses): Thariq Badiudeen

Additionally, the longer we chew, the higher the number of odorant molecules released, thus increasing and prolonging orthonasal and retronasal sensations. Brillat-Savarin explains, “Men who eat quickly and without thought do not perceive the [succession of] taste impressions, which are the exclusive prerequisite of a small number of the chosen few; and it is by means of these impressions that gastronomers can classify, in the order of their excellence, the various substances submitted to their approval” (This, H. (2006), page 117).

Taste is a proximal chemical sense (energy falling on a receptor surface) perceived by specialized receptor cells and interpreted in the parietal cortex. The chemoreceptors that detect taste are called gustatory receptor cells. Approximately 50 receptor cells, plus basal and supporting cells, make up one taste bud. These taste buds are crammed into goblet-shaped papillae (the visible bumps sprinkled over your tongue), some of which help create friction between the tongue and food. Each gustatory cell has a gangling protrusion called a gustatory hair, which interfaces with the outside environment through an opening called a taste pore. Molecules mix with saliva, enter the taste pore and interact with the gustatory hairs. This stimulates the sensation of taste (Dowdy, S. 2014).

We currently have five basic taste sensations: salty, sweet, sour, savory (umami) and bitter. A sixth taste sensation, fat (fatty acid transporter, known as CD36) is currently under investigation by French scientists (Biello, D. 2005). The effect of one taste stimulus can enhance another. For instance, two weak testants (taste molecules) may not be perceived alone, but together each can be detected (Shepherd, G.M. 2004, pg. 122). This becomes important when considering different flavor combinations. The synergistic effects of flavors and textures should be evaluated rather than the profiles of individual ingredients.

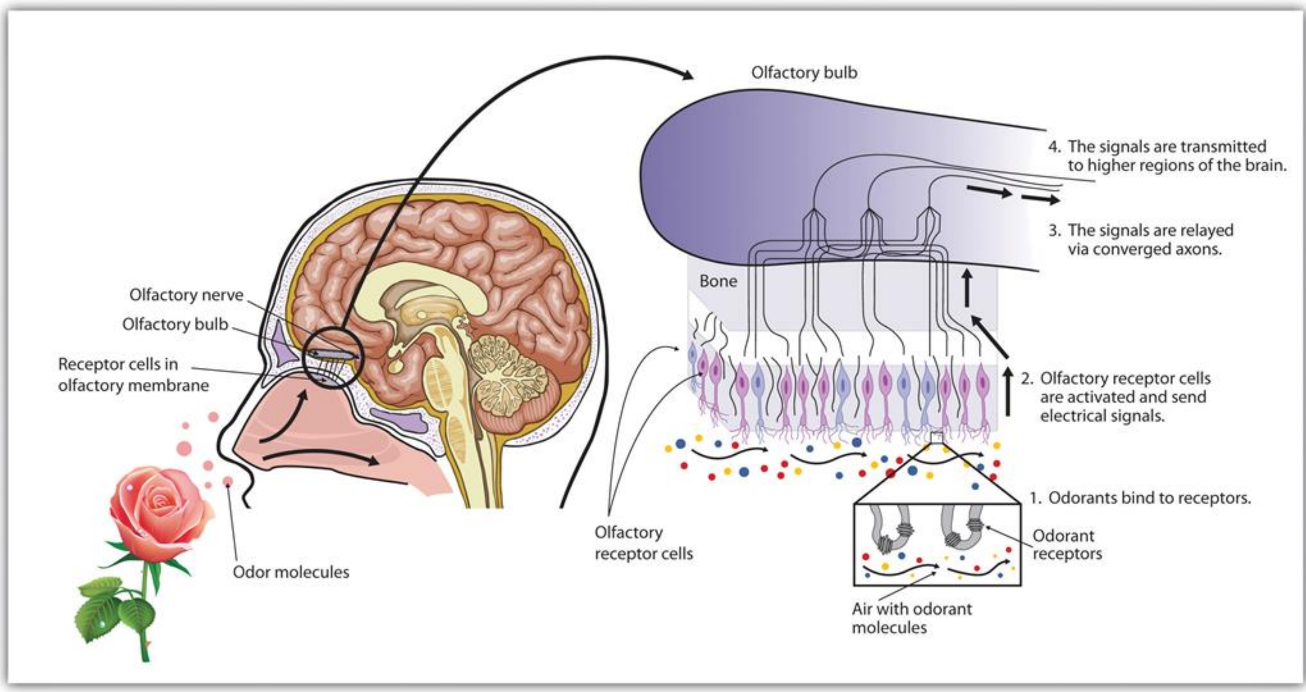
Unlike olfactory receptor cells, receptor cells in taste buds lack axons to carry their responses to the brain. Instead, the cells interact with each other and with the endings of the 7th, 9th and 10th cranial nerves. These taste nerves enter the part of the brain directly continuous with the spinal cord, that which is responsible for automatic functions (control of heart rate, breathing, etc.). “It's as if the multisensory flavor sensation is designed to allow ingested foods to be analyzed at both the highest cognitive levels as well as at the level of the most vital functions. It has all bets covered” (Shepherd, G.M. 2004, pg. 119).

So what ***is*** flavor and how is it perceived? “Flavor is a fusion of multiple senses. To perceive flavor, the brain interprets not only gustatory (taste) stimuli, but also olfactory (smell), tactile (touch) and thermal (hot/cold) sensations” (Dowdy, S. 2014). The ability of one sense to evoke sensation in another is common in chemoreception (the physiological response to chemical stimuli) (Martin, N.G. 2013). When we speak of taste, often what we mean is flavor. Smell and taste together are regarded as forming the main basis of flavor. In fact, “the two sensations are so closely related that in some cases smells take on the qualities of taste ~ as when one says something smells sweet. [Additionally], when we sense the flavor of the food in our mouths, it is not by sniffing in, which we usually associate with smelling something like an aroma, but by breathing out, when we send little puffs of smell from our food and drink out the back of our mouths and *backward* up through our nasal passages as we chew and swallow” (Shepherd, G.M. 2004, pgs. 5, 123). World-renowned food chemist and writer Harold McGee explains flavor this way:

> Flavor is a composite quality, a combination of sensations from the taste buds in our mouth and the odor receptors in the upper reaches of our nose.

> And these sensations are chemical in nature: we taste tastes and smell odors when our receptors are triggered by specific chemicals in foods. There are only a handful of different tastes...while there are thousands of different odors. It [is these] odor molecules that make an apple “taste” like an apple, not like a pear or radish. So most of what we experience as [taste] is odor, or aroma. The aroma chemicals of herbs and spices are *volatile*: that is, they're small and light enough to evaporate from their source and fly through the air, which allows them to rise with our breathing into the nose, where we can detect them. High temperatures make volatile chemicals more volatile, so heating herbs and spices liberates more of their aroma molecules and fills the air with their odor (McGee, H. (2004) pages 387-388).

“The brain processing mechanisms of the smell pathway bestows a richer world of smell and flavor on humans than on other animals. Humans have a much more highly developed sense of flavor because of the complex processing that occurs in the large brain” (Shepherd, G.M. 2012, pg. 115). More than any other sense, smell is intimately linked to parts of the brain that process emotion and associative learning. The olfactory bulb in the brain is what sorts sensation into perception and is part of the limbic system – the system that includes the amygdala and hippocampus, vital structures to our behavior, memory and mood. The olfactory cortex is responsible for our ability to smell something and



https://lumen.instructure.com/courses/204120/pages/tasting-smelling-and-touching sense its flavor.

An experiment was conducted using rats to determine the functions of the olfactory cortex. Of the 20 amino acids required for building proteins, 10 are essential; an animal's health begins to fail and it will die if a deficit is uncorrected. Rats will cease feeding within 30 minutes if their chow lacks just one of these" (Shepherd, G.M. 2012, pg. 104). An unexpected hidden function of the olfactory system may be crucial, according to Shepherd, to the nutrition of people in conditions of poverty and starvation worldwide. This would indicate food flavors must be learned in order to supply the needed amino acids.

Tastes are strong elicitors of emotion. Is this hedonic (emotional) quality of the food hardwired or learned? Israeli pediatrician, Jacob Steiner, set to discover the answer. In 1974 he arranged to test newborns within the first hours of birth before they had exposure to any taste. He filmed their facial expressions and the results were dramatic! Sour produced a definite aversive puckering of the lips, bitter produced a face of disgust and distress (with an open mouth trying to eject the substance), salt showed little facial expression, and sugar elicited a fleeting but unmistakable smile, indicating the hedonic quality of food is in fact hardwired (Shepherd, G.M. 2012, pg. 124).

There are individual variations in taste as well, some natural and some conditioned. Conditioned taste aversion (called bait shyness in animals) and similarly, food phobias, were found to be much more powerful than classical learning. In a famous study conducted in 1966, John Garcia and Robert Koeling found that an animal that had been made sick from a food just once, and even though the sickness occurs hours later, will avoid that food ever after (Shepherd, G.M. 2012, pg. 126). This can also be seen (perhaps to a lesser extent) in humans. Consider the last time you became ill after something you ate. How long after the illness did it take before you ate that food again, if ever?

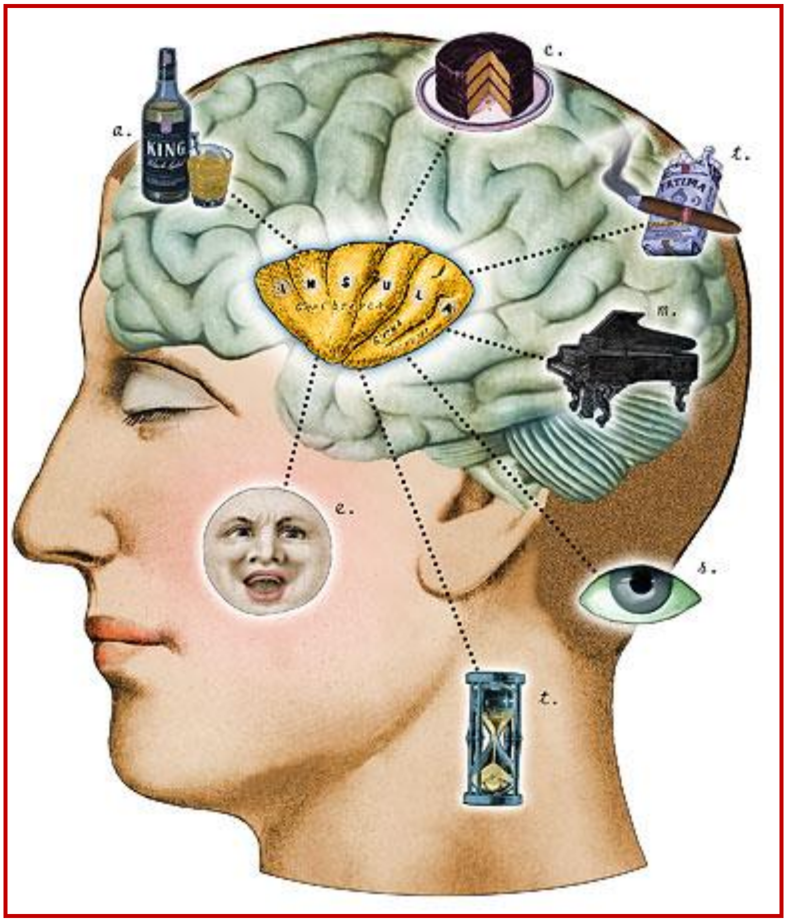
Natural aversions can be seen in a small portion of the population; "super-tasters" exhibit taste mutation that make them extremely sensitive to bitter compounds (present in many vegetables, cheese, coffee, etc.), making it difficult to eat a balanced diet. Conversely, some people are "non-tasters" to bitter compounds, or have a lower response. This group appear to like fat, sweet foods and alcoholic beverages; are heavier and at greater risk of alcohol over-consumption (Shepherd, G.M. 2012, pg. 126, Anthes, E. 2011). Some hardwired aversion behavioral responses can be overcome through learning, as seen with pain tolerance wrought by capsaicin molecules in chili peppers – ghost pepper, anyone?

In addition to smell and taste influencing flavor, sight, touch, sound and (as a subset) language all influence flavor as well. Sight clearly influences the flavor of food, which is why advertisers manipulate the visual impact of food and drink to influence how much we like them (Shepherd, G.M. 2012, pg. 135). Color is the most important quality in identifying a food object and judging its attractiveness, which especially influences the sense of smell. Some psychologists regard this as a kind of "Pavlovian conditioning" – "just as Pavlov's dogs expected flavorful meat when it was paired with a bell, so we expect a juice to be flavorful when it has the appropriate color" (Shepherd, G.M. 2012, pg. 138). A complicated relationship exists between a behavioral property (expectation of flavor) and its brain mechanisms. Think about the rare store-bought *red* tomato purchased in January. You know it's out of season, but because it's actually bright red (as opposed to the usual pink/orange/light red variations available during the winter), you expect it to be flavorful, and are disappointed when it is not. Similarly, because taste and odor molecules are so volatile, fruits, vegetables and herbs quickly begin losing flavor once they are removed from their energy source (harvested). This is why harvesting as close to consumption as possible is critical to maximizing flavor value (not to mention reducing the carbon footprint of buying produce shipped from long distances). The exceptions here are the few edibles that require a hibernation period (potatoes, onions, etc).

Touch and sound are often experienced together adding to a flavor impression. Hearing, "although not essential to our eating experience, it is part of what we expect of it. If it's not there we notice it" (Shepherd, G.M. 2012, pg. 144). Think about the sound of a bottle of wine being poured, a bite of crisp celery, the crackle of a hunk of hot French bread torn off, the crunch of fresh popcorn – in general, the clearer and louder the sound, the more we like it. Likewise, the muscles of the mouth engaged while eating produce flavor: chewing, swishing, swallowing and breathing; and as mentioned previously, the longer we chew the more flavor we experience.

Shepherd explains, we have a "***uniquely human brain flavor system:*** fewer olfactory receptors than other animals but much more adapted to retronasal smell, larger brains and more brain areas and connections between them. ***And we have language***" (Shepherd, G.M. 2012, pg. 155). How many times have you ordered from a menu just because the description of the dish put the flavor right in your mouth? Or bought something from the grocery store because the billboard or commercial brought forth tantalizing aromas and flavors? Descriptive language clearly influences smell and flavor. I use flavor here rather than taste because we each have so many more flavor profiles than taste, currently limited to five.

In addition to the human brain flavor system, Shepherd describes an "action system of flavor: emotion, memory, decisions, plasticity, language and consciousness" (Shepherd, G.M. 2012, pg. 165). Emotion is derived from the word "to move", and for many people, the most important parts of smell and flavor are the memories they evoke and the emotions associated with them. This is where the term "comfort food" comes – the positive memories we associate with particular flavors or food dishes that incorporate those flavors. Where do these flavor memories originate? "The key structures include the ***hippocampus***, a central organizing node for single-event episodic memories and the ***amygdala***, which in parallel with the o***rbitofrontal cortex***, is involved in stimulus reinforcement association learning" (Shepherd, G.M. 2012, pg. 178), ie: each time we eat something delicious the memory of that occasion is stored and we learn to expect the same experience the next time we encounter the same food. Also, the ***insula***, a portion of the cerebral cortex, is the site of convergence of taste and smell inputs; and has been shown to be involved in taste memories. The insula also registers our physical gut feelings,



Lou Beach http://www.nytimes.com/2007/02/06/health/psychology/06brain.html

including the sensation of a distended stomach, warmth and a full bladder. The hippocampus has also been shown to be involved in cocaine addiction, "possibly by reinvoking memory mechanisms that drive the behavior and may similarly drive food cravings" (Shepherd, G.M. 2012, pg. 168).

How is ***flavor*** involved in food cravings? One of the principles of neurogastronomy is that "the brain responds to multiple sensory inputs. Satiety to one flavor does not produce satiety to other flavors. This means that we can ***and will*** eat much more in response to multiple different smells, tastes and textures" (Shepherd, G.M. 2012, pg. 187), and with each delicious experience we add to our flavor memories. This is why it is so easy to over-eat whenever food is offered buffet-style; our smell and taste receptors over-ride our satiety cues sending our brains the signal ***we must taste one more dish!*** The salty/sweet/savory (and most likely fat) flavors in the foods will be fondly remembered over the bloated discomfort of overeating. "Food cravings stimulate activation of specific brain regions: left hippocampus, left insula and right caudate nucleus" (Shepherd, G.M. 2012, pg. 168). The caudate nucleus plays a vital role in how the brain learns, and it also plays a highly important role in storing memories (more on the caudate nucleus in a bit). This same group is activated by drug cravings.

When we think of food cravings we generally conjure up images of foods that satisfy salty, sweet, savory and/or fat tastes, and sometimes creamy or crunchy textures. The fast food menu satisfies each of these – and keeps us coming for more! These foods are high in sensory stimulation and dense in calorie content. A healthy diet has more fiber or roughage to make us feel full faster, and drinking water with the meal hydrates and makes us feel full more quickly. When we wash down our fast food meal with sugary soda we only increase the calories and flavor stimulation. (Diet sodas have been shown to make us think we've consumed something sweet, which still contributes to over-sensory stimulation). The sensory stimulation and "buffet effect" of fast food entice us to continue eating even when full. In 1981 Barbara Rolls and her colleagues at Oxford termed this "sensory-specific satiety, and a study conducted in 2002 by Gene-Jack Wang and his colleagues at the Brookhaven National Labratory in New York found obese individuals to have "long-term over-stimulation of the skin and membranes of the lips and mouth," which are activated by food when we are eating, but can also be overactive even when we are not eating (Shepherd, G.M. 2012, pg. 189). There are several theories for why we overeat: hypersensitive emotional network, "ineffective inhibitory circuits...combined with heightened excitability of circuits mediating reward, and the possibility that overeating does not have enough reward value; the brain does not register pleasure with lesser amounts of food" (Shepherd, G.M. 2012, pg. 189-191).

Here's how Shepherd sums it up: "If flavor plays this central role in what we eat (and it does!), the brain must contain mechanisms for making decisions about whether a food that produces an attractive internal flavor image in the brain is also nutritious. This is a final critical part of the human brain flavor system for determining normal function in healthy people and abnormal function in people who overeat" (Shepherd, G.M. 2012, pg. 191).

One heartening fact that may be capable of positively impacting craving-induced overeating and/or obesity is that ***stem cells make new flavor cells.*** "The brain is born with its full number of nerve cells, except in four regions, where new cells arise from stem cells throughout adult life. It is astonishing that all these regions happen to be key players in creating flavor (!)" (Shepherd, G.M. 2012, pg. 200). First of these cells are the taste buds, second are the receptor cells in the nose, third the small cells in the olfactory bulb, and forth is the hippocampus, specifically the region called the dentate gyrus. Exactly why these particular cells regenerate is unknown, but one of the benefits could be the ability to create new flavor memory reward pathways with healthy foods, ***rewriting the food script***, so to speak. This also provides an enormous opportunity for innovative chefs to learn new flavor profiles to mimic or replace unhealthy versions ***and*** maintain food integrity; by this I don't mean merely chemically creating flavors and textures, but discovering new ways of growing, preparing and combining natural ingredients that elevate taste ***and*** nutrition; and synergistically creating subtle and intense flavors. The average American now places more emphasis on healthy food decisions than ever before. According to the Futures Company, 73% of Americans (16 and older) say they are more interested in healthy eating practices than they were a few years ago. There is growing evidence that health and wellness is quickly emerging as a serious focus for the future of food service...***good news!***

What about the ***dopamine-flavor connection***? Stay with me, this connection is important. Dopamine is a neurotransmitter and one of the key molecules to how our brains work. The largest population of dopamine-containing neurons is in the mid-brain. Some dopamine go to the striatum, the large region under the cerebral cortex involved in planning, initiating and carrying out movements as well as in various motivational states. This is part of the system for food cravings. The other important concentration of dopamine is located in the ventral tegmental area (VTA). The VTA-dopamine connections form what is called the ***reward system*** of the brain. Many experiments providing evidence of this have been carried out on rats, monkeys and humans (Shepherd, G.M. 2012, pg. 193).

Dopamine neurons fire to any rewarding stimulus or conditioning stimuli (such as a light or bell that signals a future reward), therefore dopamine neurons are able to predict future rewards. "This ability constitutes one of the highest cognitive functions of the brain" (Shepherd, G.M. 2012, pg. 193). These functions modulated by dopamine are important for all sensory systems, but especially so for flavor. Dopamine fibers not only connect from the mid-brain to the olfactory cortex, where they are capable of modulating the formation of odor images and odor objects, but also to the orbitofrontal cortex (which contains the secondary taste cortex, in which the reward value of taste and odor is represented). Additionally, there are dopamine-containing interneurons in the olfactory bulb indicating dopamine can be involved in the shaping of the initial smell images in the glomercular layer (Shepherd, G.M. 2012, pg. 194).

Now, back to the caudate nucleus mentioned earlier. It is part of the striatum system and also contains a high concentration of dopamine. This system plays multiple critical roles in sensorimotor coordination and is vulnerable to a number of degenerative diseases (Parkinson's, Alzheimer's, Korsakoff's syndrome) when disorders of dopamine are also present. In fact, an early sign of these diseases is a ***decline in smell*** (Shepherd, G.M. 2012, pgs. 169, 194).

Worth a quick mention is the ongoing research on the similarities between ***food flavors and mood-stabilizing drugs***. The research team of Karina Martinez-Mayorga, Ph.D. with the Chemistry Institute at the National Autonomous University of Mexico, is leading the pack with research conducted at the Torrey Pines Institute for Molecular Studies giving a large body of evidence indicating chemicals in chocolate, blueberries, raspberries, strawberries, teas and certain foods could well be mood-enhancers similar to the drug valporic acid, currently used to smooth out mood swings of individuals with manic-depressive disorder and related conditions. Martinez-Mayorga's team, and other research groups, are looking to identify the chemical compounds that not only moderate mood swings, but that help maintain cognitive health, improve mental alertness and delay the onset of memory loss (American Chemical Society, 2012).

In sum, the effects of the flavor system are just beginning to be realized, but the evidence of ***the***

impact of flavor can be seen in all stages of human development. Thanks to a number of diligent research teams, we now know that flavors are transmitted from the mother through the amniotic fluid and particular foods consumed during pregnancy are favored after birth (Shepherd, G.M. 2012, pg. 234). We know flavor preferences of the mother affect flavor preferences of her infant and that there is a sensitive learning period in infancy (up to six months) where infants can be trained to different flavors (Shepherd, G.M. 2012, pg. 235). We know that flavor has a powerful effect on young children, so much so that one researcher proposed "children live in a different sensory world than adults" (Shepherd, G.M. 2012, pg. 235). Of course the nation's food producers, providers and advertisers know this too. We know flavor holds sway over adolescents as well, just as they are gaining confidence and independence, keen on trying out their own purchasing power. "Perhaps one of the most important factors in this is that the highest cognitive levels of the brain – the areas in the prefrontal cortex that are involved in making decisions on the basis of limited information, making plans with short-term as well as long-term consequences, and weighing immediate desires in the context of long-term goals – are still developing" (Shepherd, G.M. 2012, pg. 237). Advertisers for fast foods and junk foods have been keenly aware of this age vulnerability for decades, targeting the baby-boomer youth culture to the highest degree. In our adulthood, we've learned the hazards of ***"too much flavor"***. "Food critics provide insights into food flavor, but how flavor is produced is usually in terms of what is in the food, rarely in terms of how the brain creates it" (Shepherd, G.M. 2012, pg. 237). We are bombarded with countless diets aimed to control our food cravings and help us lose weight, and increasingly strong evidence indicate [that] strong desires for flavors and strong desires for drugs of abuse activate similar brain mechanisms. Increased research on these brain mechanisms could lead to better insight into why we have difficulty controlling what we eat (Shepherd, G.M. 2012, pg. 238). Finally, we know an effect of advancing age can be a loss of flavor because of diminished ability to taste and/or smell. This often is the reason behind "failure to thrive" in some of our elderly population. We also know, as it is now well documented, that an early sign of Alzheimer's, and Parkinson's disease especially, is a loss of smell. There is still a lot more research to be done on the importance of smell and taste and the synergies at work creating flavor, but clearly smell and taste are of critical importance to our well-being.

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