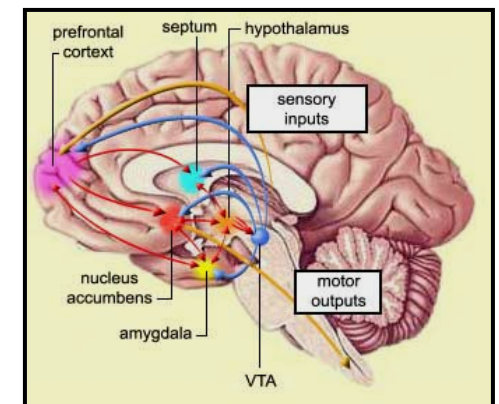
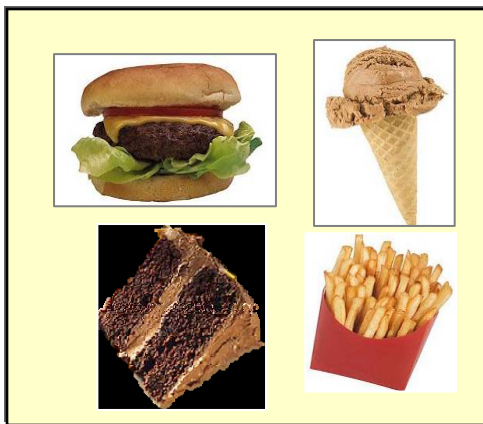
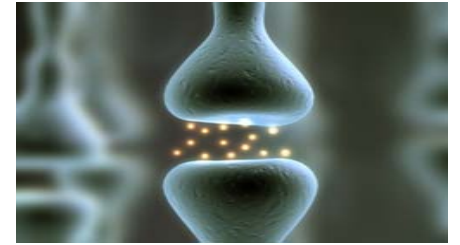


Highly Palatable Foods: The Brain Reward Pathways and Connections to Overeating

Dr. Micheline Vargas, DrPH, CNS, RCEP
Research Scientist, Nutrilite Health Institute

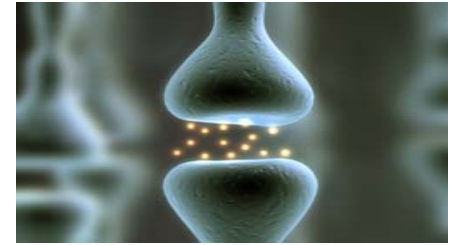


Agenda



- Excessive food consumption and the brain's pleasure pathways
- Obesity and reduced food reward
- Connection between the pleasure pathways, habits, and addiction
- Drives for highly palatable foods
- Brain reward circuitry and stress related food intake
- Treating obesity by changing the brain

Global Obesity Epidemic



World Health Organization Estimates

2005

1.6 million overweight & 400 million obese
20 million children under 5 y/o overweight

2015

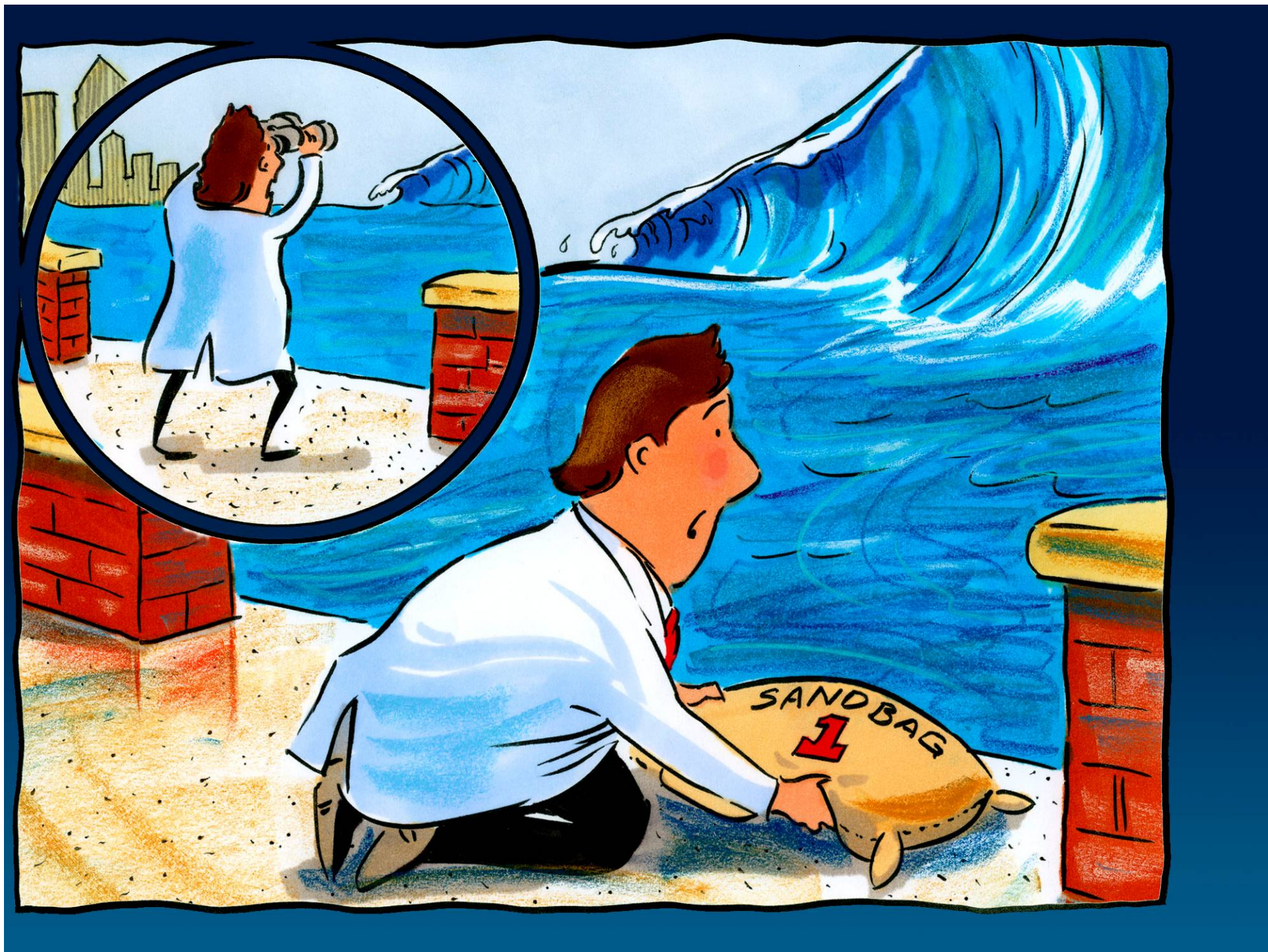
2.3 million overweight
700 million obese adults

Health Risks

Cardiovascular disease
Diabetes
Osteoarthritis
Some cancers

Causes

Too many calories
Not enough exercise

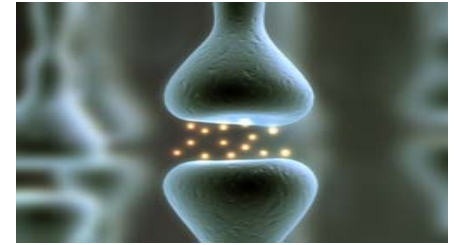






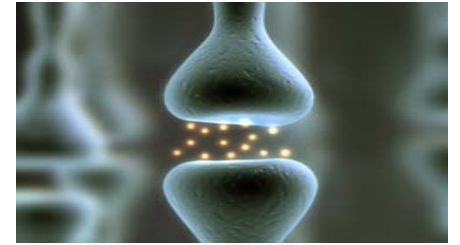






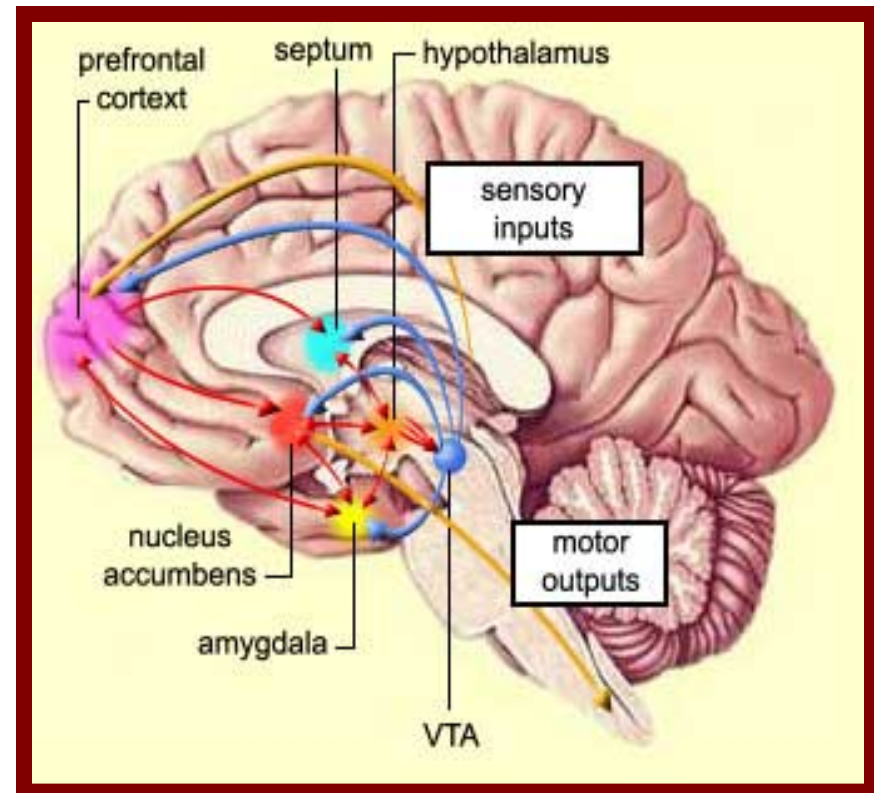
The Brain is Reward Driven

Brain Pleasure Centers

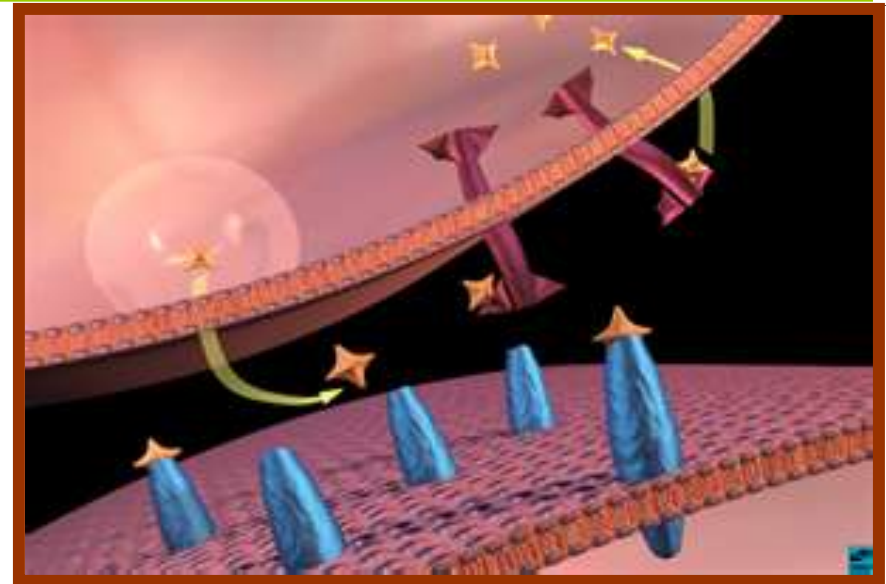
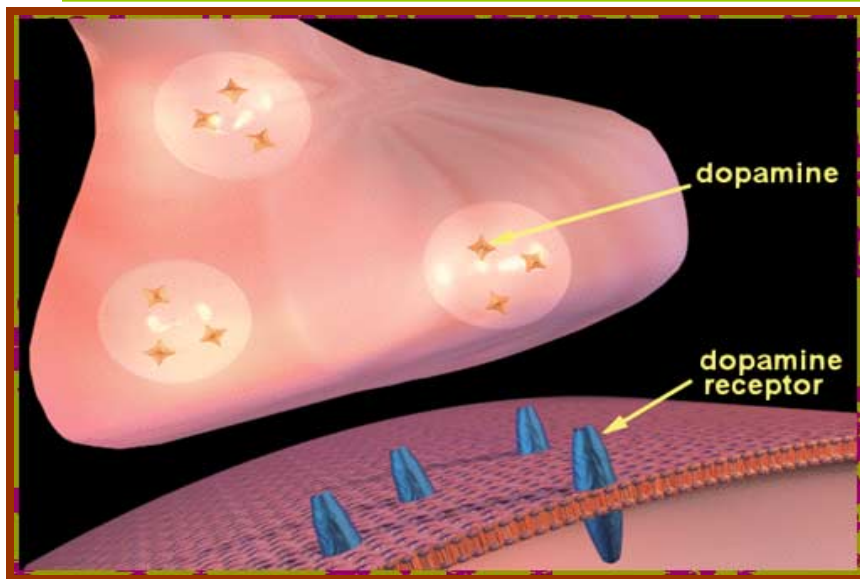
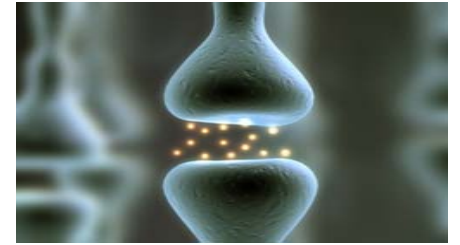


- **Reward circuit**

- Ventral tegmental area (VTA)
- Nucleus accumbens
- Septum
- Amygdala
- Prefrontal cortex



Brain Pleasure Centers



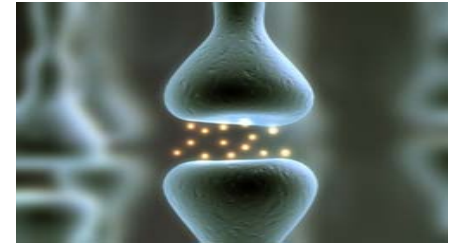
Higher dopamine levels = higher gratification

Pleasure perception

“Incentive value” and “pleasure seeking”

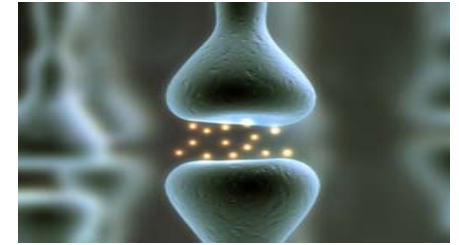
Gratifying behavior

Memory



Obesity & Reduced Food Reward

Brain Pleasure Centers



What do the colors mean?

RED

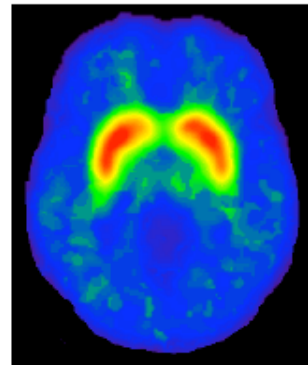
high dopamine
normal pleasure
& interest

YELLOW

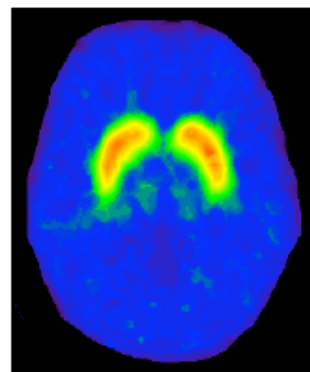
medium dopamine
difficult feeling joy
or pleasure

GREEN

low dopamine
lack of pleasure



Control Subjects

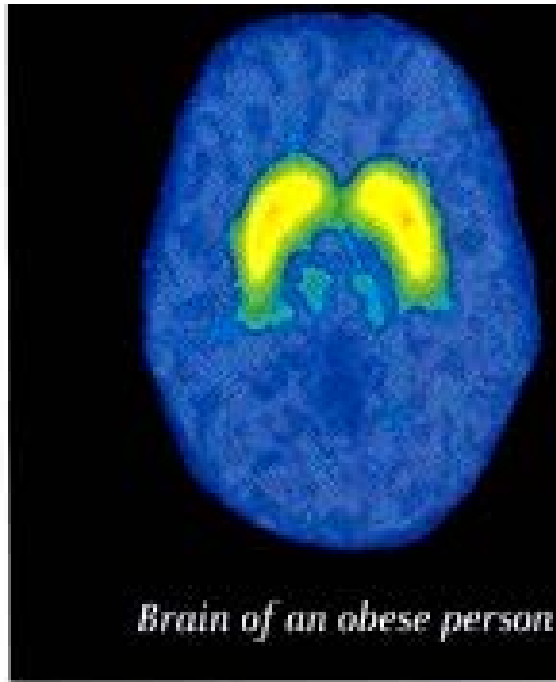
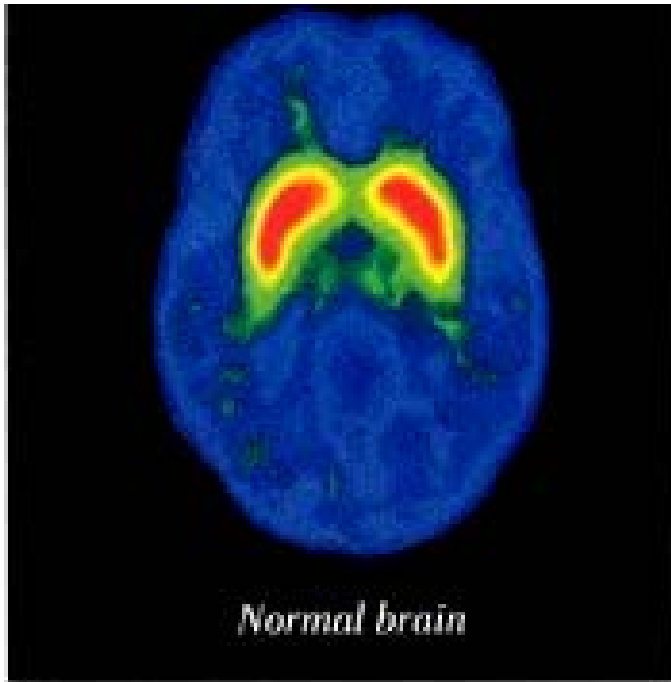


Obese Subjects

- Lower dopamine D2 receptors in obese than control subjects
- Lower D2 make the obese individual less sensitive to reward stimuli
- Obese similar to drug addicted

Wang et al., Lancet 2001

Wang et al., Lancet 2004



BRAIN REWARD CENTER

What do the colors mean?

RED

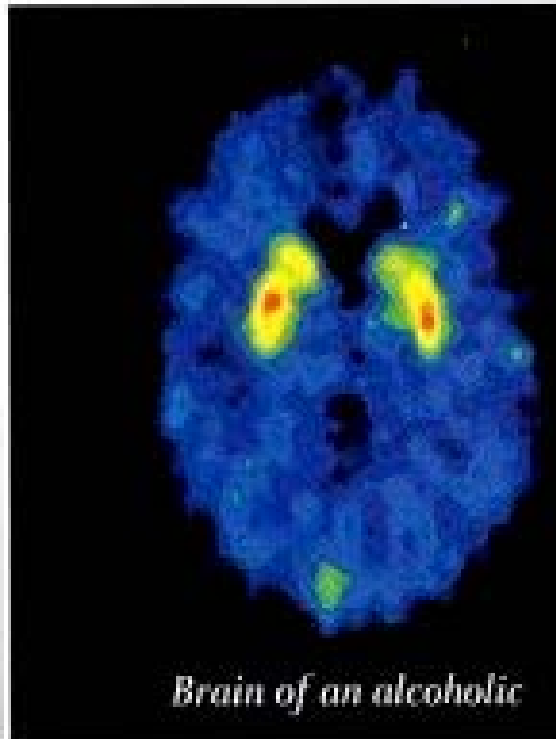
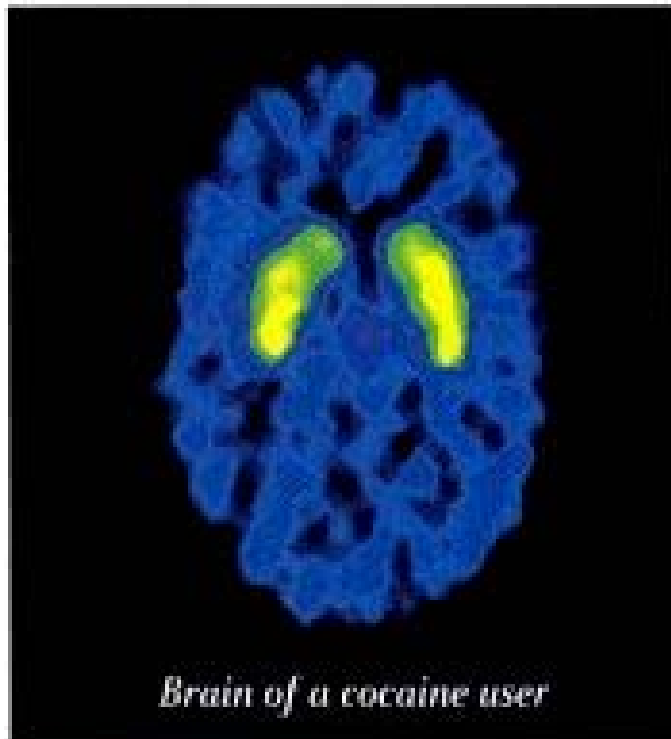
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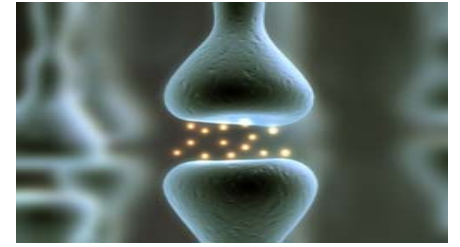
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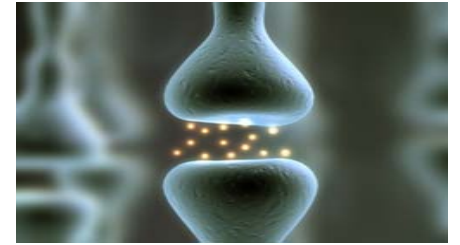


Genetic Variations



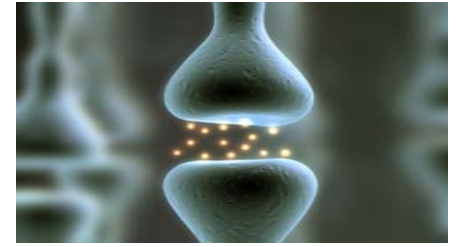
- A genetic variation may be the cause in some obese
- Association between the Taq 1 A allele and lower levels of dopamine D2 receptors

Stice E, et al., *J Abnorm Psychol.* 2008
Felsted JA, et al., *The J Neurosci*, 2010

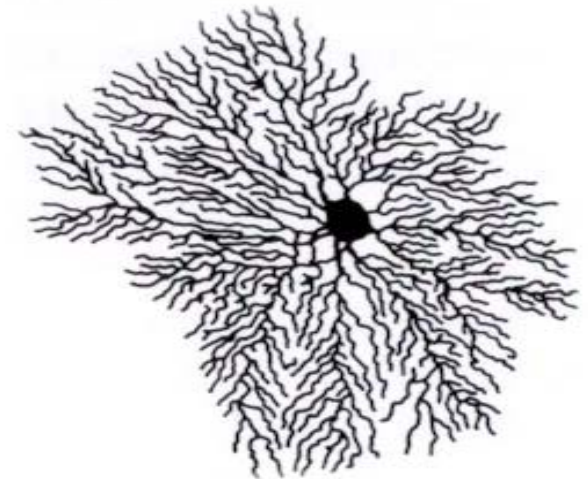


Connection Between Pleasure Pathways, Habits, and Addiction

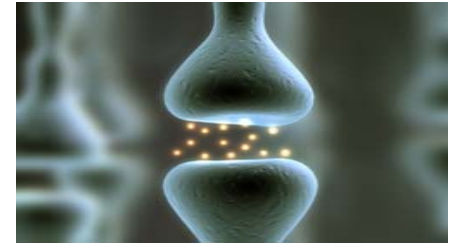
The Brain is Plastic



- The brain is plastic, meaning it can change
- Experience-dependent plasticity
- Learning occurs in the brain through the process of strengthening or weakening synapses
- The brain will be modified by the repeated act of overeating

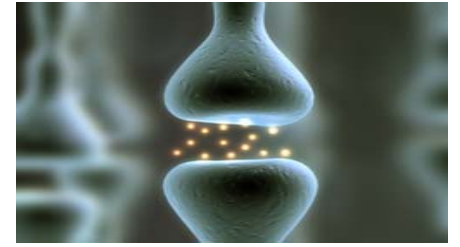


Memories, Learning & Conditioning

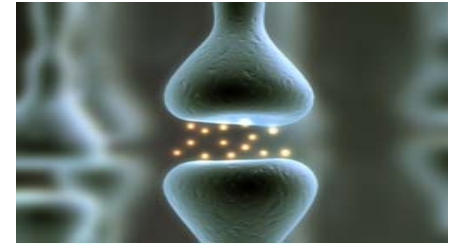


- The brain creates memories about eating behaviors
- Glutamate, an excitatory neurotransmitter, plays a role in synaptic plasticity
 - Involved in cognitive functions such as learning and memory
 - Important in storing information about eating experiences, such as pleasure felt when eating.
- Cues in the environment can “trigger” memories of the pleasurable experience.
- Pleasurable memories can lead to cravings and relapse

Addiction

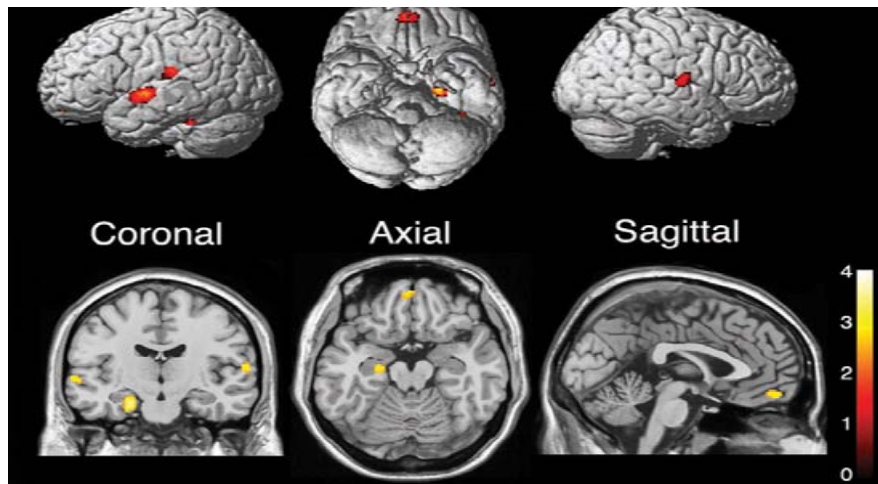
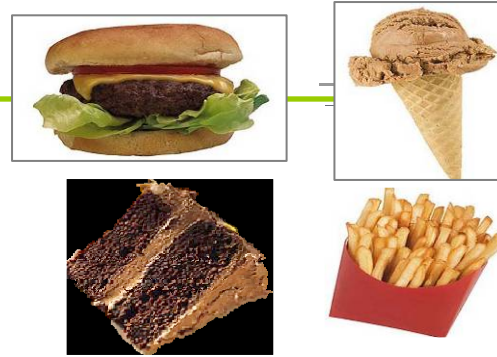
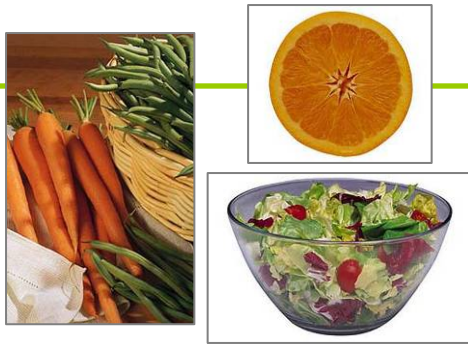


- **Pleasure circuits are “hijacked”**
- **There is a cascade of pleasure neurotransmitters**
 - **serotonin, dopamine, enkephalin, and GABA**
- **With repeated abuse the amount of neurotransmitter released in response to normal stimuli is reduced**
- **More substance is needed to get the same sense of pleasure**

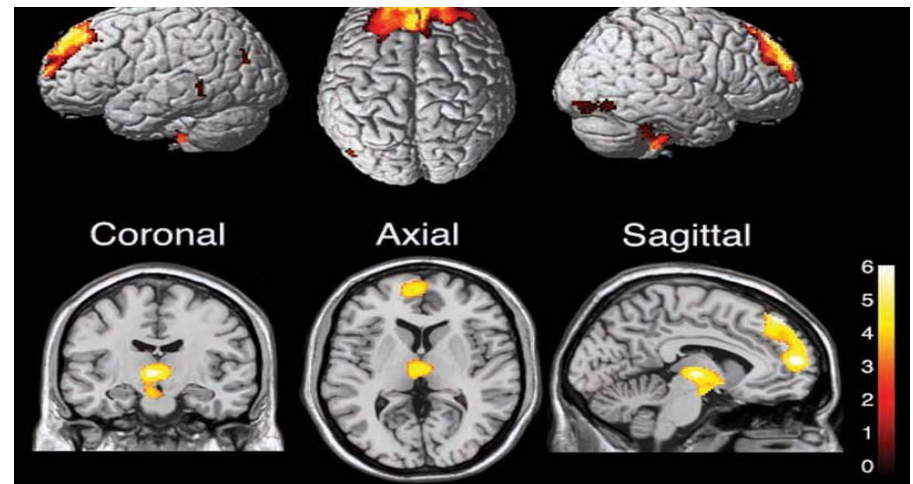


Drives for Highly Palatable Foods

Why Don't We Binge on Broccoli?

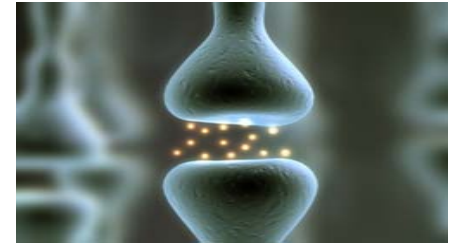


Low calorie foods lead to little activation in the brain reward centers



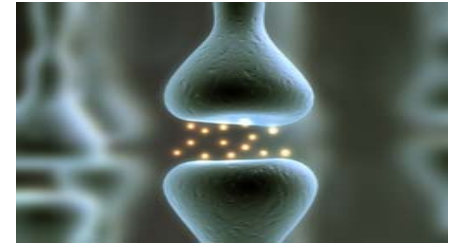
High calorie foods with high reward lead to significant activation in the brain reward centers

Neurotransmitters Involved in Food Intake Regulation



Stimulate Feeding (usually decrease energy expenditure)	• Anandamide • β-endorphin • Dynorphin • GABA • Ghrelin • Growth hormone releasing hormone • Neuropeptide Y • Norepinephrine
Inhibit Feeding (usually increase energy expenditure)	• Cholecystokinin (CCK) • Corticotropin-releasing factor (CRF) • Dopamine • Insulin • Leptin • Neurotensin • Thyrotropin-releasing hormone • Melanocyte-stimulating hormone

Are We Addicted to Sugar?



- Behavioral and neurochemical changes in the brain resemble those seen in after taking drugs
- Behavioral patterns after sugar-binging
 - Withdrawal, craving, and relapse
- Neurochemical changes after learning to binge on sugar
 - Binging on sugar triggered a surge of dopamine in the nucleus accumbens
 - Fewer dopamine receptors than before and more opioid receptors
 - Dopamine and opioid systems are involved in reward and motivation and are important in controlling wanting and liking something.

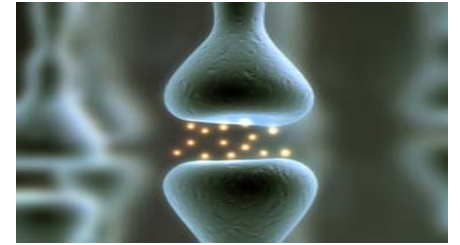


Are We Addicted to Sugar?



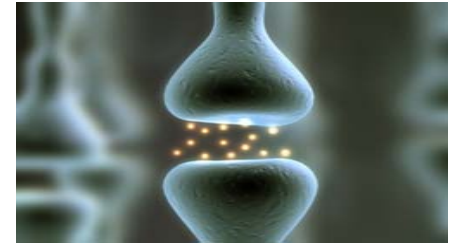
- The pleasure from the sweet taste of sugar-dense foods and beverages initially motivates over-consumption
- Sweet taste may be more rewarding and possibly more addictive than cocaine
- Choice between water sweetened with saccharin and intravenous cocaine - 94% of the animals preferred the saccharin
- Supra-normal stimulation of sweet receptors by sugar-rich diets could create a supra-normal reward signal in the brain
- Self-control mechanisms could be overridden and lead to addiction

Does Eating High Fat Stimulate Eating?

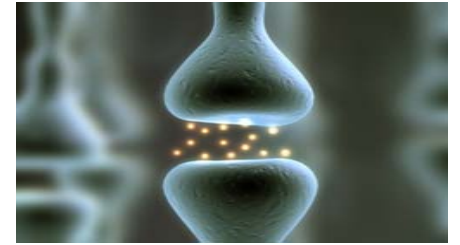


- **Animals fed a small HF meal early in the day ate more calories throughout the day compared to those fed a low fat meal**
- **TG levels increased 2-3 times in the HF group**
- **No changes in leptin or insulin levels**
- **Expression of orexigenic peptides were increased**
 - galanin
 - orexin

Does Eating High Fat Stimulate Eating?

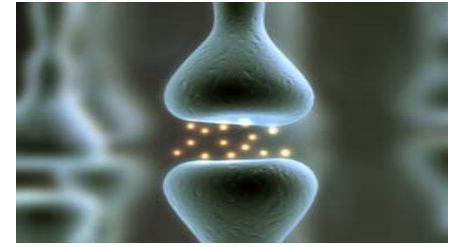


- **Maternal HF diet exposure lead to changes in rodent offspring following weaning**
- **In as little as two weeks of exposure to a HF diet, offspring increased**
 - intake of calories
 - body weight
 - a stronger drive for fat intake
 - brain peptides that are stimulated by fat
- **Brain systems involved in reward and palatability can each stimulate and be stimulated by the intake of diets rich in fat**



Brain Reward Circuitry & Stress Related Food Intake

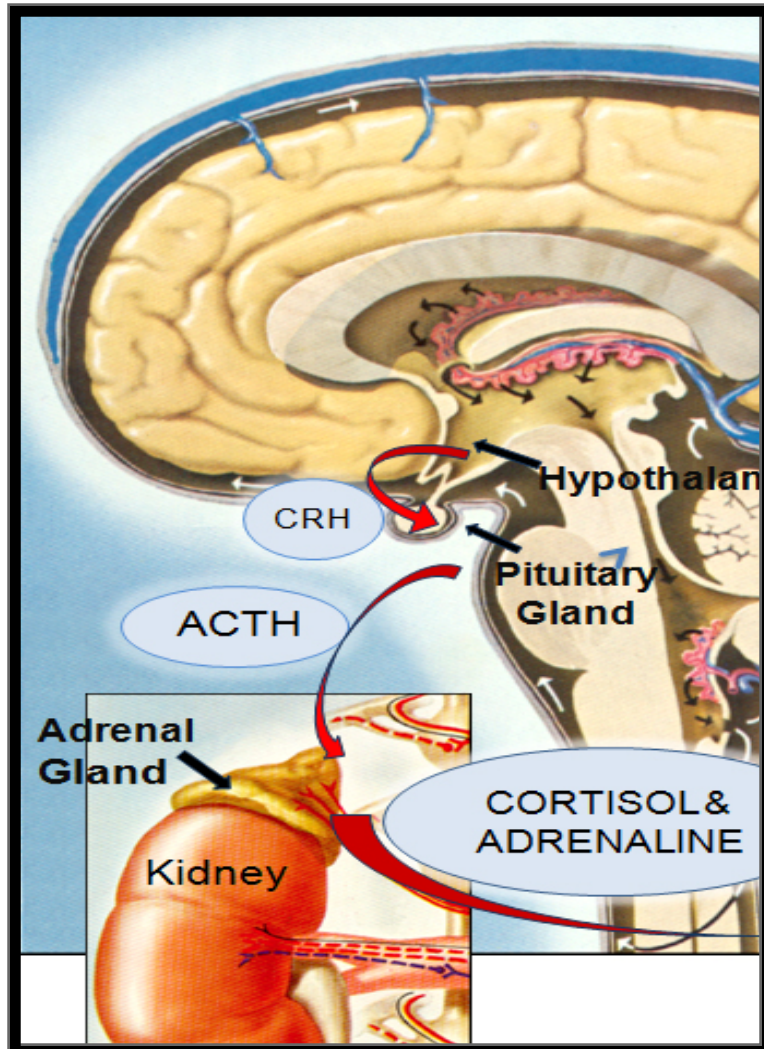
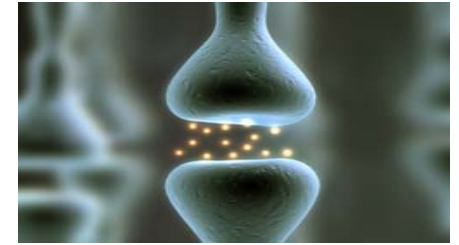
UCSF Department of Psychiatry - Reward Based Stress Eating Model



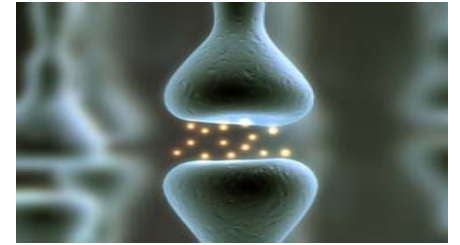
- Relationship between stress, eating, and potential neuroendocrine mediators
- Cortisol and the reward circuitry affect motivation for calorically dense food intake
- Reward value of food may be influenced by cortisol via neuroendocrine & peptide mediators



Stress, Opioids & HPA Axis

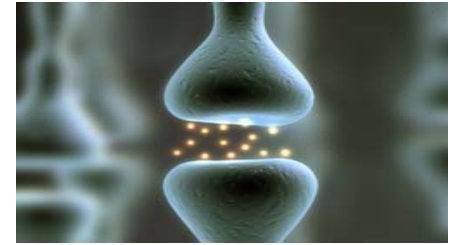


- Stress stimulates hypothalamic-pituitary-adrenal (HPA) axis activity
 - Intake of comfort foods reduces HPA axis activity
- Stress can stimulate endogenous release of opioids
- Opioids (+) excessive intake of palatable food
 - Suppress brain mechanisms responsible for terminating eating
- Sensation of pain reduced by sucrose
- Withdrawal symptoms from opiates relieved by sweets

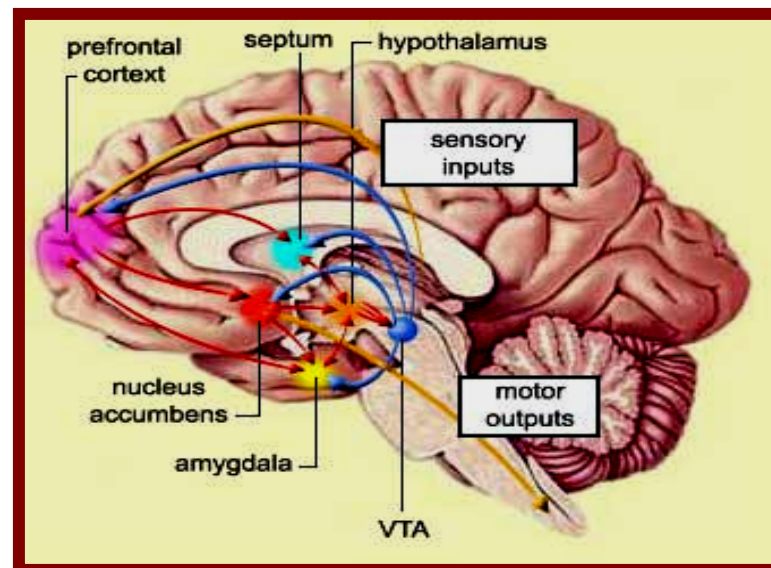


Treating Obesity by Changing the Brain

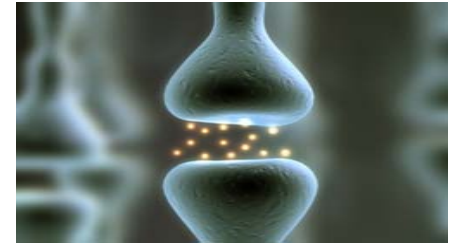
Strategies Aiming at Improving Dopamine Function



Comprehensive behaviorally based programs designed to “re-wire” the brains reward pathways can be an effective way to reduce food cravings and overeating.

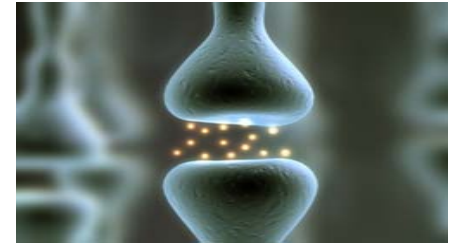


Treating Obesity by Changing the Brain



- **A variety of professionals along with a variety of formats might be incorporated**
- **Treatment should be individualized and incorporate a variety of cognitive and behavioral tools**
 - decrease the reward value of the food or behavior
 - increase the reward of the new positive behaviors
 - reduce the power of triggers
 - strengthen new neural circuits by learning new habits

Treating Obesity by Changing the Brain



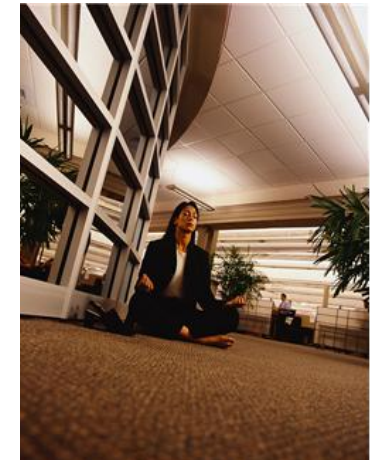
- Analysis of stimuli, situations, and cues that trigger out-of-control-eating is critical

- Initially avoiding certain triggers or foods may be necessary



- Stress management tools should be incorporated daily to weaken neural circuits that promote stress

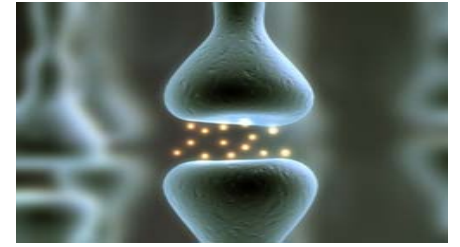
- Exercise
 - Mindfulness meditation



To weaken the strong neural circuits that favor overeating, cognitive and behavioral tools must be practiced repeatedly.



Questions & Answers



Thank You!