

**THE SCIENCE OF
FOOD
ADDICTION:
HOW OUR
BRAINS
RESPOND TO
PROCESSED
FOODS**

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A white icon on a teal background depicting a hamburger and a soft drink cup with a straw.

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DISCLOSURES

No relevant disclosures.

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OUTLINE OF THE PRESENTATION

Obesity and the challenges it poses

Factors that influence food intake

Brain systems that regulate the rewarding aspects of food

What is a “reward” vs. an “addiction”?

Food addiction as a measurable construct?

Minimizing and preventing addiction to sugar

3

WHY ARE SO MANY PEOPLE OVERWEIGHT OR OBESE?

4

FOOD ACQUISITION



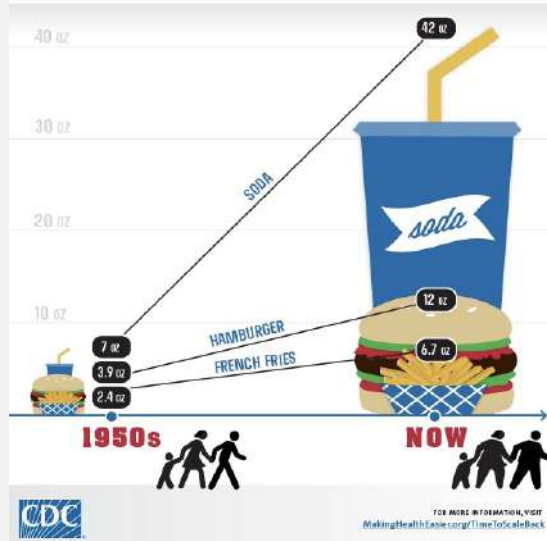
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FOOD ACQUISITION



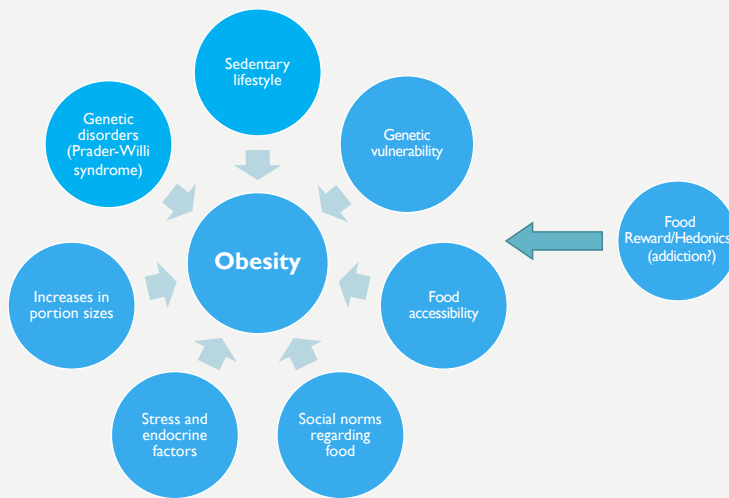
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PORTION SIZES



7

OBESITY IS AN ENDPOINT, WITH MULTIPLE CONTRIBUTING FACTORS



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WHAT IS A FOOD?

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Nutrition Facts

Serving Size 100 grams (100 grams)

Amount Per Serving
Calories 36 **Calories from Fat 4**
% Daily Value*

Total Fat 0g	1%
Saturated Fat 0g	0%
Trans Fat 0g	
Cholesterol 0mg	0%
Sodium 68mg	3%
Total Carbohydrates 8g	3%
Dietary Fiber 3g	13%
Sugars 5g	

Protein 1g
 Vitamin A 284% • Vitamin C 4%
 Calcium 4% • Iron 2%

*Percent Daily Values are based on a 2,000 calorie diet. Your daily values may be higher or lower depending on your calorie needs:

	Calories	2,000	2,500
Total Fat	Less than	65g	80g
Sat Fat	Less than	20g	25g
Cholesterol	Less than	300mg	300mg
Sodium	Less than	2,400mg	2,400mg
Total Carbohydrate		300g	375g
Fiber		25g	30g

Calories per gram:
 Fat 9 • Carbohydrate 4 • Protein 4

Ingredients: Whole Baby Carrots, Frozen, Unprepared



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Nutrition Facts
Serving Size 1 Pouch (14g)

Amount Per Serving
Calories 60 Calories from Fat 15

Total Fat 1.5g	% Daily Value*	2%
Saturated Fat 0.5g		3%
Trans Fat 0g		
Polyunsaturated Fat 0.5g		
Monounsaturated Fat 0g		
Cholesterol 0mg		0%
Sodium 75mg		3%
Total Carbohydrate 11g		4%
Dietary Fiber 0g		0%
Sugars 5g		
Protein less than 1g		

Vitamin A	6%	Vitamin C	0%	Calcium	0%	Iron	6%
Thiamin	6%	Riboflavin	6%	Niacin	6%	Vitamin B6	6%

* Percent Daily Values are based on a 2,000 calorie diet. Your daily values may be higher or lower depending on your calorie needs:

	Calories	2,000	2,500
Total Fat	Less than	65g	80g
Sat. Fat	Less than	20g	25g
Cholesterol	Less than	300mg	300mg
Sodium	Less than	2,400mg	2,400mg
Total Carbohydrate	Less than	300g	375g
Dietary Fiber	Less than	25g	38g

Calories per gram: Fat 9 • Carbohydrate 4 • Protein 4

INGREDIENTS: ENRICHED FLOUR (WHEAT FLOUR, NIACIN, REDUCED IRON, VITAMIN B1 (THIAMIN MONONITRATE), VITAMIN B2 (RIBOFLAVIN), FOLIC ACID), SUGAR, SOYBEAN AND PALM OIL (WITH TBHQ FOR FRESHNESS), CORN SYRUP, CONTAINS TWO PERCENT OR LESS OF MODIFIED CORN STARCH, SALT, WHEAT STARCH, DEXTROSE, BAKING SODA, GELATIN, CANOLA OIL, CORNSTARCH, CORN SYRUP SOLIDS, NATURAL AND ARTIFICIAL FLAVOR, BLUEBERRY JUICE CONCENTRATE, COLOR ADDED, GLYCERIN, CONFECTIONER'S GLAZE, CARNAUBA WAX, VITAMIN A PALMITATE, BLUE 2 LAKE, NIACINAMIDE, REDUCED IRON, VITAMIN C (ASCORBIC ACID), RED 40 LAKE, VITAMIN B6 (PYRIDOXINE HYDROCHLORIDE), VITAMIN B3 (NICOTINAMIDE), VITAMIN B1 (THIAMIN HYDROCHLORIDE), BLUE 1 LAKE, YELLOW 6, RED 40, YELLOW 5 LAKE, YELLOW 5, BLUE 1, SOY LECITHIN.

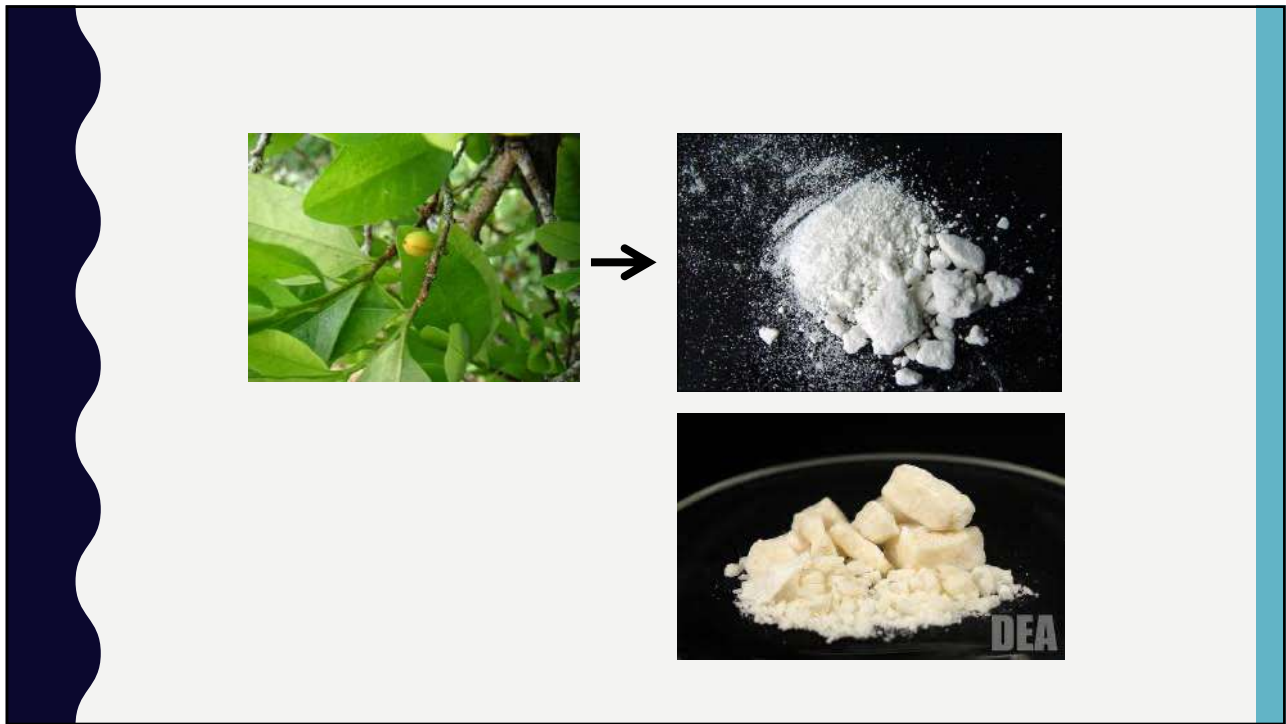
CONTAINS WHEAT AND SOY INGREDIENTS.



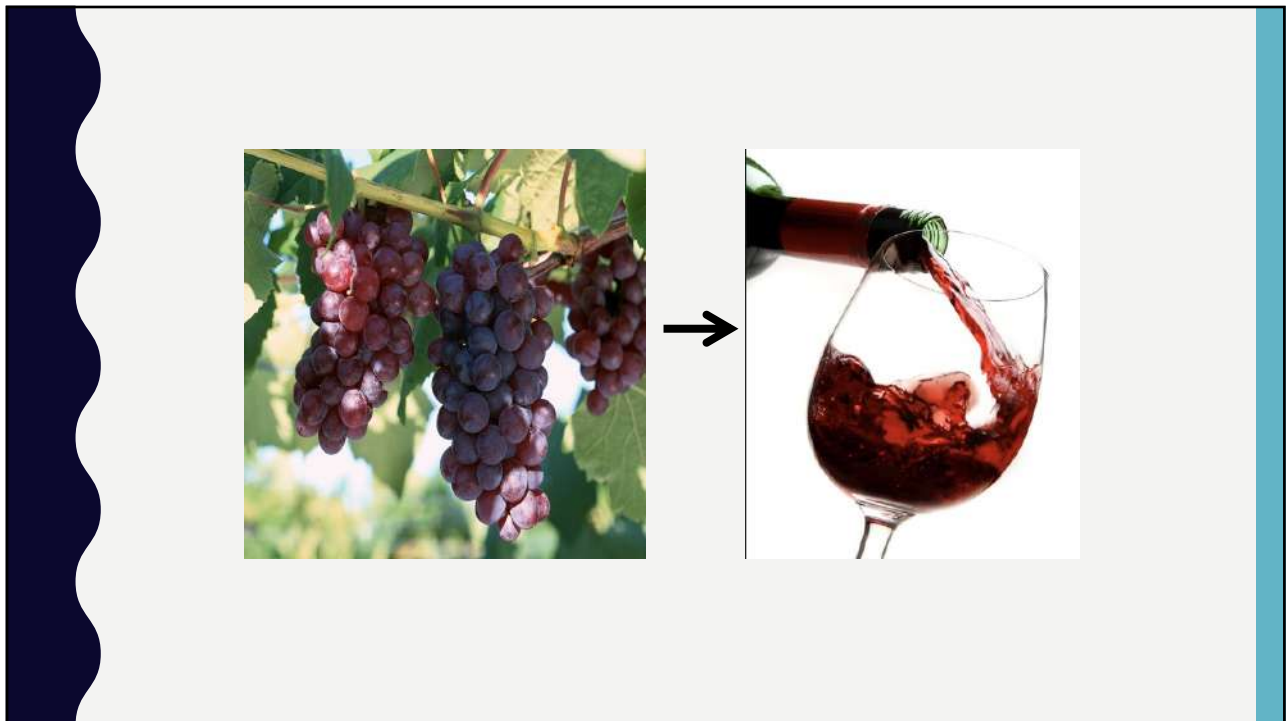
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WHAT'S THE BIG DEAL ABOUT PROCESSING?

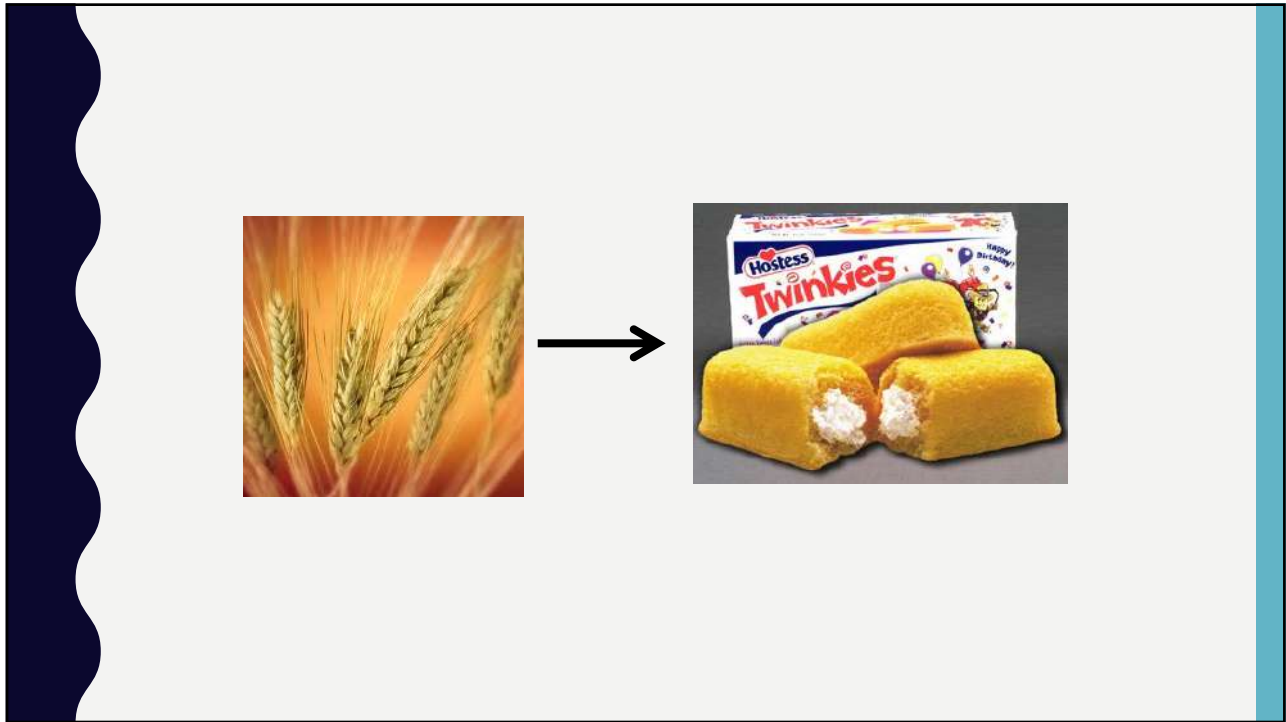
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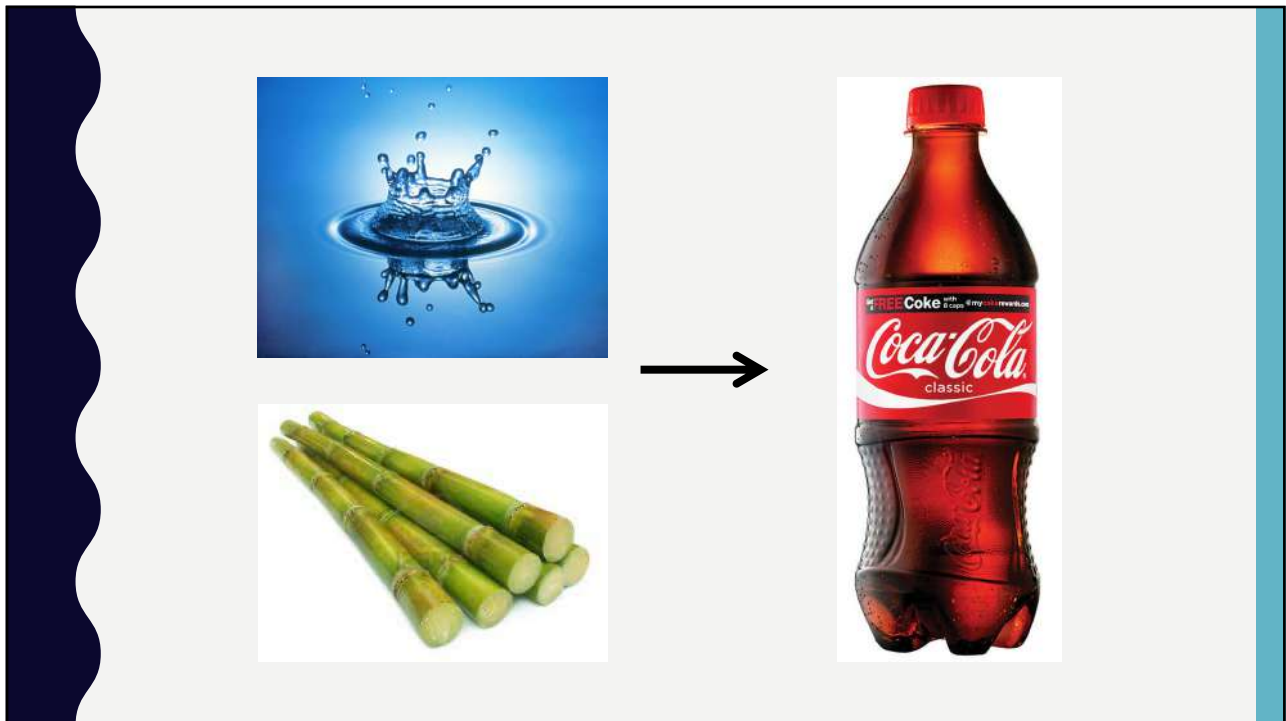
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WHAT IS ULTRA-PROCESSED FOOD?

Ultra-Processed food is defined as:

Formulations of several ingredients which, besides salt, sugar, oils, and fats, include food substances not used in culinary preparations, in particular, flavors, colors, sweeteners, emulsifiers and other additives used to imitate sensorial qualities of unprocessed or minimally processed foods and their culinary preparations or to disguise undesirable qualities of the final product.



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HOW MUCH ULTRA-PROCESSED FOOD DO WE EAT?

BMJ Open Ultra-processed foods and added sugars in the US diet: evidence from a nationally representative cross-sectional study

Euridice Martinez Steele,^{1,2} Larissa Galestri Baraldi,^{1,2} Maria Laura da Costa Louzada,^{1,2} Jean-Claude Moubarac,² Dariush Mozaffarian,³ Carlos Augusto Monteiro^{1,2}

Results: Ultra-processed foods comprised 57.9% of energy intake, and contributed 89.7% of the energy intake from added sugars. The content of added sugars in ultra-processed foods (21.1% of calories) was eightfold higher than in processed foods (2.4%) and fivefold higher than in unprocessed or minimally processed foods and processed culinary ingredients grouped together (3.7%). Both in unadjusted and adjusted models, each increase of 5 percentage points in proportional energy intake from ultra-processed foods increased the proportional energy intake from added sugars by 1 percentage point. Consumption of added sugars increased linearly across quintiles of ultra-processed food consumption: from 7.5% of total energy in the lowest quintile to 19.5% in the highest. A total of 82.1% of Americans in the highest quintile exceeded the recommended limit of 10% energy from added sugars, compared with 26.4% in the lowest.

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WHY SUGAR?

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ADDED SUGAR CONSUMPTION IN THE UNITED STATES

Usual Daily Intake of Added sugars

Table A40. Added sugars: Means, percentiles and standard errors of usual daily intake, 2007-2010

Age (Years)	N ¹	teaspoons ³								
		Mean (SE) ²	5% (SE)	10% (SE)	25% (SE)	50% (SE)	75% (SE)	90% (SE)	95% (SE)	
Males										
1-3	774	9.4 (0.31)	3.1 (0.17)	4.1 (0.19)	5.9 (0.24)	8.6 (0.29)	12.0 (0.39)	15.7 (0.51)	18.2 (0.62)	
4-8	1001	15.7 (0.56)	6.5 (0.31)	7.9 (0.34)	10.9 (0.41)	14.8 (0.53)	19.6 (0.70)	24.6 (0.91)	28.1 (1.07)	
9-13	850	21.5 (0.46)	5.9 (0.30)	8.0 (0.31)	12.5 (0.36)	19.3 (0.43)	27.9 (0.62)	37.9 (0.91)	44.8 (1.19)	
14-18	808	24.6 (0.74)	7.3 (0.39)	9.7 (0.43)	14.7 (0.53)	22.2 (0.69)	31.9 (0.95)	42.8 (1.36)	50.2 (1.73)	
19-30	1,113	23.5 (0.79)	6.8 (0.45)	9.1 (0.51)	14.0 (0.61)	21.2 (0.77)	30.5 (1.00)	40.9 (1.32)	48.0 (1.59)	
31-50	1,825	20.5 (0.61)	5.6 (0.28)	7.5 (0.31)	11.8 (0.40)	18.2 (0.55)	26.8 (0.83)	36.4 (1.18)	43.3 (1.45)	
51-70	1,773	16.5 (0.56)	3.9 (0.24)	5.4 (0.28)	8.9 (0.36)	14.4 (0.50)	21.8 (0.74)	30.3 (1.08)	36.2 (1.32)	
71+	912	14.0 (0.32)	2.9 (0.19)	4.3 (0.22)	7.3 (0.27)	12.0 (0.31)	18.5 (0.42)	26.1 (0.61)	31.6 (0.79)	
10+	5,623	19.4 (0.48)	4.7 (0.21)	6.6 (0.24)	10.7 (0.30)	17.1 (0.42)	25.7 (0.67)	35.4 (1.01)	42.2 (1.26)	
Females										
1-3	715	8.4 (0.27)	2.7 (0.17)	3.5 (0.20)	5.2 (0.23)	7.7 (0.28)	10.8 (0.33)	14.3 (0.41)	16.7 (0.45)	
4-8	894	14.3 (0.37)	5.7 (0.27)	7.1 (0.30)	9.7 (0.33)	13.4 (0.37)	17.8 (0.44)	22.6 (0.57)	25.9 (0.68)	
9-13	867	17.8 (0.44)	6.0 (0.29)	7.7 (0.31)	11.2 (0.35)	16.3 (0.42)	22.7 (0.55)	29.8 (0.77)	34.7 (0.96)	
14-18	727	17.5 (0.54)	5.8 (0.34)	7.5 (0.37)	10.9 (0.43)	16.0 (0.52)	22.4 (0.65)	29.5 (0.90)	34.2 (1.10)	
19-30	1,160	16.7 (0.61)	5.4 (0.30)	7.0 (0.36)	10.4 (0.44)	15.2 (0.57)	21.4 (0.77)	28.3 (1.03)	33.1 (1.22)	
31-50	1,994	15.1 (0.43)	4.6 (0.24)	6.1 (0.26)	9.2 (0.30)	13.7 (0.39)	19.5 (0.56)	25.9 (0.79)	30.4 (0.95)	
51-70	1,740	12.5 (0.28)	3.5 (0.18)	4.7 (0.19)	7.3 (0.22)	11.1 (0.27)	16.2 (0.38)	22.0 (0.54)	26.0 (0.69)	
71+	964	10.9 (0.31)	2.8 (0.17)	3.8 (0.19)	6.1 (0.22)	9.6 (0.28)	14.2 (0.40)	19.5 (0.57)	23.4 (0.73)	
10+	5,858	14.7 (0.35)	4.0 (0.17)	5.3 (0.18)	8.3 (0.20)	12.7 (0.26)	18.4 (0.42)	24.9 (0.65)	29.4 (0.82)	
All 1+	18,117	16.8 (0.28)	4.4 (0.13)	5.9 (0.14)	9.3 (0.17)	14.5 (0.23)	21.7 (0.37)	30.4 (0.62)	36.7 (0.83)	

1. Number of persons in sample
 2. Standard errors (df=32)
 3. One teaspoon of added sugars = the same amount of total sugars as 1 teaspoon (4 g) of table sugar (sucrose)

Added sugar, as measured here, includes: white, brown and raw sugar, syrup, honey, and molasses that were eaten separately or used as ingredients in processed or prepared foods such as breads, cakes, soft drinks, jams, and ice cream.

The National Institutes of Health, retrieved 2019

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Circulation
ORIGINAL RESEARCH ARTICLE
Long-Term Consumption of Sugar-Sweetened and Artificially Sweetened Beverages and Risk of Mortality in US Adults

BACKGROUND: Whether consumption of sugar-sweetened beverages (SSBs) or artificially sweetened beverages (ASBs) is associated with risk of mortality is of public health interest.

METHODS: We examined associations between consumption of SSBs and ASBs with risk of total and cause-specific mortality among 37 716 men from the Health Professionals Follow-up study (from 1986 to 2014) and 80 647 women from the Nurses' Health study (from 1980 to 2014) who were free from chronic diseases at baseline. Cox proportional hazards regression was used to estimate hazard ratios and 95% confidence intervals.

RESULTS: We documented 36 436 deaths (7896 cardiovascular disease [CVD] and 12 380 cancer deaths) during 3 415 564 person-years of follow-up. After adjusting for major diet and lifestyle factors, consumption of SSBs was associated with a higher risk of total mortality; pooled hazard ratios (95% confidence intervals) across categories (<1/ mo, 1–4/mo, 5–6/week, 1–2/d, and ≥2/d) were 1.00 (reference), 1.01 (0.98, 1.04), 1.06 (1.03, 1.09), 1.14 (1.09, 1.19), and 1.21 (1.13, 1.28), P trend <0.0001. The association was observed for CVD mortality (hazard ratio comparing extreme categories was 1.31 [95% confidence interval, 1.15, 1.50], P trend <0.0001) and cancer mortality (1.16 [1.04, 1.29], P trend = 0.0004). ASBs were associated with total and CVD mortality in the highest intake category only; pooled hazard ratios (95% confidence interval) across categories were 1.00 (reference), 0.96 (0.93, 0.99), 0.97 (0.95, 1.00), 0.98 (0.94, 1.03), and 1.04 (1.02, 1.12), P trend = 0.01 for total mortality and 1.00 (reference), 0.93 (0.87, 1.00), 0.95 (0.89, 1.00), 1.02 (0.94, 1.12), and 1.13 (1.02, 1.25), P trend = 0.02 for CVD mortality. In cohort-specific analysis, ASBs were associated with mortality in HPS (Nurses' Health Study) but not in HPPS (Health Professionals Follow-up Study) (P interaction, 0.01). ASBs were not associated with cancer mortality in either cohort.

CONCLUSIONS: Consumption of SSBs was positively associated with mortality primarily through CVD mortality and showed a graded association with dose. The positive association between high intake levels of ASBs and total and CVD mortality observed among women requires further confirmation.

Key Words: *alcoholic drink; artificial sweetener; beverage; cardiovascular death; cardiovascular mortality; cancer; mortality; sugar-sweetened beverage*

Introduction of Funding: www.ajph.org

© 2021 American Heart Association. <https://www.ahajournals.org/journal/circ>

Circulation 00:0(18):00–00 DOI: 10.1161/CIRCULATION.119.527461

www.ahajournals.org

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HOW MUCH SUGAR IS TOO MUCH SUGAR?

The 2015-2020 Dietary Guidelines for Americans recommend **NO MORE** than 10% of daily caloric intake come from added sugar

If you are on a 2,000 calorie diet, no more of 200 of those calories should come from added sugars (50 grams or 12 teaspoons)

“Added Sugars” DO NOT include foods and beverages that **NATURALLY** contain sugar, such as fruit, vegetables and milk

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16 OZ STARBUCKS CARAMEL FRAPPACCINO

64 g of sugar
(128% of DV)



23

CLASSIC CINNABON ROLL



59 g of sugar (109% of DV)

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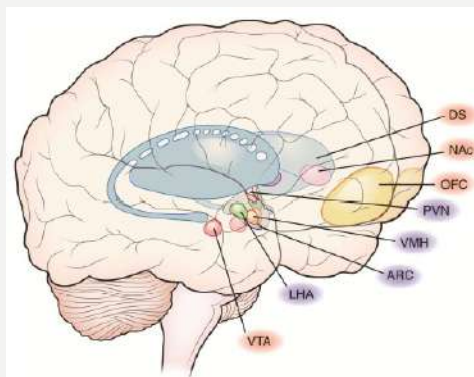
DANNON “FRUIT ON THE BOTTOM” YOGURT



24 g of sugar (48% of DV)

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WHAT HAPPENS IN REWARD-RELATED PARTS OF THE BRAIN WHEN WE EAT?



- Drugs that are abused act on brain systems that evolved to reinforce natural behaviors (e.g., sex, feeding).
- There are overlaps in the brain pathways activated by palatable foods and drugs of abuse.

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TWO KINDS OF HUNGER



hun·ger
həNGgər/
noun: **hunger**

- a feeling of discomfort or weakness caused by lack of food, coupled with the desire to eat.
- *Negative reinforcement*



he·don·ic
hē dānik/
adjective: **hedonic**

- relating to or considered in terms of pleasant sensations.
- *Positive reinforcement*

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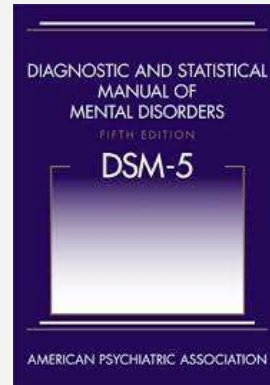
ARE WE ADDICTED TO SUGAR AND HIGHLY PROCESSED FOODS?

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HOW DO WE DEFINE ADDICTION?

The DSM-5 describes a substance use disorder as...

“a cluster of cognitive, behavioral, and physiological symptoms indicating that the individual continues using the substance despite significant substance-related problems.”



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DSM-5 CRITERIA FOR SUBSTANCE USE DISORDERS

Criterion A: Impaired Control

- **Binge** - Taking the substance in larger amounts or over a longer period than originally intended
- **Desire to limit or quit** - Persistent desire to cut down or regulate substance use and may report multiple unsuccessful efforts to decrease or discontinue use
- **Time** - A great deal of time is spent obtaining, using, or recovering from the effects of the substance
- **Craving** - an intense desire or urge for the drug

Criterion B: Social Impairment

- Recurrent substance use may result in a **failure to fulfill major role obligations** at work, school, or home
- Substance **use is continued despite** having recurrent **social or interpersonal problems** caused or exacerbated by the effects of the substance
- Important social, occupational, or recreational **activities may be given up or reduced**

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DSM-5 CRITERIA FOR SUBSTANCE USE DISORDERS

Criterion C: Risky Use

- Recurrent substance use in situations in which it is physically hazardous
- The individual may continue substance use despite knowledge of having a persistent or recurrent physical or psychological problem that is likely to have been caused or exacerbated by the substance

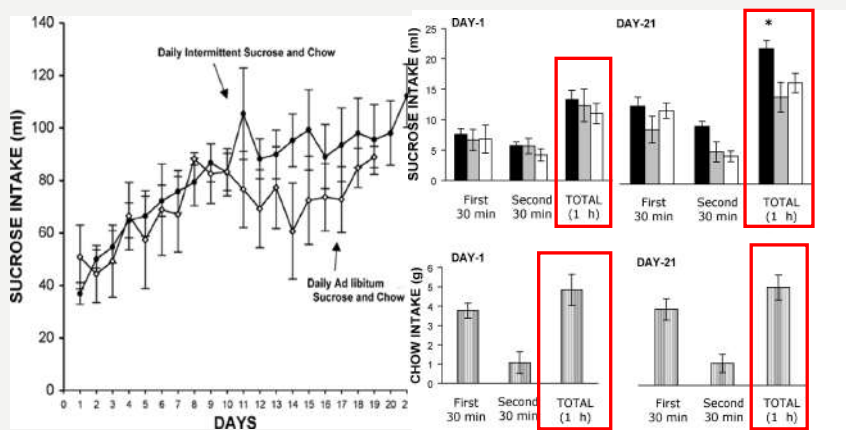
Criterion D: Pharmacological

- Tolerance - requiring an increased dose of the substance to achieve the desired effect or a markedly reduced effect with the usual dose
- Withdrawal - occurs when blood or tissue concentrations of a substance decline in an individual who had maintained prolonged heavy use of the substance

Note: The DSM-5 indicates that "for certain classes [of drugs] some symptoms are less salient, and in a few instances not all symptoms apply (e.g., withdrawal symptoms are not specified for inhalant use disorder).

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BINGEING/TOLERANCE



Rada, Avena, & Hoebel (2005)

Daily Intermittent Sucrose and Chow
 Sucrose Twice
 Daily Ad libitum Sucrose and Chow

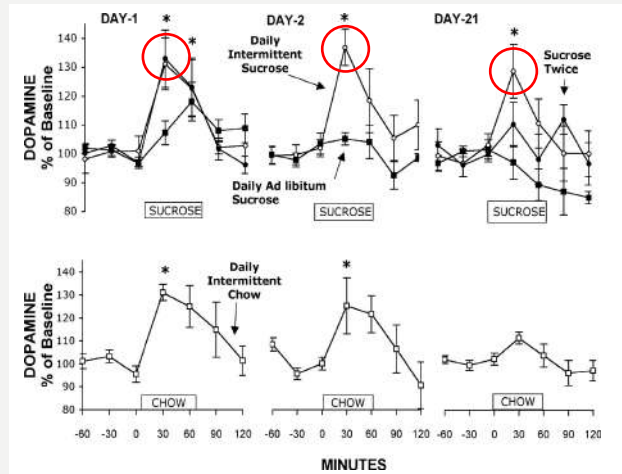
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ALTERATIONS IN BRAIN DOPAMINE LEVELS

Increases in dopamine (DA) release wane with repeated exposure to chow; however, these increases continue in response to sugar.

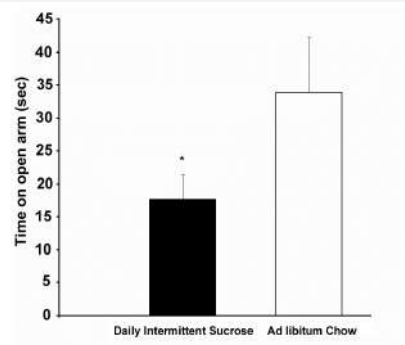
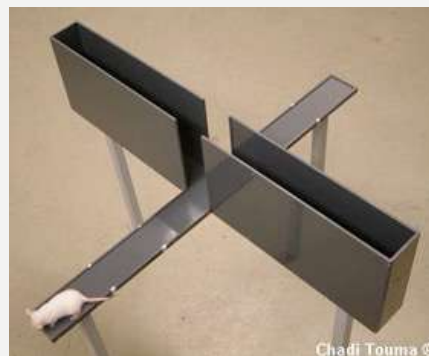
This effect is only seen in sugar-bingeing rats, not control rats.

Rats are not overweight.



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WITHDRAWAL

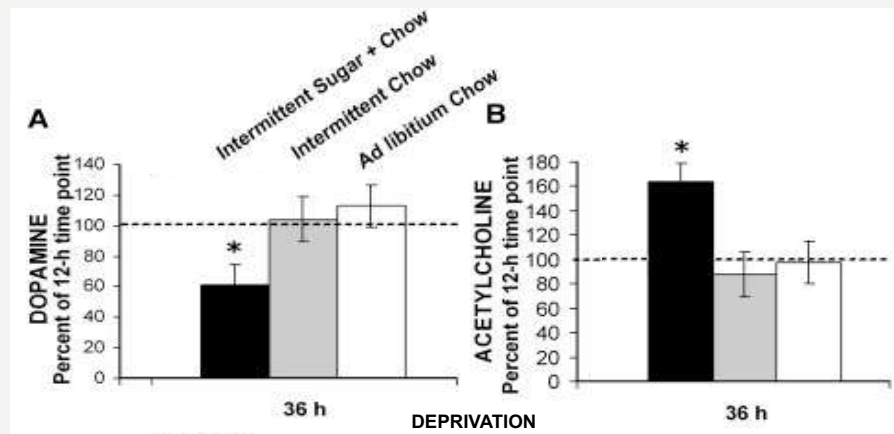


- Sugar bingeing rats show signs of anxiety when given an opioid antagonist (naloxone) or when fasted from all food for 36 h.
- Opioid systems are perturbed by overeating, as revealed by increased mu-opioid receptor binding in these animals prior to withdrawal.

Colantuoni et al. (2001); Avena, Bocarsly, et al. (2008)

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NEURAL CORRELATES OF WITHDRAWAL



Withdrawal from sugar is concurrent with decreases in dopamine and increases in acetylcholine levels in the nucleus accumbens, similar to the pattern seen during drug withdrawal.

Avena, Bocarsly, et al. (2008)

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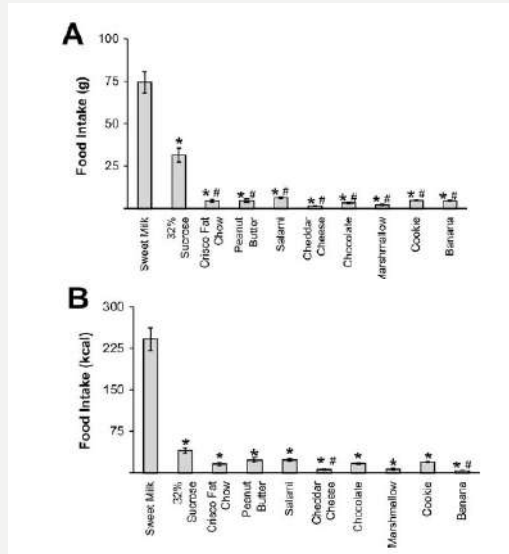
VARIETY AND FOOD CONSUMPTION



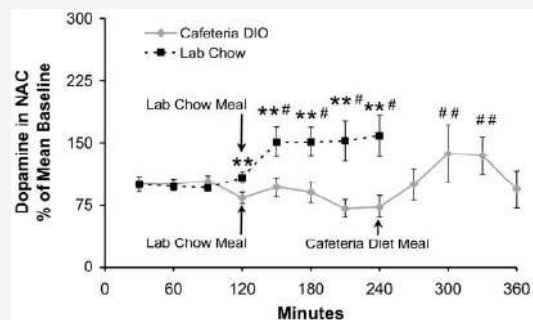
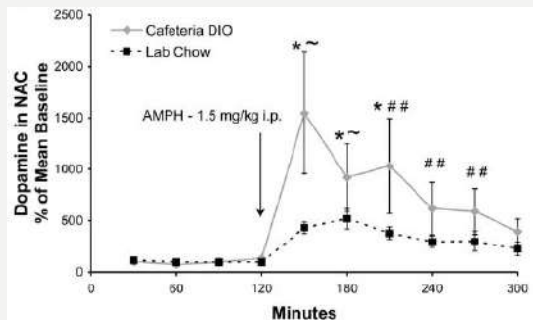
- A number of studies have also shown that when we have a variety of foods available to us, we tend to eat more (*Rolls et al., 1981; McCrory et al., 1999; Moore et al., 2013*)
- One possible reason for this is termed “**sensory-specific satiety**” (*Remick et al., 2009*), which means that as people eat the same food item, they tend to consider it less pleasant and consume less of it. If a different food item is introduced, this process can essentially begin all over again, whereas if no new food was available, the person may have stopped eating after that first food became less pleasant.

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CAFETERIA-STYLE DIET



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Rats with access to a cafeteria-style diet are hyper-responsive to amphetamine in terms of dopamine release.

However, they do not respond to a lab chow meal. These rats need “junk food” to release accumbens dopamine.

Geiger et al. (2009)

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MEASURING “FOOD ADDICTION” IN CLINICAL SAMPLES

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YALE FOOD ADDICTION SCALE

- ❖ The Yale Food Addiction Scale (YFAS) was created to study food addiction in clinical samples by applying the DSM-IV criteria for substance dependence to eating behaviors.
- ❖ Questions are answered using a Likert-type scale (i.e., Never, Once a month, 2-4 times a month, 2-3 times a week, 4 or more times or daily).

Sample items:

“I find myself continuing to consume certain foods even though I am no longer hungry”
“I eat to the point where I feel physically ill”
“I find that when I start eating certain foods, I end up eating much more than planned”

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SELECT FINDINGS FROM STUDIES USING THE YFAS

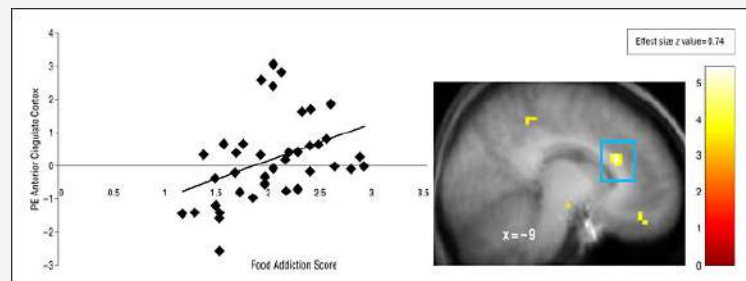
- In a group of about 200 undergraduate students, 11.4% met the criteria for food addiction (Gearhardt et al., 2009).
- Among 72 obese participants, 25% met the criteria for food addiction (Davis et al., 2011).
- Two studies assessing food addiction symptoms in obese individuals with binge eating disorder reported that 42-57% met the criteria for food addiction (Gearhardt et al., 2012; 2013).

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Neural Correlates of Food Addiction

Ashley N. Gearhardt, MS, MPhil; Sonja Yokum, PhD; Patrick T. Orr, MS, MPhil; Eric Stice, PhD; William R. Corbin, PhD; Kelly D. Brownell, PhD

(REPRINTED) ARCH GEN PSYCHIATRY PUBLISHED ONLINE APRIL 4, 2011 WWW.ARCHGENPSYCHIATRY.COM



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WHICH FOODS ARE ADDICTIVE?

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MOST PROBLEMATIC FOODS

Average food ratings based on 7-point scale
(1= not problematic at all, 7 = extremely problematic)

MOST ADDICTIVE	LEAST ADDICTIVE
PIZZA Rating: 4.01	CUCUMBER (NO DIP) Rating: 1.53
CHOCOLATE Rating: 3.73	CARROTS Rating: 1.60
CHIPS Rating: 3.73	BEANS (NO SAUCE) Rating: 1.63
COOKIE Rating: 3.71	APPLE Rating: 1.66
ICE CREAM Rating: 3.68	BROWN RICE (PLAIN, NO SAUCE) Rating: 1.74

Source: University of Michigan

THE HUFFINGTON POST

Other Problematic Foods

- French Fries
- Cheeseburger
- Soda (Not Diet)
- Cake
- Cheese
- Bacon
- Fried Chicken
- Rolls (Plain)
- Popcorn (Buttered)
- Breakfast Cereal

Factors Associated With Problematic Eating

Large Positive Predictors

- Processing
- Fat
- Glycemic Load

Small-to-Moderate Positive Predictors

- BMI
- YFAS Symptom Count

Schulte et al. (2015)

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**HOW CAN WE MITIGATE
FOOD ADDICTION?**

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**WE NEED PREVENTION
THROUGH EDUCATION**

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FIRST 1000 DAYS OF LIFE ARE CRITICAL WINDOW OF OPPORTUNITY TO PROMOTE HEALTH AND WELLNESS VIA PROPER NUTRITION



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IS IT REALLY LIKE A DRUG ADDICTION?

WHAT ABOUT THE LOSS OF CONTROL THAT WE SEE IN DRUG ADDICTION?

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The “loss of control” does not have to be “extreme” as we typically think of it.

It is in many ways dictated by social norms.

The most common addict in our society is a smoker

- likely a fully functioning individual
- little noticeable intoxication
- withdrawal syndrome is not physically life-threatening
- However, because of smoking’s health-related complications, it is the number 1 cause of preventable death in the U.S.

Addiction to highly-palatable, processed foods may resemble nicotine addiction

SUMMARY

Table 1
Common dietary obesity and DSM IV criteria for addictive disorders. Three of the 7 criteria need to be met for diagnosis.

DSM IV criteria	Animal model	Humans	Evidence
1 Tolerance	✓	✓	Food binging, hyperphagia, delayed satiety
2 Withdrawal	✓	✓	Hypofunctioning brain dopamine system, opiate withdrawal-like symptoms, psychological and physical dependence
3 Use more than intended in longer periods of time	✓	✓	Hyperphagia, change of eating patterns and meal frequency (snacking), negative experience triggers, cue-induced behaviors, larger portion size, proximity to food sources, lower cost of high-energy foods
4 Attempts to cut back		✓	Dietary restraint
5 Spend time in the pursuit/use/recovery of the substance	✓	✓	Participation in weight loss programs, Anticipation and preoccupation, cravings, food thoughts, increased brain dopamine levels in response to anticipation and consumption, negative experience triggers, cue-induced behaviors, change of eating patterns and meal frequency, increase in habitual (vs. physical) hunger
6 Missed important activities	✓	✓	Social & occupational activities given up, social marginalization, psychological distress, discrimination
7 Persistent behavior in spite of knowledge of consequences	✓	✓	Lack of diet compliance, failure to achieve long-term weight loss, hyperphagia resistant to aversive cues

Allen et al. (2012)

THANK YOU!

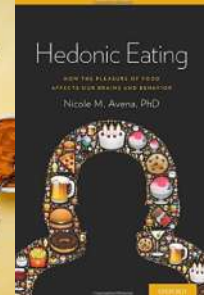
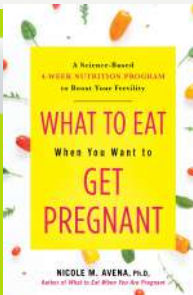
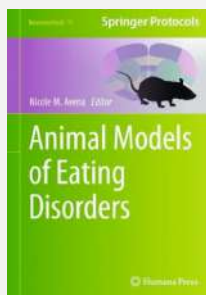
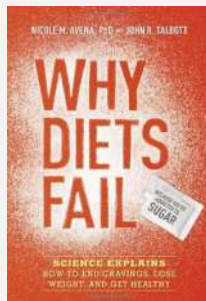


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