

# Why Humans Like Junk Food



By

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Technical Products Inc.

Note: The Original Slide Version that Started my Research on Food Pleasure  
Now Updated with **current research!**

# Why Study Junk Food?



- Insights into Ingestive Behavior
- Design Healthy Foods
- Understand Obesity Crises
- Study Weight Loss Ingredients

*Lecture was dedicated to Professor Rose Marie Pangborn who asked us to write about food palatability*

# The Doritos Effect...

“What Makes Food Taste Good?”

Snack Food Equals Food Pleasure



Steven Witherly, PhD

what makes food taste good?



# Doritos Effect... • what makes food taste good?

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- Studying Doritos may Provide Clues on the Construction of a Highly Palatable Food, from a:
  - Sensory
    - taste, smell, orosensation, dynamic contrast
  - Nutritional
    - Macronutrients, vitamins, minerals, fatty acids
  - Physiological Standpoint
    - Gut/brain axis; neurochemical
    - Reward Neurochemistry
    - Food memory formation

# Junk Food is Like the “Ring”

- “It wants to be found!”
  - Brain memorizes surroundings where food was eaten.
  - So that you can find it again!



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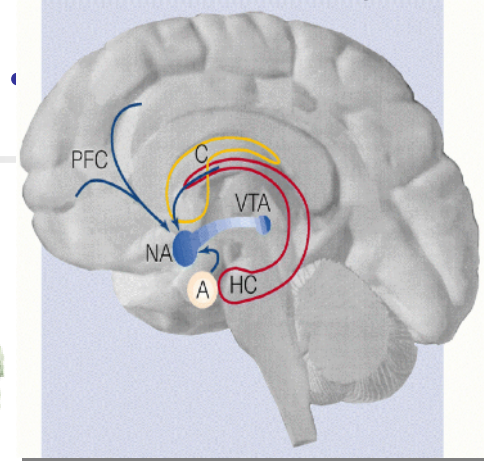
Steven Witherly, PhD

What makes food taste good?

# This Lecture Explains..

- Why We Like French Fries
- Why We Like Ice Cream 
- Why is Doritos the #1 Snack Food of all Time? 
- Why is the Oreo the #1 Cookie of all time? 100 Billion made and Eaten.
- Why is Hot or Cold Food Pleasurable?
- Why is Starbucks Coffee so Popular? 

Addiction Circuitry



# This Lecture Explains...

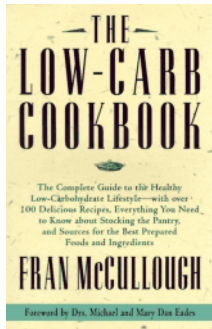
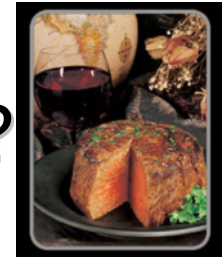
- Are McDonald's French Fries better?
- Is Flame Broiling best?
- What Is So Special about BBQ Food?
- Why Do We Like Donuts?
- Why is Vanilla Such a Popular Flavor?
- Do Quizno's Subs Taste Better Toasted?
- Is it the Cheese?



# This Lecture Explains.



- Why is Pop Corn So Popular?
- Can You Make your Kids eat Their Fruit and Vegetables?
- What two mistakes did P and G make with the design of Pringles?
- How does the Brain see Low-Carb Food?
- Will the Low-Carb Craze Continue?
- Why did Olestra Fail? Or did it?
- Are Ruth's Chris Steaks really better?





# Junk Food Outline

- Definitions of Junk Food
- Principles of Food Perception
  - Taste, smell, orosensation
  - Food addiction principles
- Food Memory & Pleasure
  - How food forms memory engrams
- Food Pleasure (FP) Equation
  - $(FP) = \text{Sensation} + \text{Calories}$
- Design of Junk Food
  - Sensation/Calories/Addictive Food Ingredients





# Self Study Format!

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- This slide presentation is designed to be a self study course on Food Pleasure and Food Design.
- The materials in the slides are explained in more depth in the Notes Section of each slide.
- Any or all material may be used without permission, just mention where it came from.
- A small donation would be appreciated!
  - Steven A. Witherly, Ph.D.

# The Doritos Effect



- The first new product since the corn curl is introduced Doritos, meaning "little gold" in Spanish. Three decades later, Doritos are the largest selling snack food in the world.
- What makes Doritos so special?
- What can we learn from its food construction?
- What ingredients or physiochemical parameters make for the **tastiest and most addicting** snack food ever invented?

# Definition of Junk Food

- Traditional Definition(s)
- Dietitian Definitions
- Medical Definitions
- Junk Food Industry Definitions
- The Real Physiological Definition
  - Junk Food is pleasurable food
    - Sensory input
    - Caloric input
    - Pain reduction
    - Addictive (pharmacological) ingredients





# Common Junk Food Definitions

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- [n] food that tastes good but is high in calories having little nutritional value
- "Junk-food", we must therefore conclude, is any consumable prepared outside the home which children find delicious
- Junk food is food that is high in calories **but** low in nutritional content
- There is no scientific definition for junk food but to most people, anything that is high in fat, salt, sugar and maybe even processed foods

# Dietitians & Junk Food

- Junk food is a slang word for foods with limited nutritional value. Every person has their own list of foods that they call junk foods. I would include foods that are high in salt, sugar, fat or calories and low nutrient content.
- **One-third** of the average American's diet comes from junk foods and alcoholic beverages
- **Typical Junk Foods:**
  - Visible fats (butter, margarine, oils, dressings, gravies)
  - Sweeteners (sugar, syrup, candy, sweetened beverages)
  - Desserts (cookies, cakes, pastries, ice cream, pudding)
  - Salty snacks (potato chips, corn chips, tortilla chips)
  - Miscellaneous (coffee, tea)





# Medical Junk Food Definition

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- Junk food can be defined as any food that contributes little or no nutrient value to the diet, but instead provides **excess calories and fat**. Some examples of junk food are candy, breakfast pastries, high fat chips and dip, and high fat foods from fast food restaurants





# Food Industry Definition

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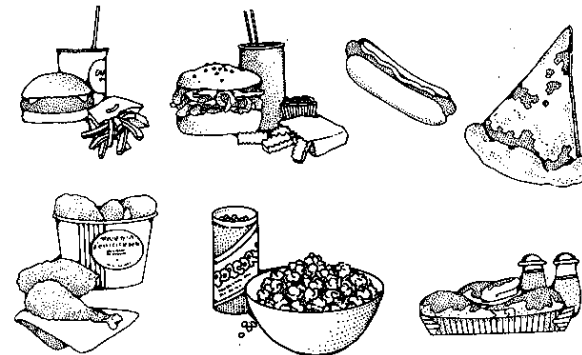
- Junk Food = Snack Food
- Junk Food = Fun Food
- Junk Food = Indulgent Food





# Physiological Definition of Junk Food by Witherly

- Junk Food is *any* food that excites:
  - Caloric pleasure centers, *both*
    - Fat content >30%
    - Carbohydrate >25%
  - Orosensation
    - Snap, crackle, pop
    - Dynamic Contrast
  - Taste Hedonics (both salt & sugar)





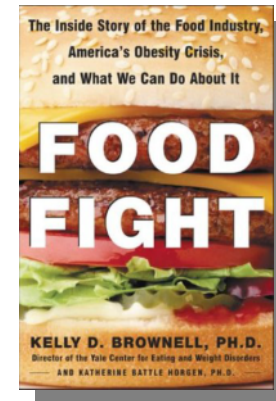
# What is Junk Food...

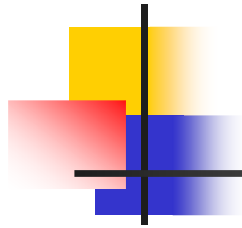
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- Sugar laced sodas
  - They may be empty calories but not JF
- Major Players:
  - Ice cream
  - Chocolate (although healthier than it looks)
  - Most snacks (NOT nuts)
  - Many Fast Foods Qualify
    - Pizza may be nutritious but it can be loaded with fat
    - Even Chinese Food can be made into JF
  - French Fries (big problem)

# Food Industry (Big Bucks)

- Food Industry is Almost a Trillion Dollar Industry!
- Fast Food alone is 100 billion!
- Snack Food 100 billion!





# Snack Food Market I

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- The USA has by far the largest snack market in the Americas region
- Around 90 billion in 2002
- Four snacks categories - savory snacks (47% share), potato chips, popcorn and snack nuts

# Snack Food Market II



- Doritos and Tostitos have combined sales of about \$3 billion in the U.S
- Pepsi's Frito-Lay, sells about 15 billion bags of snacks worldwide each year,
- Total Domination:
  - "Never have we introduced Lay's potato chips and had it not be successful," said Dwight Risky, the Research and Development head who devised Frito-Lay's global strategy five years ago. "It's been successful every single place we've introduced it."
  - Frito Lay is basically the best snack food company ever...perhaps the best food company ever!



# Snack Food Development

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- "It's difficult to get kids to eat something they don't want," says Rocco Papalia, senior vice president of technology at Frito-Lay. "It doesn't do any good to **reduce calories, fat or sodium** on something nobody wants [good point actually]."
- "Twenty percent of the snacks we sell today fall into the category of what we call "better for you snacks," says Rocco Papalia, senior vice president of technology for Frito-Lay
  - [they got rid of trans fat...this is good also]
- "We have potato chips that are 0 grams of fat, 1 gram of fat, 3 grams of fat, 7 grams of fat, 8 grams of fat, 10 grams of fat," says Papalia
  - CBS Evening News, November 4, 2003 20:51:32



# Snack Food Quotes & Reality 1

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- Trans Fat out of fast food (Frito Lay first, McDonald's kind of)
  - Long overdue (Marion Nestle, PhD)
- ``There are no good foods and bad foods. It's about the totality of what you eat," said Rocco Papalia, Frito-Lay's senior vice president of technology.
  - Classic sound bite supported by the snack food industry and by many dietitians. High fat, high carbo food with virtually no other redeeming feature isn't a health food! But it is tasty.
- Walt Riker, a spokesman for McDonald's:" There are a lot of choices on the menu. ... We have salads," Riker said. ``It's very basic food. It's quality food."
  - "Where fast food goes fat people follow" (Boudrain)

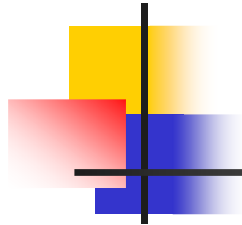


# Snack Foods and Reality 2

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- About 20 percent of Frito-Lay's sales come from pretzels and baked and reduced-fat chips, and Papalia said that could rise to **one-third** of sales in a few years.
  - This might be good on the surface but what happens is:
    - Body learns to return to higher fat product, but at least the company is trying.
    - High glycemic, low fat pretzels are a disaster for blood glucose maintenance and they really elevate insulin (not good).  
Excellent companion to beer however.
  - So are healthy chips that taste good possible?
    - Absolutely. But it would take...





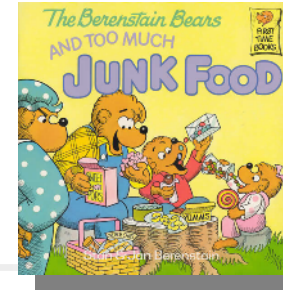
# Junk Food Diet Increases

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- Americans have increased their energy intake of French fries, hamburgers, cheeseburgers, pizza and Mexican food as part of their meals.
- Overall, they found that total (food) energy intake has increased over the past 20 years, with shifts away from meals to snacks and from at-home to away-from-home.
- Children are making a definite shift away from milk to sodas and sugary drinks
- The war between milk and soda is indicative of a shift in the U.S. diet, where nutrient-poor "junk foods" are gradually replacing healthier items such as low-fat milk, fruits and vegetables [actually, snack foods are nutrient poor, not burgers]!

**Annual Experimental Biology 2002 Conference New Orleans, LA April 22, 2002**

# Junk Food, Humans & Bears



- Last week the bear chased a couple into the lake to steal their **tortilla chips**, which it smashed and left in a pile
- Williams said the case is a reminder for campers to store their food properly, not only for the safety of wildlife, but for the safety of themselves. Once a bear gets **even a little taste**, like this bear, it is “poisoned by human food, so to speak,” Williams said. “If they **get rewarded once**, they're very intelligent, and they'll come back,” he said
- Seems bears not so different than us!
  - Deadly yen for nachos by the AP - 07/08/03 KALISPELL (AP)



# Paleolithic & Junk Food

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- Ancestors ate meat and **low carb** plant materials
  - High fiber (low glycemic), nuts and seeds
  - Low salt
  - No sugar
  - Low Fat (hi in omega-3's)
- Modern snack food are just the **opposite!!!**
  - Hi in salt, fat and sugar!!!
  - Hi in Omega-6's!!!
  - Hi glycemic carbs!!!



# Paleolithic Diets

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- Our genetic make-up, shaped through millions of years of evolution, determines our nutritional and activity needs
  - human genome has remained primarily unchanged since the agricultural revolution 10,000 years ago
- Diets were high in lean protein, polyunsaturated fats (especially omega-3 [omega-3] fatty acids), monounsaturated fats, fiber, vitamins, minerals, antioxidants, and other beneficial phytochemicals
  - adults would have benefited from volumetrically concentrated, high quality foods such as meat (meat eaters not carbo eaters!!!).

**Junk food design is based on our paleolithic past!**



# Principles of Food Perception

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- Sense of Taste
  - The 7 basic tastes
  - Additional taste sensations
- Sense of Smell
  - Aroma sense
  - Trigeminal sense
- Orosensation
- Brain Flavor Processing (OFC)



# Function of Tastes

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- Prepare Body for Ingestion
- Encourage eating thru pleasure
  - Sugars the biggest pleasure whack
- Select toxins from foods
  - Most bitter compounds are poisonous
- Ensure adequate caloric ingestion
  - Sense high calorie foods
- Ensure proper nutritive ingestion
  - Eat protein (MSG or umami taste)
  - Essential fatty acids taste
  - Vitamin C
  - Glucose for the neurons



# Taste is Number One

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- “However, I can tell you that taste is always No. 1 and food cost is always last”
  - John Buchanan, Lettuce Consulting Group, New productsmag, feb. 2004
- Good taste drives the ingestion of all food; aroma and vision help but they are not as hedonically active as taste!



# 7 Basic Tastes, Many Sensations

- Hedonic Tastes
  - Salty
  - Sweet
  - Umami
- Aversive Tastes
  - Bitter
  - Sour
- Energy Tastes
  - Fatty acid taste
- Heat Taste
  - Vanilloid receptor
- Taste Sensations
  - Astringent
  - Electric taste
  - Alkaline taste
  - Alcohol taste
- Orosensation (trigeminal)
  - Touch
  - Temperature
  - Pain
  - Pressure





# 7 Basic Tastes!

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- Hedonic Tastes
  - Salty
  - Sweet
  - Umami
- Aversive Tastes
  - Bitter
  - Sour
- Energy Tastes
  - Fatty acid taste
- Heat Taste
  - Hot pepper taste



# Taste Bud

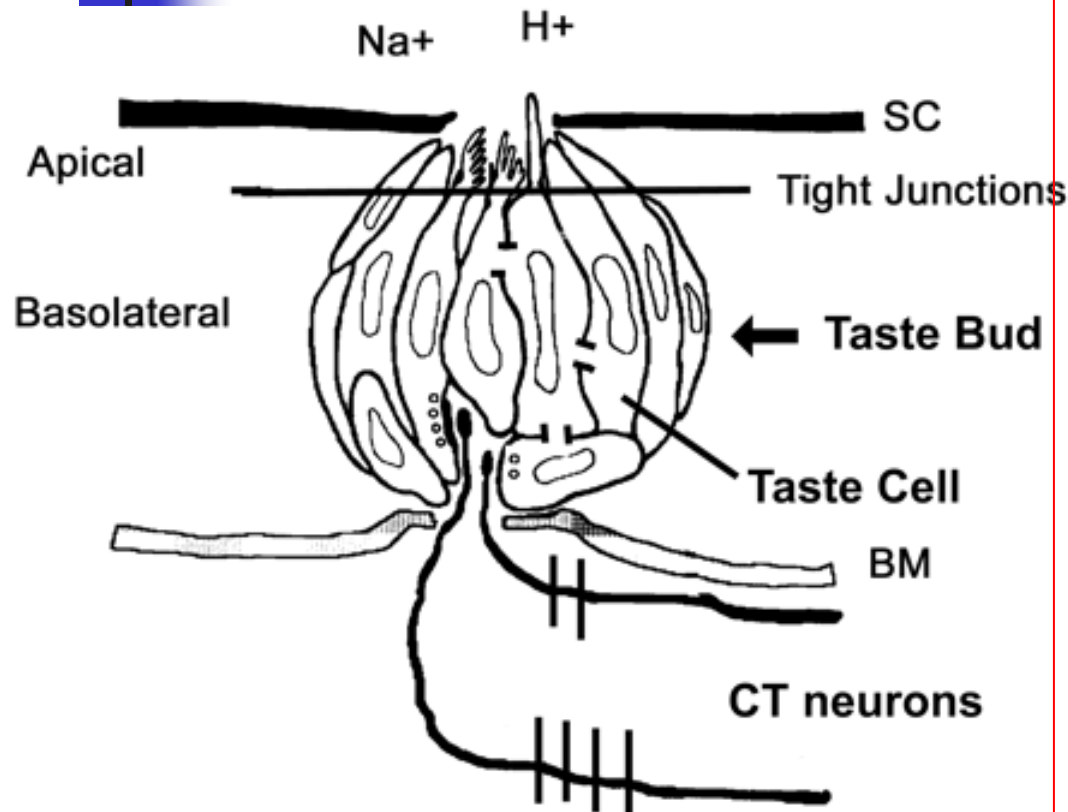
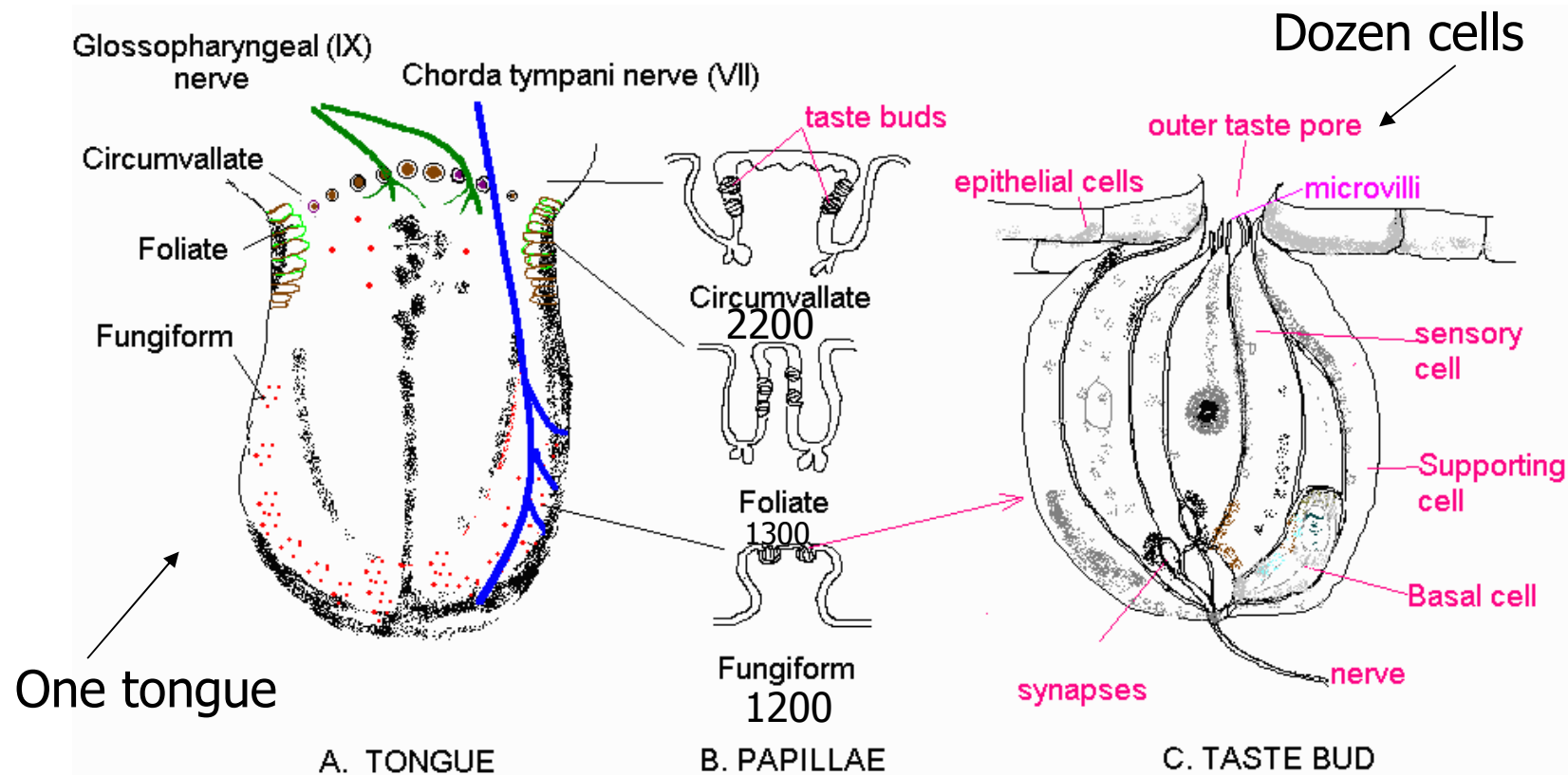


FIGURE 1. Diagram of a taste bud (arrow) that is embedded in stratified layers of epithelial cells (not depicted). The layer of tight junctions defines the apical and basolateral regions of the taste cells. Gap junctions couple clusters of taste cells. Coupled cells are indicated by short lines (see cell labeled "taste cell"). The stratum corneum (SC) of the epithelium opens to form a taste pore through which microvilli of taste cells protrude. Shown are a sodium ion and a proton about to enter the taste pore. Taste cells terminate at the basement membrane (BM), which separates the epithelium from the papillary layer. Two taste cells are shown to synapse with chorda tympani (CT) neurons

J Gen Physiol. 2002 Dec;120(6):787-91.

# Taste Buds

- 5000 taste buds/tongue
- 30-100 tb's per papillae
- 2500 taste buds elsewhere in mouth

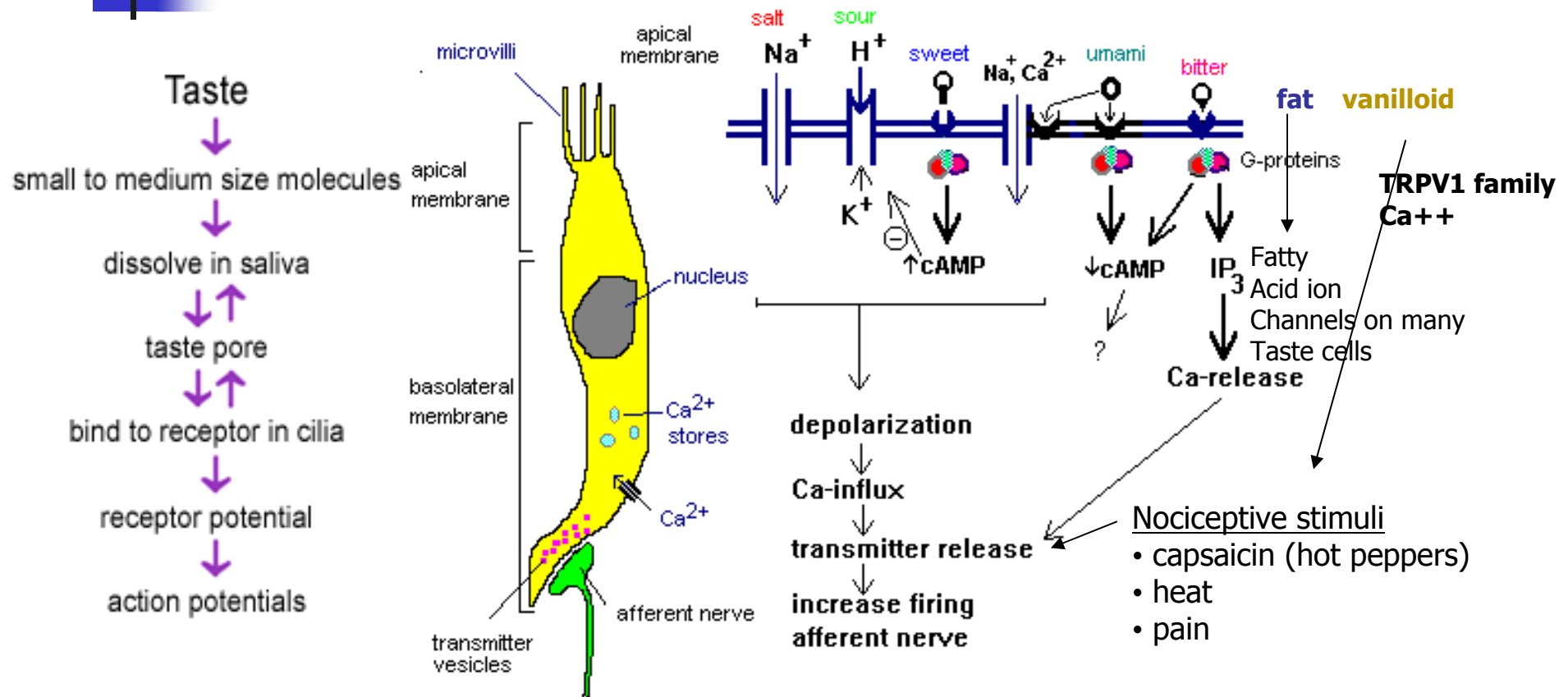


<http://www.cf.ac.uk/biosi/staff/jacob/teaching/sensory/taste.html>

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What makes food taste good?

# General Taste Transduction

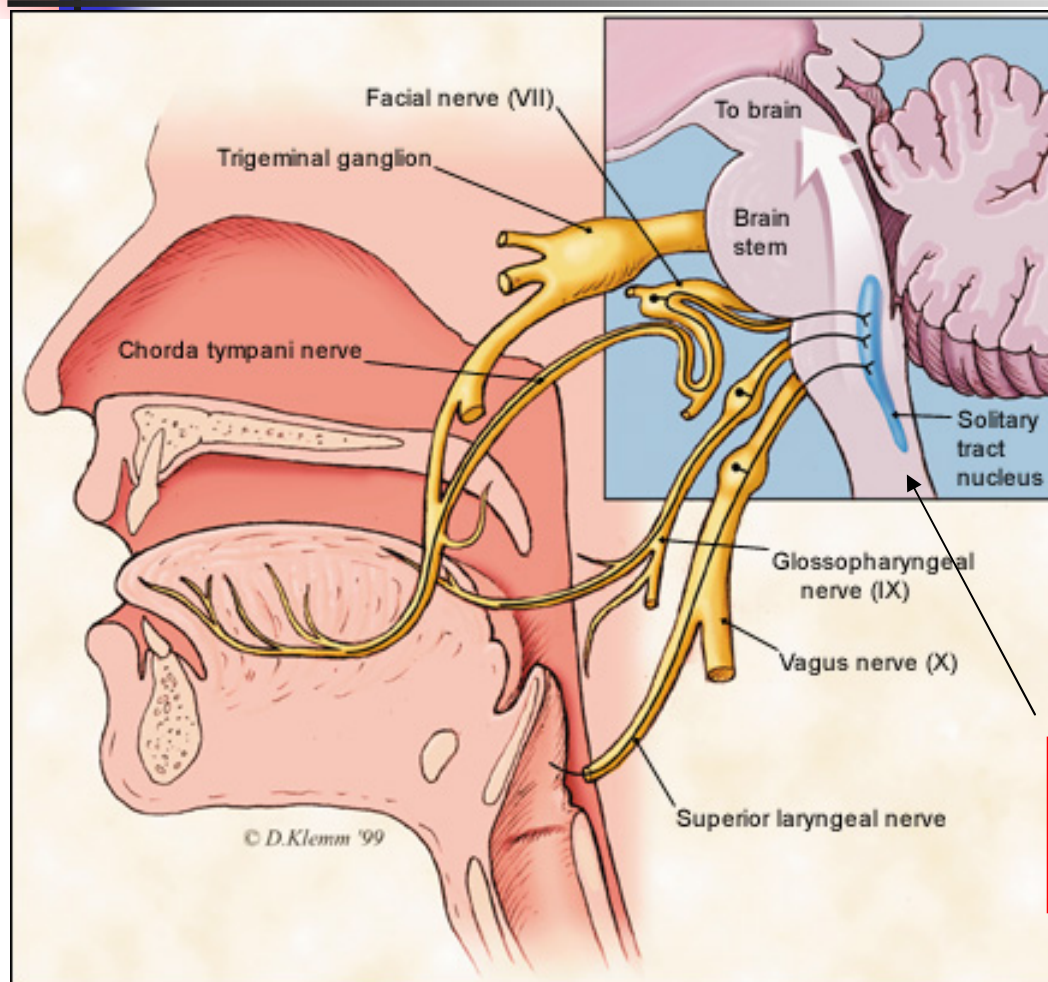


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What makes food taste good?

# Taste Pathways

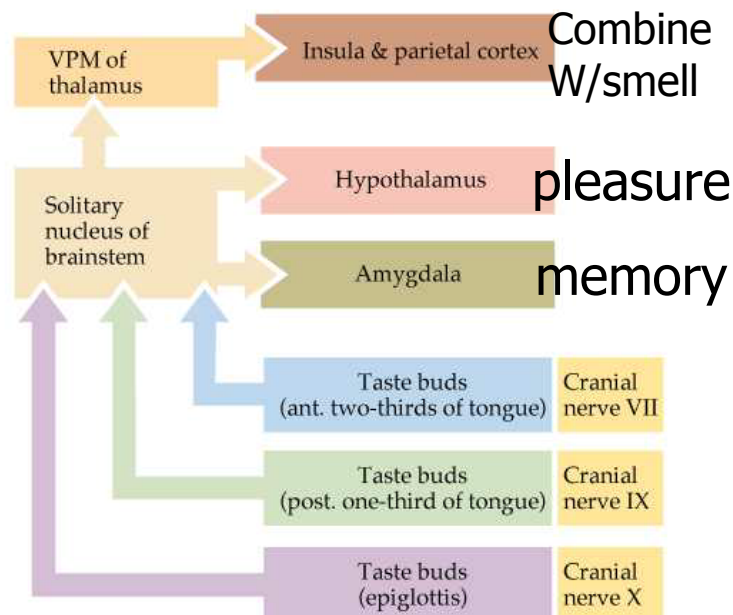
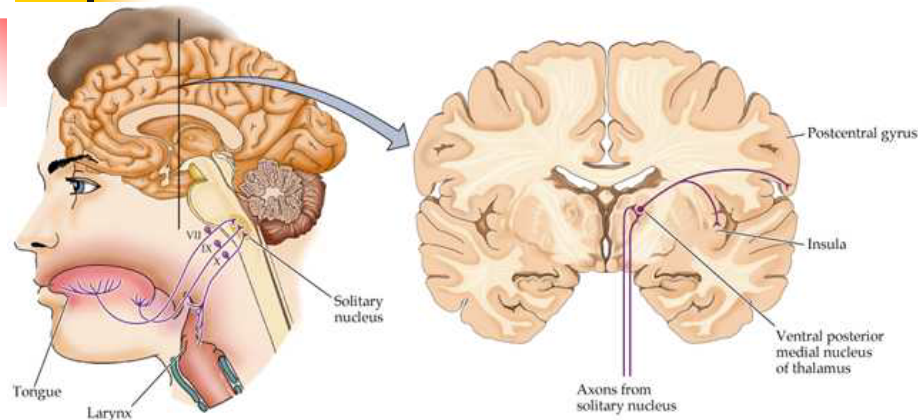


© 2000 David Klemm

- The **Gustatory Nucleus** receives projections from the taste buds of the tongue via cranial nerves VII (facial nerve), IX (glossopharyngeal nerve), and X (vagus nerve). The paired gustatory nuclei are located in the medulla, and are often called the **solitary nuclei**. Neurons within these nuclei encode the acceptability of a taste as well as its quality. For example, dangerous sour and bitter substances are encoded as bad tasting and are spit out, while life-sustaining **sweet** and **salty** substances are encoded as good tasting and are swallowed.
- The **gustatory nuclei** send profuse projections to a number of brain regions including the pons, lateral hypothalamus, amygdala, ventral posterior thalamic nucleus, and the primary and secondary gustatory cortical regions. Gustatory projections to the hypothalamus (**pleasure center**) may play a role in the reinforcing effects of sweet and salty tastes when we are hungry.

Gastrointestinal input  
into solitary nuclei!

# Final taste Pathways



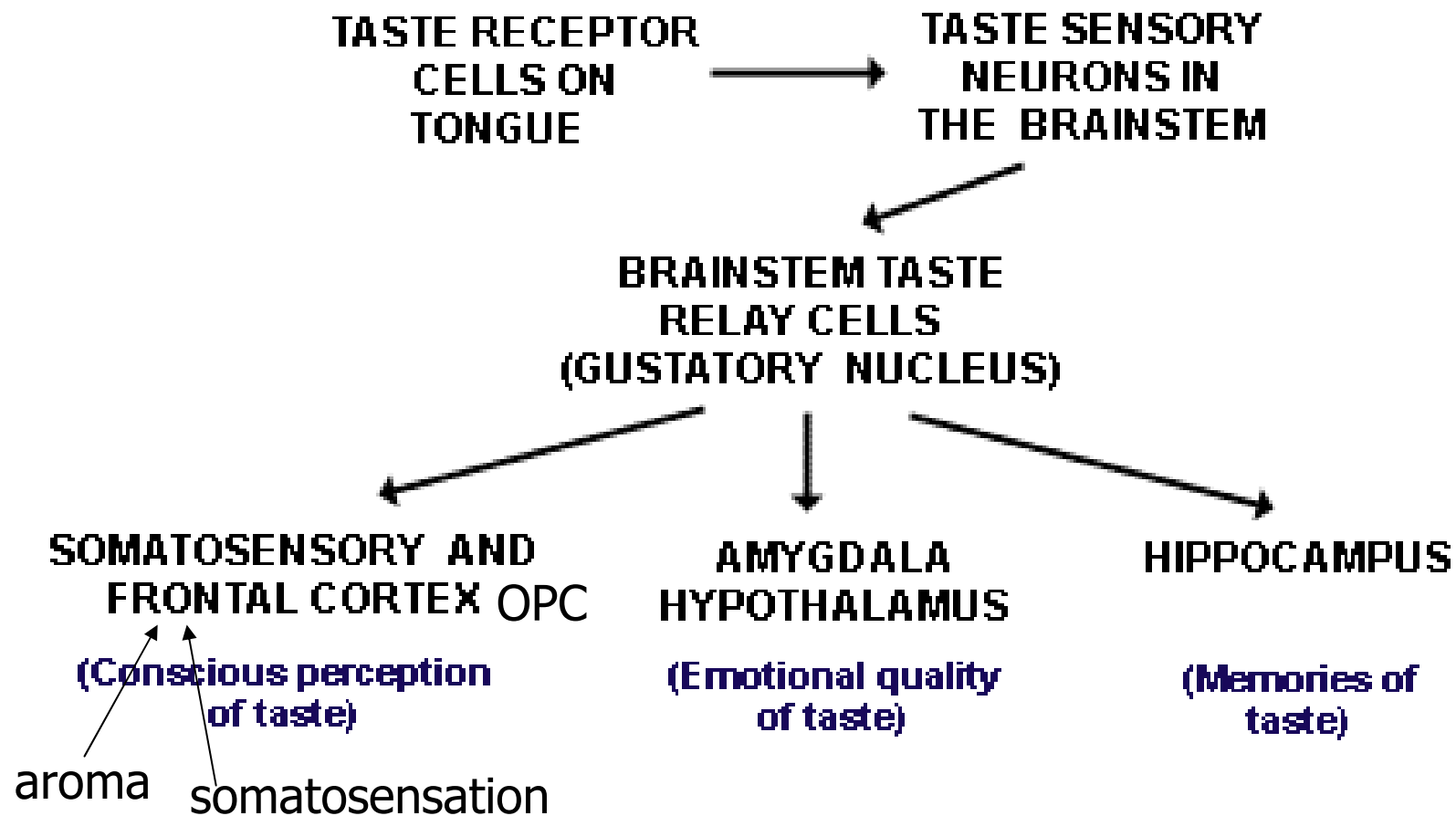
## Central pathways

Primary gustatory fibers synapse centrally in the medulla (in a thin line of cells called the nucleus of the solitary tract). From there the information is relayed (1) to the somatosensory cortex for the conscious **perception** of taste and (2) to the hypothalamus, amygdala and insula, giving the so-called "**affective**" component of taste. This is responsible for the behavioural response, e.g. aversion, gastric secretion, feeding behaviour.





# Taste Summary





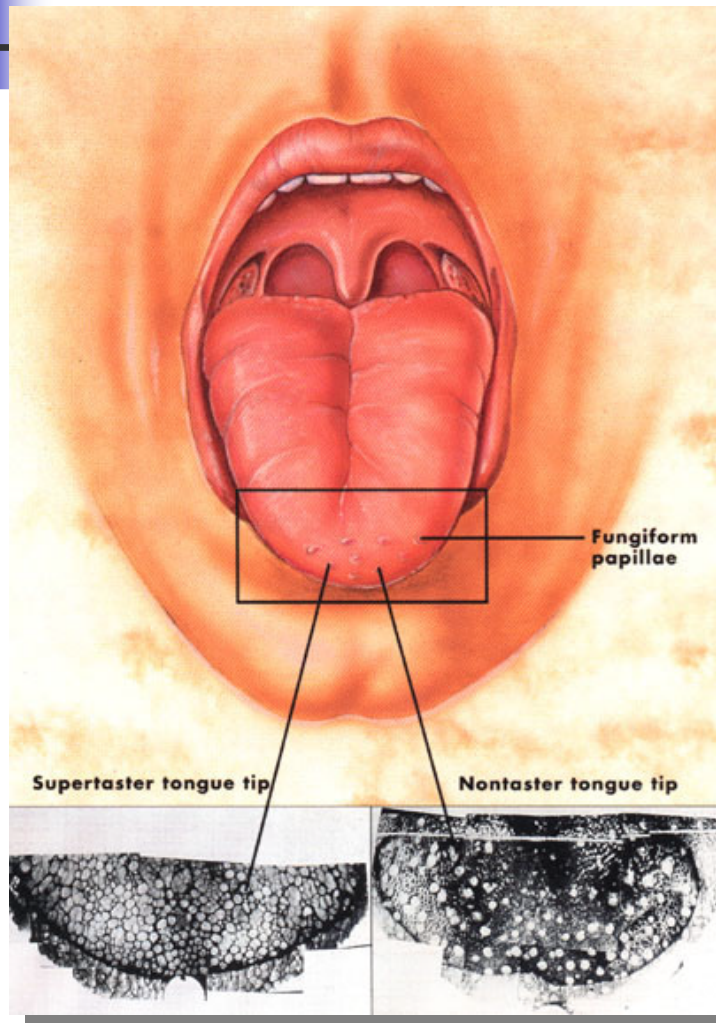
# Supertasters

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- Supertasters (Find PROP very bitter)
  - 25% population
    - Dislike bitter and hot foods
    - High taste bud density
    - More tactilely acute and like high fat foods
- Normal tasters
  - 50% population
- Non tasters (can't taste Prop)
  - 25% population
    - Like bitter, strong, hi sugar and salt foods



# Supertasters



Supertasters have  
higher number of  
Taste buds...foods  
In general are too  
intense for these  
folks. Beware of these  
People in taste panels

Photos courtesy of Linda Bartoshuk, Ph.D.  
Yale. Illustration by Lydia Kibiuk.

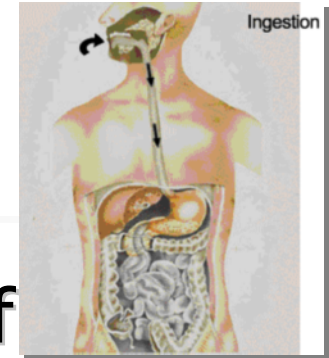


# Taste & Self Stimulation (SS)

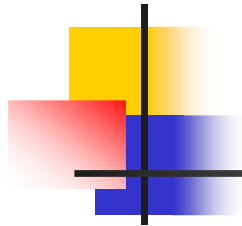
- “Rolls found that neurons that were responsive to taste stimuli when monkeys were hungry were also activated by SS” (Stellar & Stellar 1985)
- Also, an animal's level of sucrose preference can predict its desire to self-administer cocaine. Such data suggest a relation between sweet taste and drug reward
  - Am J Clin Nutr. 2003 Oct;78(4):834S-842S
- Insular Cortex may be as critical in processing visceral stimulus, hedonic valence and/or food-reward incentive learning.
  - Brain Res. 2000 Jul 28;872(1-2):134-40

**Taste direct access to pleasure!**

# Taste Drives Ingestion



- Taste drives ingestion and way out of proportion to the other elements of food
- Taste is the #1 reason stated by many consumers and surveys as the most important aspect of food selection
- Low salt and low sugar foods simply **cannot** be made tasty with current technology, but
  - Some sodium pleasure can be replaced by MSG and nucleotides
  - Cardia salt <sup>TM</sup> works as a substitute (50% salt)
    - Tasty considering its high K+ content!



# Taste & Pleasure I

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- Salt and sugar are directly hardwired pleasure directly into medial forebrain bundle (pleasure center)
  - No learning required
  - Opioid compounds, particularly those selective for the mu receptor, induce a potent increase in food intake, sucrose, salt, saccharin, and ethanol intake
- Licking of 0.3 M sucrose caused a 305% (+/-69%) increase in NAcc DA compared with water intake

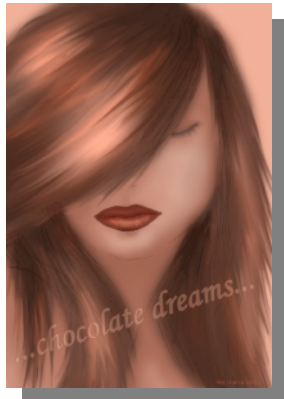


# Taste and Pleasure II

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- “Since drugs such as heroin, morphine, alcohol, and cannabinoids, interact with this system, there may be important common neural substrates between **food and drug reward** with regard to the brain's opioid systems
- “**Opioid** compounds, particularly those selective for the **mu receptor**, induce a potent increase in food intake, sucrose, salt, saccharin, and ethanol intake”
- “Activation of ventral striatal opioids specifically encodes positive affect induced by **tasty and/or calorically dense foods (such as sugar and fat)**, and promotes behaviors associated with this enhanced palatability”
- “Brain mechanism(s) was beneficial in evolutionary development for ensuring the consumption of relatively scarce, high-energy food sources. However, in modern times, with unlimited supplies of high-calorie food, it has contributed to the **present epidemic of obesity**”
- Physiol Behav. 2002 Jul;76(3):365-77.

# Taste and Pleasure III

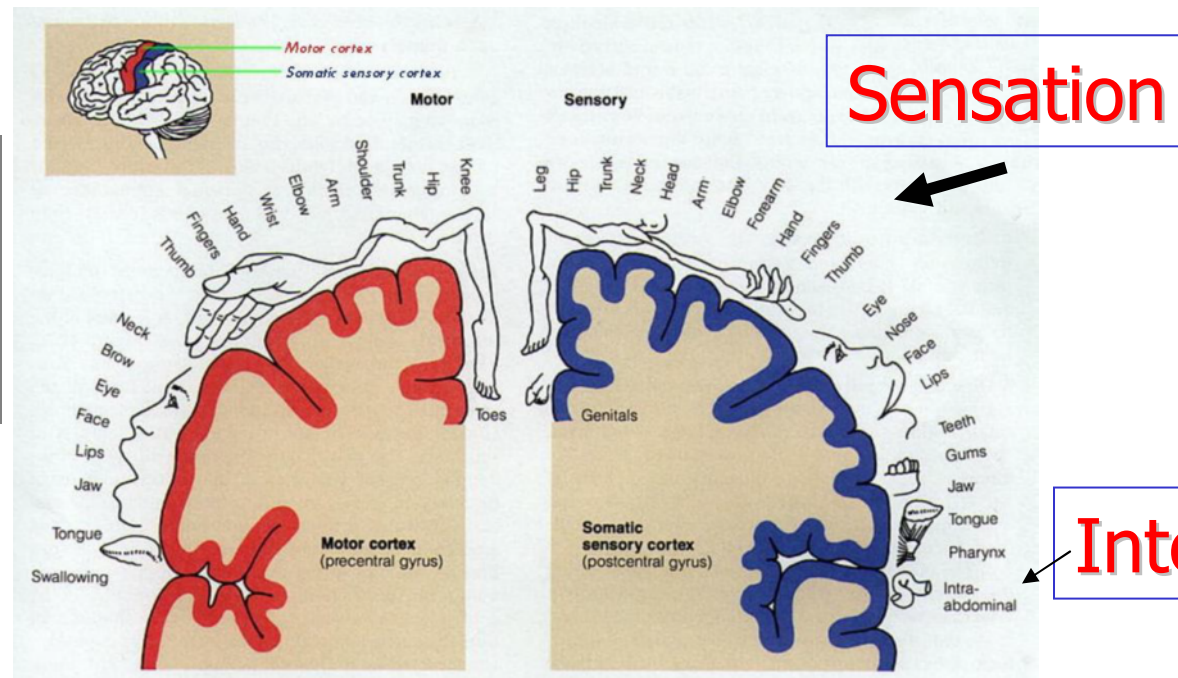
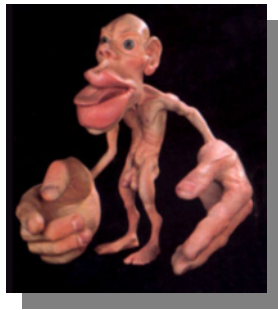


- Moreover, exposure to **cues** associated with the natural reward, **chocolate**, induced a pattern of gene expression that showed many similarities with that elicited by drug cues, particularly in prefrontal regions. These observations support the hypothesis that addictive drugs induce long-term neuroadaptations in brain regions subserving normal learning and **memory** for motivationally salient stimuli (tasty foods!).
- Once formed they cannot be undone!!!!
  - Neuroscience. 2001;105(3):535-45.



# Sensory Homunculus


- 40% of all sensation from the mouth and face
- Intestines about 5% of sensation





# Hedonic solutes

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- NaCl
  - Sugars, hi intensity sweeteners
  - Umami
    - MSG
    - 5 prime nucleotides
    - Garlic derivatives
  - Flavorants:
    - Lactones
    - Maltols
    - Chlorogenic acids
    - Many other taste-active compounds
- 
- Amino acids
  - Peptides
  - Fatty acids
  - Glycoconjugates
  - Maillard comps





# Salt and Sugar Pleasure

- Direct reward pathways from taste to pleasure center
- Sugar is mu opioid stimulator, dopamine
- Salt is mu opioid stimulator, dopamine
- Pleasure magnified when **mixed with fat(1)**
- Heroin, morphine, alcohol, and cannabinoids, interact with this system
- Ventral striatal medium spiny neurons mediate the affective or hedonic response to food ('liking' or food 'pleasure')
- Taste more sensitive when 'hungry'

(1) Emulsion pleasure theory



# Why Salt & Sugar Tasty?

- Salt essential nutrient for all neurons and cells
  - Blood 0.9% NaCl
  - Salt scarce in the evolutionary environment
  - Sodium/K<sup>+</sup> pump drives life
- Sugar is major fuel of neurons
  - NOT essential but very useful..
    - Drives ingestion
    - Increases insulin, growth promoter
    - Excellent short term energy source
    - Spares fat stores

**Hence: Body strives to find these nutrients!**



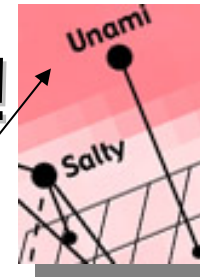
# MSG & Food Addiction?

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- Stimulates Insulin (rewarding in its own right)
- Signal for Food Protein (hardwired selection signal)
  - muscle protein is 18% protein
- Pleasurable taste (umami)
  - Independent taste
- NMDA neurons stimulated
- Increases food ingestion
- Synergistic w/ 5' nucleotides (boosting taste signal)
- Injections stimulate metabolic obesity
- Glutamic acid excitatory in brain
  - T1R1+3, an umami sensor, and T1R2+3, a sweet receptor—overlap
    - These findings support the hypothesis that the taste of MSG has broadly tuned, sweet-like characteristics, possibly due to the convergence of afferent signals for MSG, natural sugars and artificial sweeteners

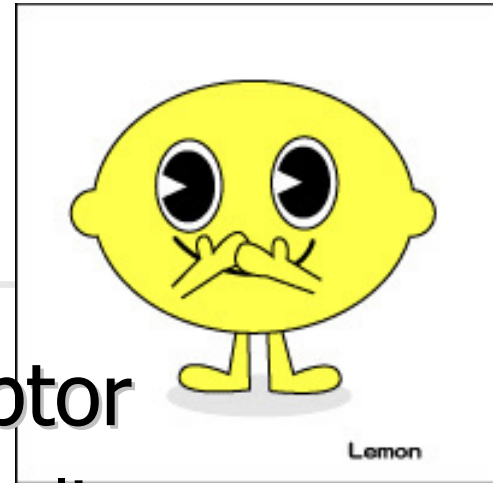
# MSG Coated Salt (Aji-Shio)

- MSG Coated salt (10% MSG)
- Absolutely wonderful salt
- And, I think, very addicting!



That should be umami!

# Acids in Food



- Activates Sour taste receptor
  - Increases attention to stimuli
  - Trigeminal oral response too
- Activates Vanilloid receptor
  - Increases sensation
- Greatest stimulator of saliva
  - Activates food ingestion response

# Foods High in MSG

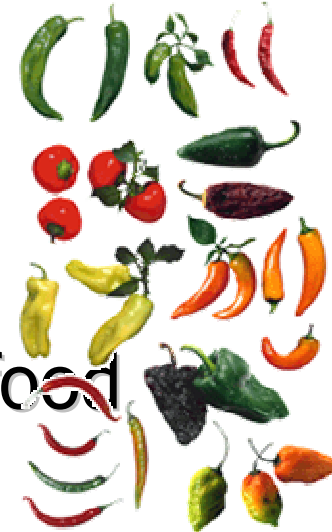
- Many preferred food are naturally high in MSG:
  - Soy Sauce
  - Parmesan cheese
  - Tomato
  - Potato
  - Breast Milk!
  - Sardines
  - Fish Sauces



# Why Do People like Spicy Food?

capsaicin & heat & acid

- Hot peppers were domesticated faster than any other plant (beside marijuana)
- Capsaicin excites vanilloid receptors for heat or hot taste (lots of receptors in mouth)
- Receptors code for PAIN
- Desensitizes over time
- Vanilla also activates
- Activated by: heat, acid, spicy food



# Spicy Food Liking 2

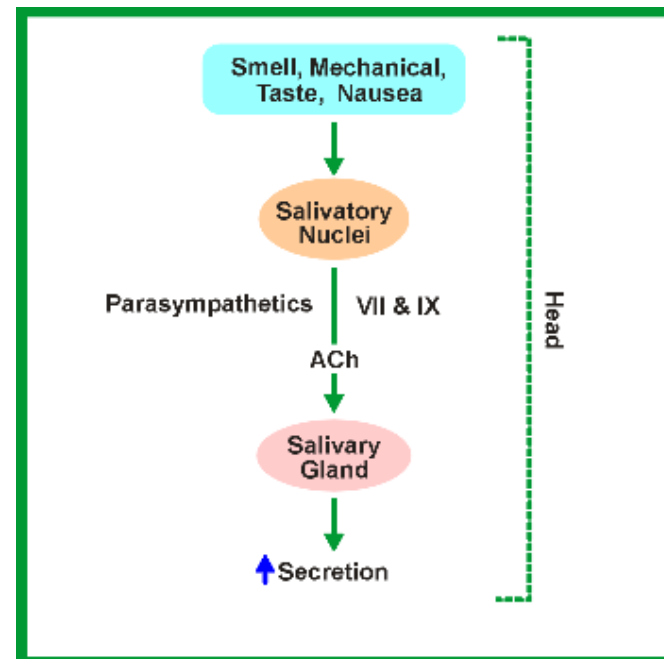
- Capsaicin, the pungent component of "hot" chili peppers, selectively activates a distinct population of primary sensory neurons responsive to noxious stimuli. Many of these fibers express neuropeptides including the tachykinin, substance P.
- Substance P relay pain and the brain produces **endorphins** (brain morphine)
- For some, spicy food is highly **addicting**
- May help release oxytocin, the hormone of bonding
  - Cannabinoid and vanilloid systems interact somehow with nociceptive processing in the periphery.





# Salivation and Food Pleasure

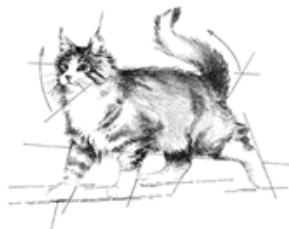
- Salivation linked to taste buds
- Saliva dissolves food and allows pleasure response
- Salivation reflex to good food
- Salivation decreases to the same foods over time. Then goes back to normal with a **new** food!



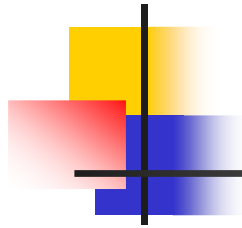
# Doritos Salivation Response

- Doritos contains acids that stimulate saliva and they make their own intraoral sauce to keep ingestion going.
- Dry Food is Sensory Death!

*cat*



Cats don't like dry food and neither do humans



# Taste and Hunger

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- Skipping Meals Increase Sensitivity to Sweet and Salty but Not Bitter!
- 25% Adults say they skip meals to lose weight (bad idea)
- Ergo: Skipping meals makes dieting worse since one will binge!
- Less snacking means you enjoy the meals more!
  - BMC Neuroscience 2005, 5:5



# Sweet Taste & Leptin

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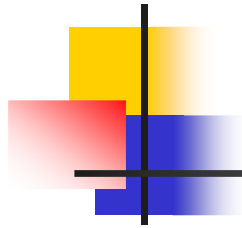
- The hormone leptin inhibits sweet cells by opening their  $K^+$  channels. This hyperpolarizes the cell making the generation of action potentials more difficult. Could leptin, which is secreted by fat cells, be a signal to cut down on sweets?
- <http://users.rcn.com/jkimball.ma.ultranet/BiologyPages/T/Taste.html>



# Taste and Smell 1

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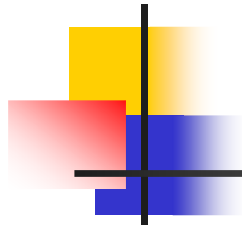
- Taste and smell represent **phylogenetically old** sensory system
- They are the sensory systems that let us **detect** and **discriminate** the molecules in our environment
- These senses help to **link** the external environment with internal needs, e.g. hunger, thirst, etc.
- Are vivid **emotionally** and perceptually
- Important nutritionally for regulating **food intake**
- Linked together in the Orbitofrontal cortex to form the term: “Flavor”
- Taste and Smell senses **sharpen** when hungry!
  - BMC Neuroscience (Professor Zverev)



# Taste and Smell 2

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- Odor identification is poor, but with training can greatly improve
- Odor memory is very long however
  - First to go in Alzheimers
- Odor always coded with an **significant event**: food, sex, strong emotions
- Aromas desensitize relatively rapidly unlike taste



# Taste and Fatty Foods

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- “The BBC News Health report on this study (taste and hunger) refers to Amanda Wynne, spokesperson for the British Dietetic Association, as saying that the findings suggest that people have a **natural disposition** towards fatty foods”
  - Daily Telegraph: 23/3/2004



# Snack Food Taste 1

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- Energy intake increases with meal and food palatability
- Taste (a factor encompassed by palatability) is reported to be the single most important reason individuals choose the foods they do, even over healthfulness
- Palatable meals may be likened to foods that have a relatively high glycemic index
  - Hunger reduction is very reinforcing
- More palatable meals may lead to greater subsequent hunger (hi glycemic) and energy intake
  - J. Nutr. 132:3830S-3834S, December 2002





# Snack Food Taste 2

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- Taste can influence meal size and body weight
- Sham feeding (bypasses taste) also stimulated accumbens dopamine overflow as a function of sucrose solution concentration
  - Shows gut filling pleasureable
- Quantitative relationship between the concentration-dependent rewarding effect of orosensory stimulation by sucrose during eating and the overflow of dopamine in the nucleus accumbens
  - Sweeter is better in general
- This finding provides new and strong support for accumbens dopamine in the rewarding effect of sucrose
  - Not all researchers agree here, but dopamine helps alert and direct attention to salient stimuli



# Snack Food Taste 3

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- We conclude that DA is not required to find the sweet tastes of sucrose or saccharin rewarding.
- We suggest that DD mice have a deficit of goal-directed behavior
  - J Neurosci. 2003 Nov 26;23(34):10827-31.
- Hence, pleasure is a function of dopamine and opiates and probably other reward neurons or neurotransmitters.
- Latest: opioids in wanting and liking, dopamine in wanting (Berridge)



# NACHO Doritos Ingredients

- Corn
  - Vegetable oil
  - Flour
  - Cheeses:
    - Romano
    - Cheddar
    - Parmesan
  - Whey protein
  - Salt
  - Tomato solids
  - Lactic acid
- 1987
- MSG
  - Buttermilk
  - Onion
  - Garlic
  - Dextrose
  - Citric acid
  - Sugar
  - Colors
  - Spice
  - 5'Nucleotides



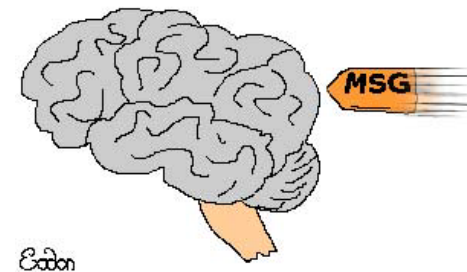
# Doritos Nacho Cheesier 2004

- Corn
- Vegetable oil
- Cheddar cheese
- Salt
- Buttermilk solids
- Wheat Flour
- Whey Protein Concentrate
- Romano Cheese
- Tomato Powder
- MSG
- Onion Powder
- Soybean oil
- Whey
- Garlic powder
- Dextrose
- Sugar
- Disodium phosphate
- Lactic acid
- Natural Flavor, Spice
- Citric acid
- Parmesan Cheese
- 5' Nucleotides



# Taste & Doritos

- Loaded with Taste Active Compounds
  - Salt
  - Sugars:
    - Dextrose
    - Sugar
  - Acids
  - 5'Nucleotides
  - Monosodium glutamate





# Pleasures of Sensation

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- 2 components
  - Arousal (increased attention to stimuli)
  - Pleasure (actual dopamine release)
- Stimulate medial forebrain bundle by:
  - Eating
  - Drinking
  - Chewing (serotonin feedback)
  - Orosensation (pleasures of sensation)
  - Gut fill with calories—direct
  - Individual nutrient effects (like CHO)
  - Relief from hunger (negative affect)



# Orosensation-what is it?

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- Orosensation (somatosensory)
  - Vast Trigeminal innervation of mouth
    - Texture, Touch
    - Temperature
    - Mouth burn and pain
  - Trigeminal system contributes to both the sensorimotor and motivational control of ingestive behavior (Zeigler)
  - Somatosensation much stronger than gustatory stimuli



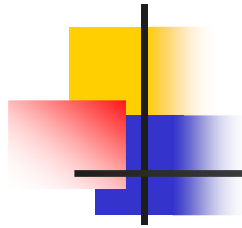
# Orosensation--Menthol

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- Nicotine pleasure allows Menthol to take on all new meaning...
- Added Orosensation to Hedonic stimuli become addicting in their own right...
- Cues for pleasure to come...
- Relive pleasures of memories past.

Orosensation drives ingestion



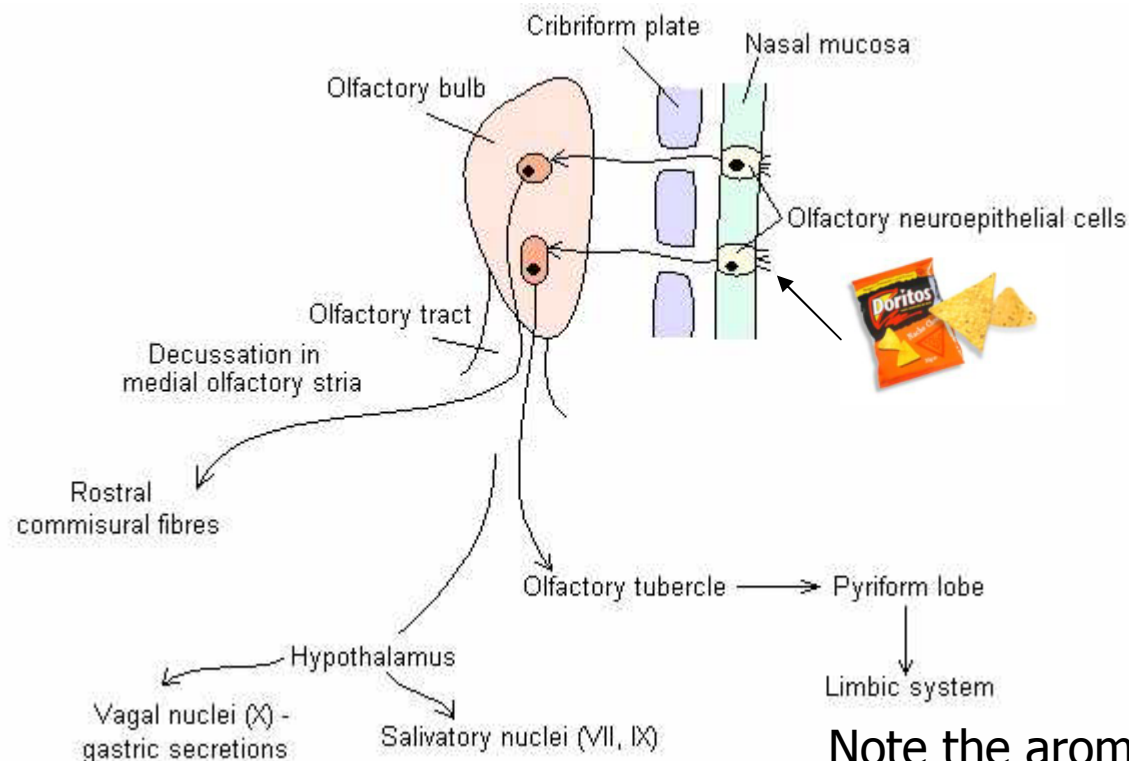


# Sense of Smell 1

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- Odorants bind to mucous, must be both fat and water soluble
- 1000 olfactory receptors
- Aromas acquire significance thru food ingestion—forms food memory
  - Fat and sugar best form memories!
- Once formed aromas resistant to extinction
- Bad aromas remembered better than good

# Sense of Smell 2



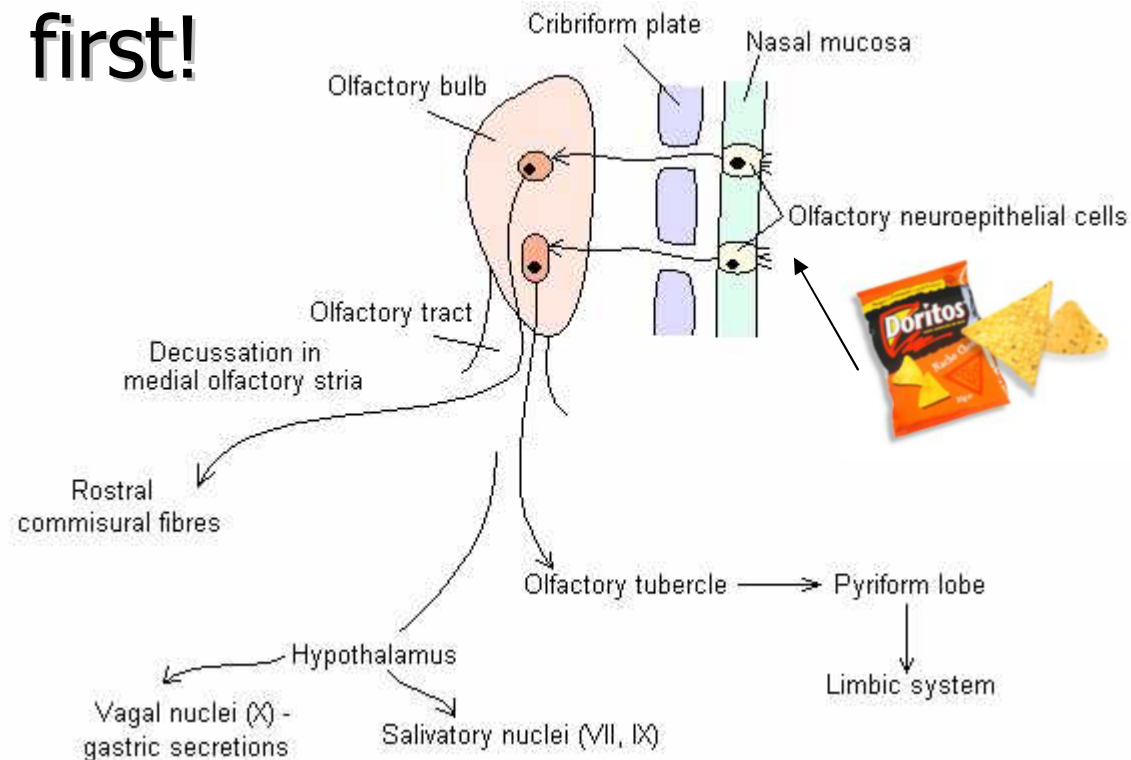
Snack foods with sugar fat, and calories are highly preferred and easily form food memories Since they release the Pleasure neurotransmitter dopamine

Aromas can stimulate digestion and salivation

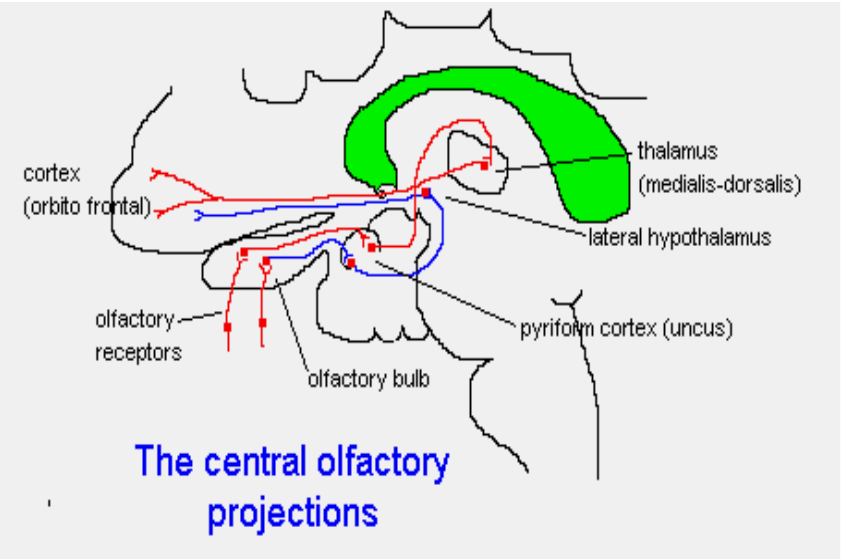
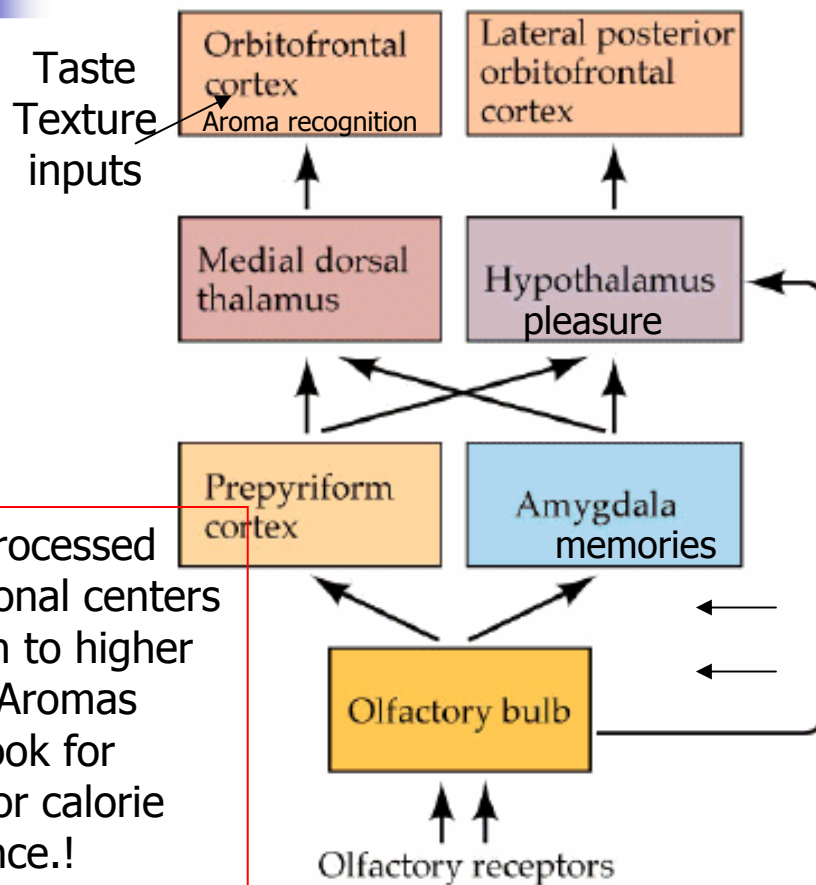
Note the aroma signals into the pleasure Centers of the limbic system, processed by the amygdala

# Olfaction Brain Pathways

- Aromas processed by the limbic system first!



# Central Olfactory Pathways



## Central olfactory pathways

Neurons from the lateral olfactory tract project to; (1) the amygdala, septal nuclei, pre-pyriform cortex, the entorhinal cortex, hippocampus and the subiculum. Many of these structures form the *limbic system*, an ancient region of the brain concerned with motivation, emotion and certain kinds of memory. The septal nuclei and amygdala contain regions known as the "pleasure centres". The hippocampus is concerned with motivational memory (the association of certain stimuli with food). (2) Projections are also sent to the thalamus and thence to the frontal cortex for recognition. There are many forward and backward connections between each other these brain centers.

From: [www.arts.uwaterloo.ca/~cellard/teaching/PSYC261/chem.ppt](http://www.arts.uwaterloo.ca/~cellard/teaching/PSYC261/chem.ppt)



# Olfaction & Junk Food I

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- Aromas become significant via linkage with a significant environmental stimulus
  - Sex, drugs, rock and roll
  - Food (salt, fat, sugar esp. good)
- Once formed, Aroma Memories never extinguish
  - Bad aromas better remembered than good!
- A food company needs to have a sensory signature (ss) for repeat business
  - SS: an aroma/taste profile that people can recognize as *yours*
  - *Hence: Constant tinkering with formulation isn't good!*
  - Once the consumer has memorized your flavor profile leave it alone!



# Olfaction & Junk Food II

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- Remember that Aroma is processed by the limbic system *first—quite unlike any other sense!*
- Aroma pleasure can extinguish over time while eating that specific food (sensory specific satiety)
- Certain aromas never seem to extinguish!
  - Vanilla, milk aroma
  - Potato aroma
  - These aromas then, can be eaten everyday without flavor burnout!



# Chemical Senses are Unique

- “Early cortical representations of vision, auditory and somatosensory info (e.g. ‘primary and secondary’ areas) are in the unimodal neocortex..in contrast the chemical senses (**taste** and **smell**) are in the limbic and paralimbic cortex”.
- Do you know what this MEANS???



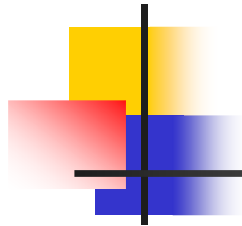


# Chemical Senses II

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- “thus...taste and smell are in regions of the brain...internal and motivational states...and affective significance of external objects”
- In English: taste and smell are for pleasure, finding pleasure and seeking more pleasure...it is what your brain **yearns for...**
- Stimulate taste & smell: potent elicitors of...amygdala, insula, OFC, cingulate cortex, basal forebrain...
  - Brain (2001), 124, 1720-1733.





# Taste & Smell=Flavor

- Central taste and olfactory systems in primates provides evidence that the convergence of taste and smell information onto single neurons is realized in the caudal **orbitofrontal** cortex
- Cortical areas thus support **flavour** processing
- Correlations with consonance ratings for the smell and taste combinations, and for their pleasantness, were found in a medial anterior part of the orbitofrontal cortex
- OFC searches for taste & smell with hedonic overtones (taste appears never to be neutral)
  - Eur J Neurosci. 2003 Oct;18(7):2059-68



# Flavor and Reward

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- Brain has two motivation systems:
  - Positive/appetitive [reward]
  - Negative/aversive [punishment]
- Chemosensory Regions in Brain:
  - Process sensory responses and
  - Process value of food reward simultaneous!
    - Brain (2001), 124, 1720-1733.

# Vanilla Theory (SAW)

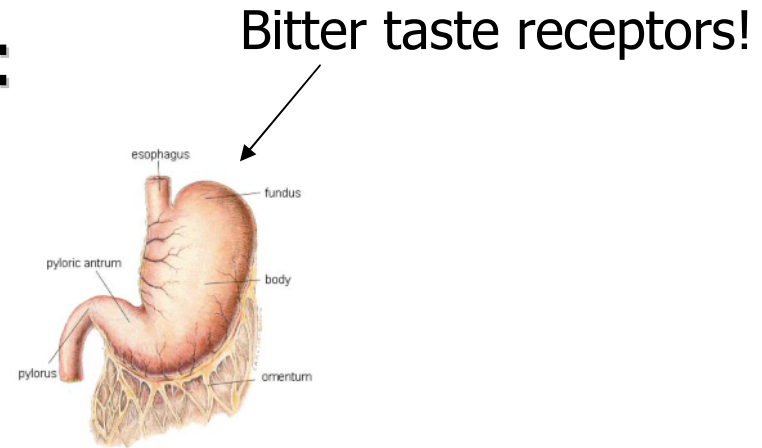


- Why do People like Vanilla Aroma?
- Here, perhaps is the answer:
  - Potent Antioxidant (Good for Tissues)
  - Stimulates Vanilloid Receptors (hot food)
  - Brain Never Tires of Vanilla aroma:
    - “...the OFC decreased after satiety to...banana aroma, but NOT in response to a vanilla odor”
  - YOU CAN'T BURN OUT!!!

Brain (2001), 124, 1720-33.

# Stomach: 2<sup>nd</sup> Oral Receptor System

- The stomach contains:
  - Osmoreceptors
  - Sense organs for:
    - Amino acids
    - Fatty acids
    - Glucose
    - Acids
  - Nociception (vanilloid)
  - Mechanoreceptors
  - Texturoreceptors
- Bodies 2<sup>nd</sup> chance to evaluate food!





# Stomach/Intestines

- Sense the Energy Content of Food
  - PYY and Ghrelin mediated
- Senses the Size of a Meal
  - CCK mediated
- Vagal Nerve senses all!
  - Sends info to caudal brain sites for processing
  - Arcuate nucleus of hypothalamus

You simply cannot fool the stomach and intestines  
by creating low fat or low sugar or fake fat foods:  
Your gut cannot be fooled!!!

# Stomach Sensing

- The stomach then is the second tongue, a chance to taste to nutrients consumed again and:
- To sense its caloric content
- Sense its metabolic usefulness
- You may fool the taste buds with low fat or fake fat---but not the stomach and upper intestines!!!
  - This is the great Olean Dilemma!
  - Fooled taste buds but not stomach





# Gut and Food Intake

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- Gut has vast sensory sheet
  - Receptors for macronutrients
  - Contains many taste/sensory cells
- Powerful controls on Food Intake
- Direct neural links to brain
  - Many neurohormones present in both gut and brain
- Many gut hormones and peptides stimulate intake



# End of Part One

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What You should have learned...