Foods that Fill

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Objectives

- Define satiety and satiation
- Summarize the satiety cascade
- Describe potential dietary interventions aimed at improving satiety

Definitions

- Satiation *(adjective): Filled to satiety*
  - Complex processes that lead to inhibition of the desire to eat during an eating event
  - Mechanism that determines meal size
  - Influenced by environment, sensory, hunger, social situations
- Satiety *(noun): State of being full*
  - Inhibitory mechanism that occurs after eating that delays feeling hungry again

"Definition of SATIATE." Accessed November 8, 2017. https://www.merriam-webster.com/dictionary/satiate.
"Definition of SATIETY." Accessed November 8, 2017. https://www.merriam-webster.com/dictionary/satiety.

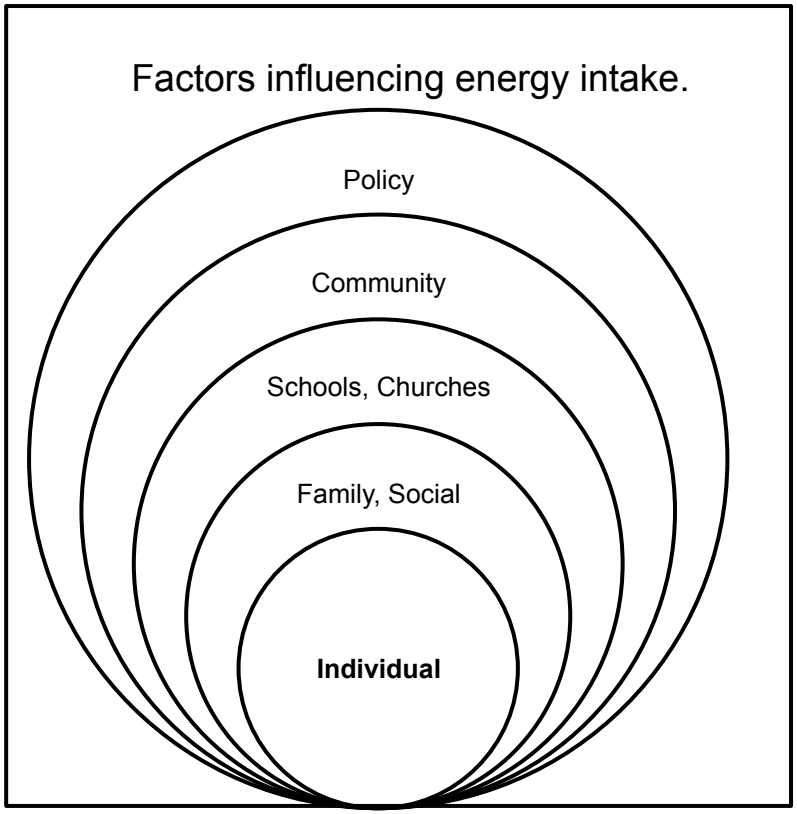
Satiety & Energy Intake

- Animal Models:
  - Energy intake is adjusted based on previous meals
  - Evidence that energy needs matched with energy intake when food is readily available
- Real Life Models:
  - Meal times related more to cultural and social norms
  - Presence of obesity epidemic is evidence that other factors may override inhibitory mechanisms

Tremblay, Angelo, and France Bellisle. “Nutrients, Satiety, and Control of Energy Intake.” *Applied Physiology, Nutrition, and Metabolism* 40, no. 10 (October 2015): 971–79. https://doi.org/10.1139/apnm-2014-0549.

Energy Intake in Real Life

- Meal times related more to cultural and social norms
- Presence of obesity epidemic is evidence that other factors may override inhibitory mechanisms



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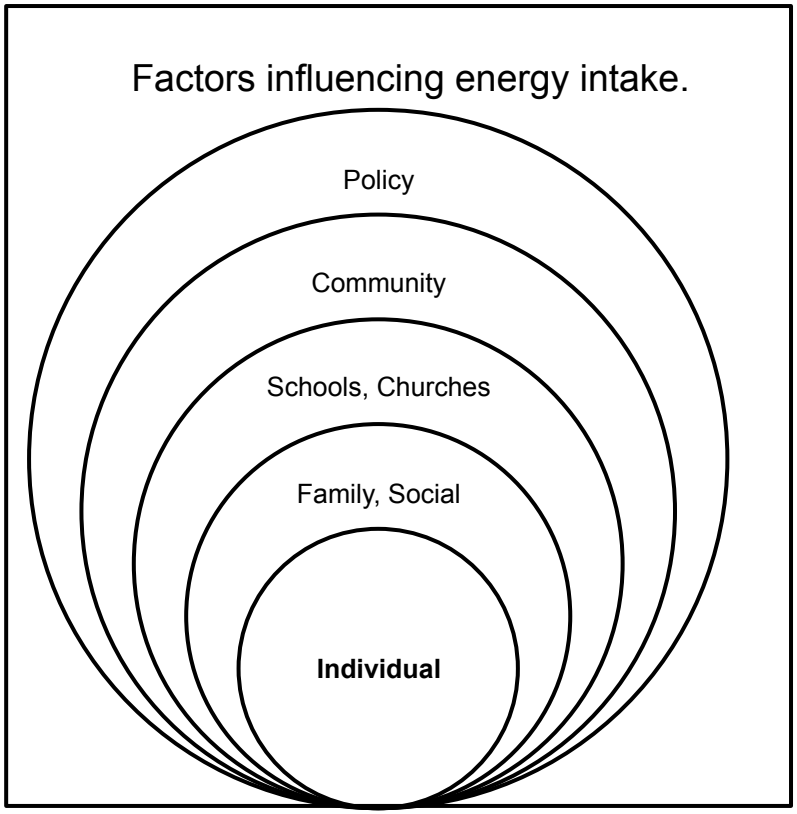
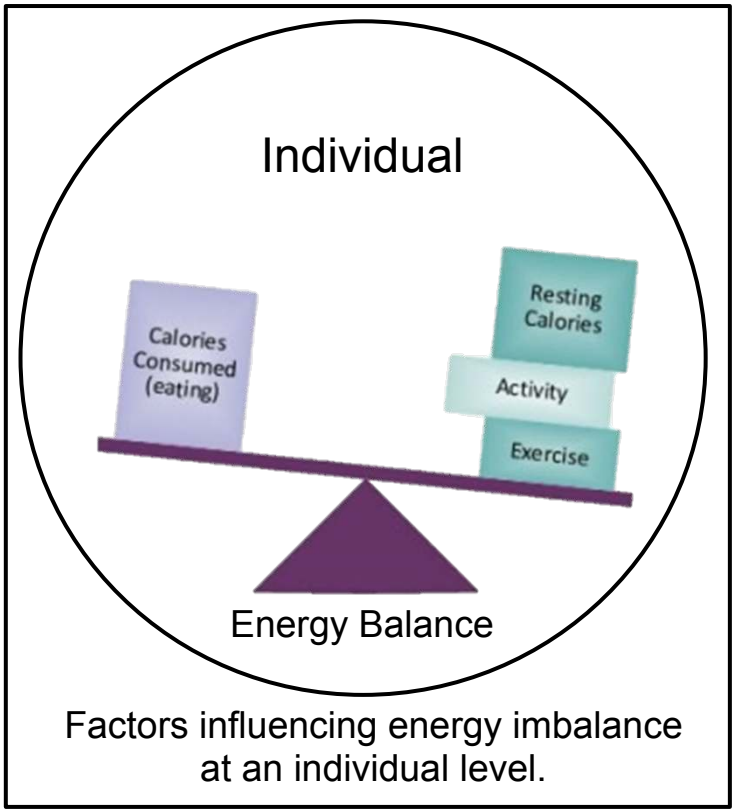
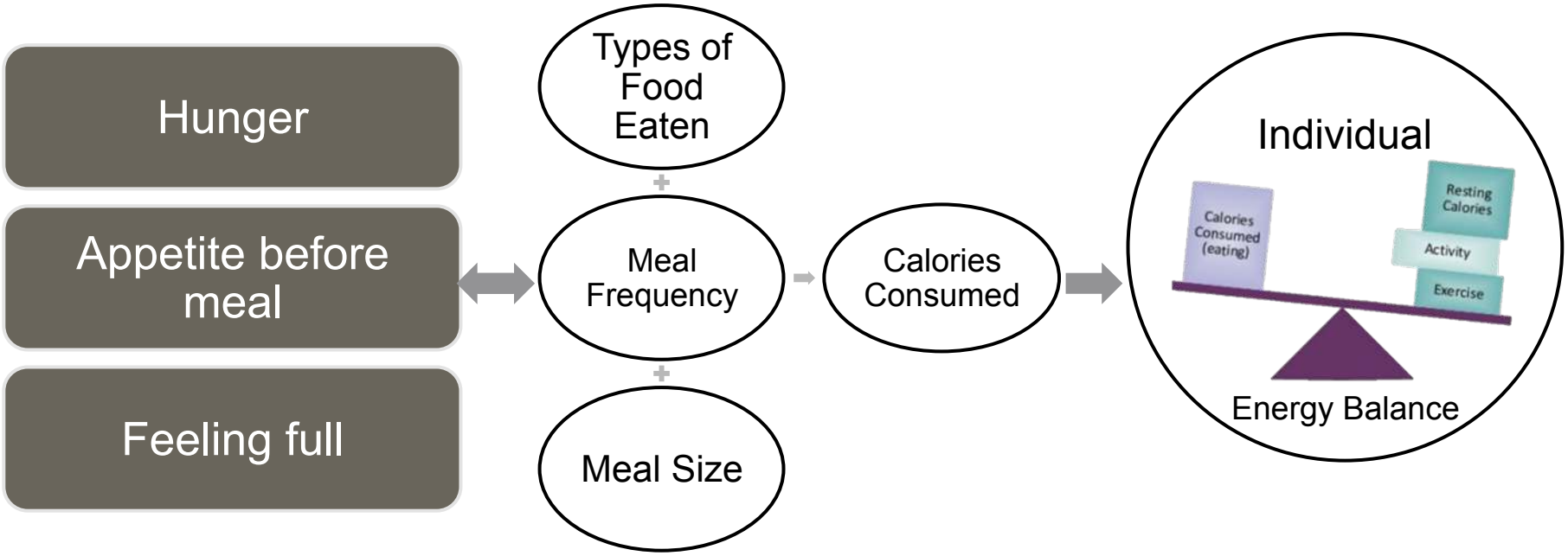




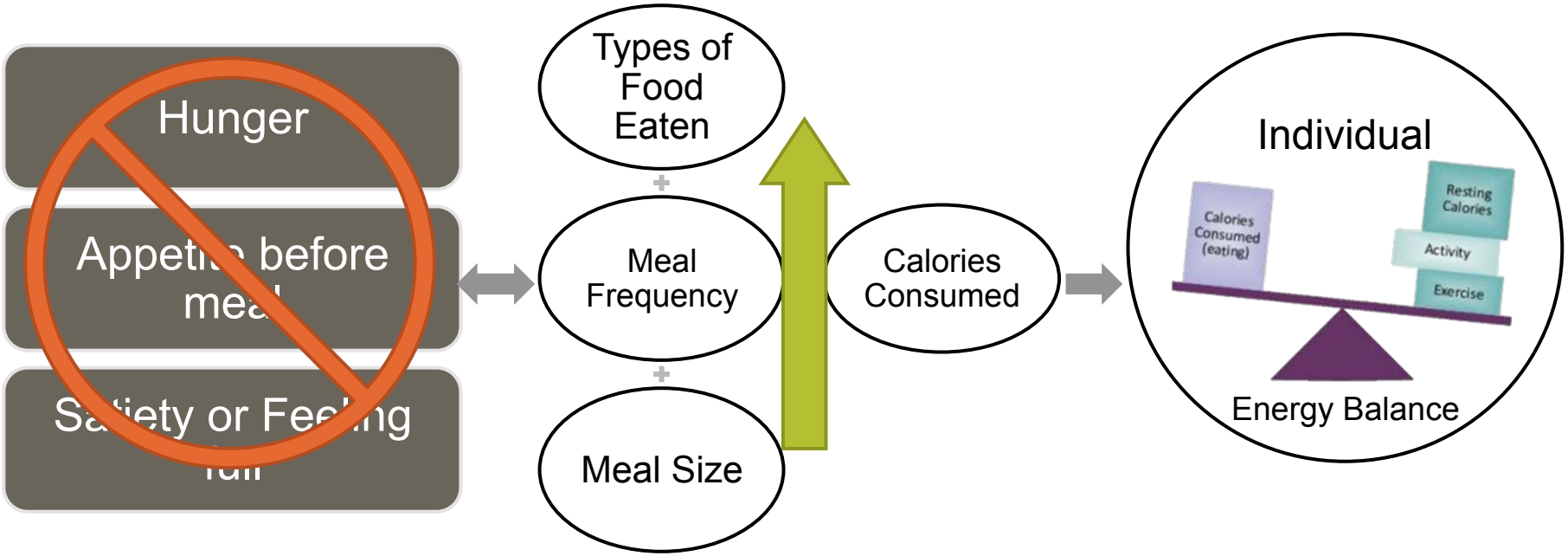
Factors influencing energy imbalance at an individual level.

Satiety, Satiation and Energy Imbalance



Satiety, Satiation and Energy Imbalance

- Decreased feelings of satiation in response to eating may contribute to metabolic syndrome or obesity



Satiety Cascade

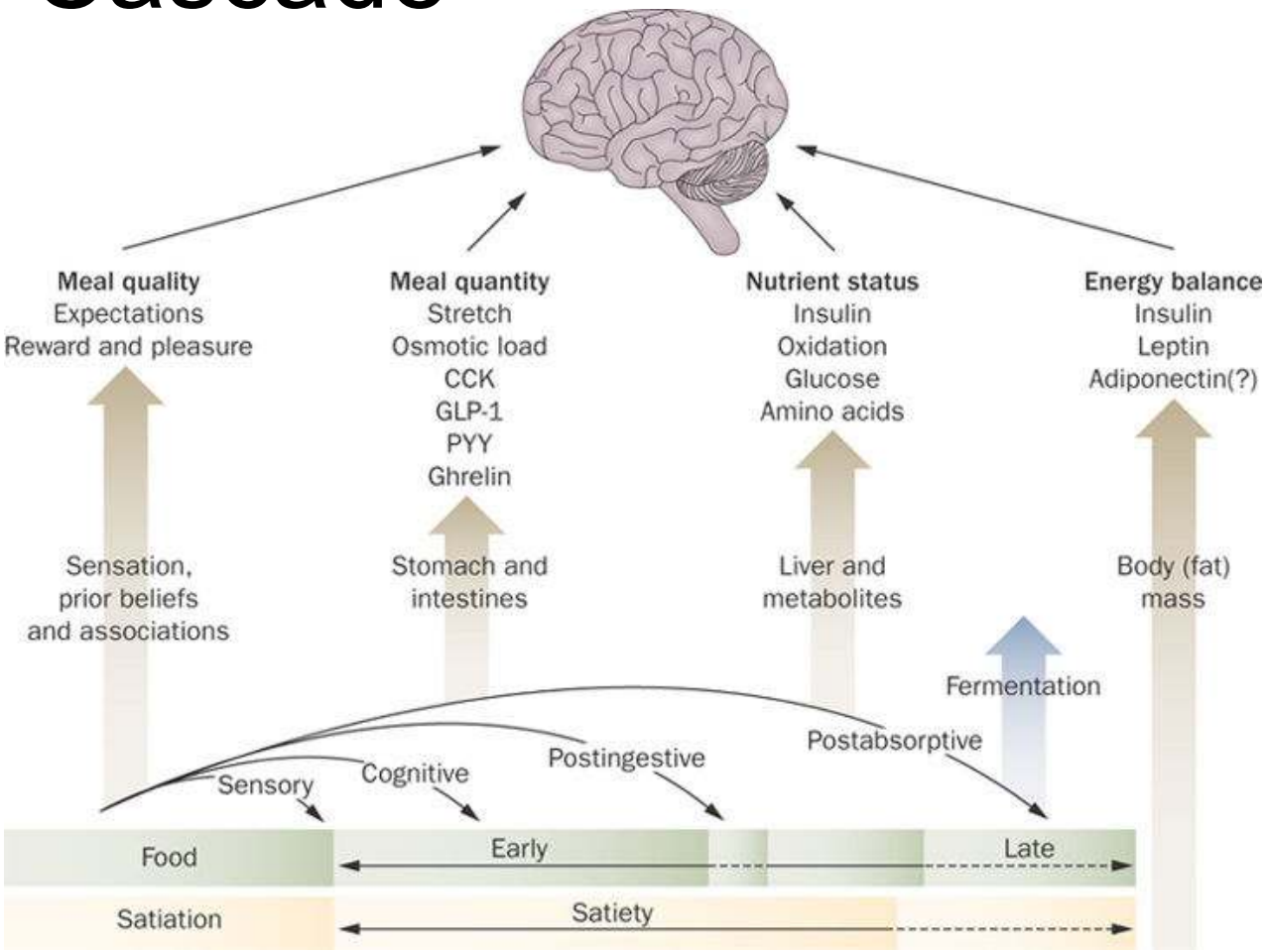
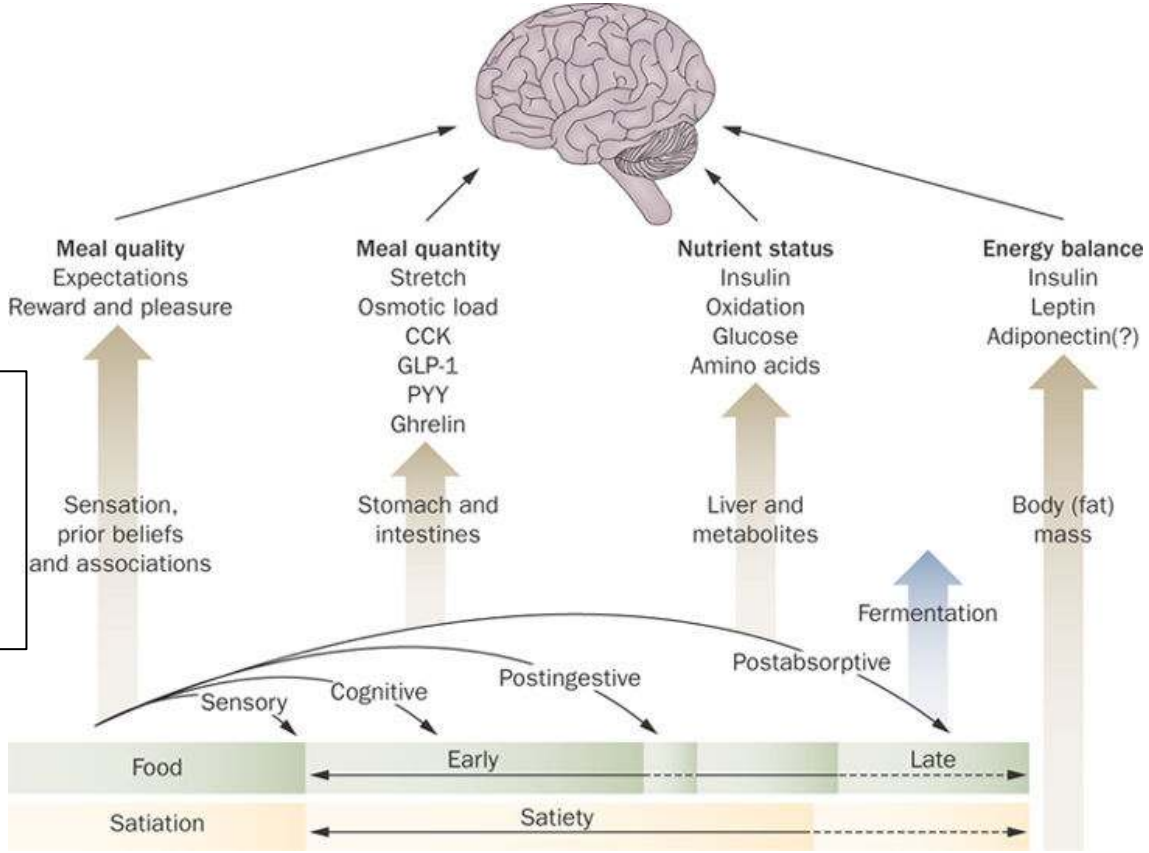


Fig. 1. The Satiety Cascade. CCK, cholecystokinin; GLP-1, glucagon-like peptide-1; PYY, peptide YY. (From Appl. Physiol. Nutr. Metab. Vol. 40, 2015)

Satiety Cascade

Sensory Factors: Stimulate intake at start of eating



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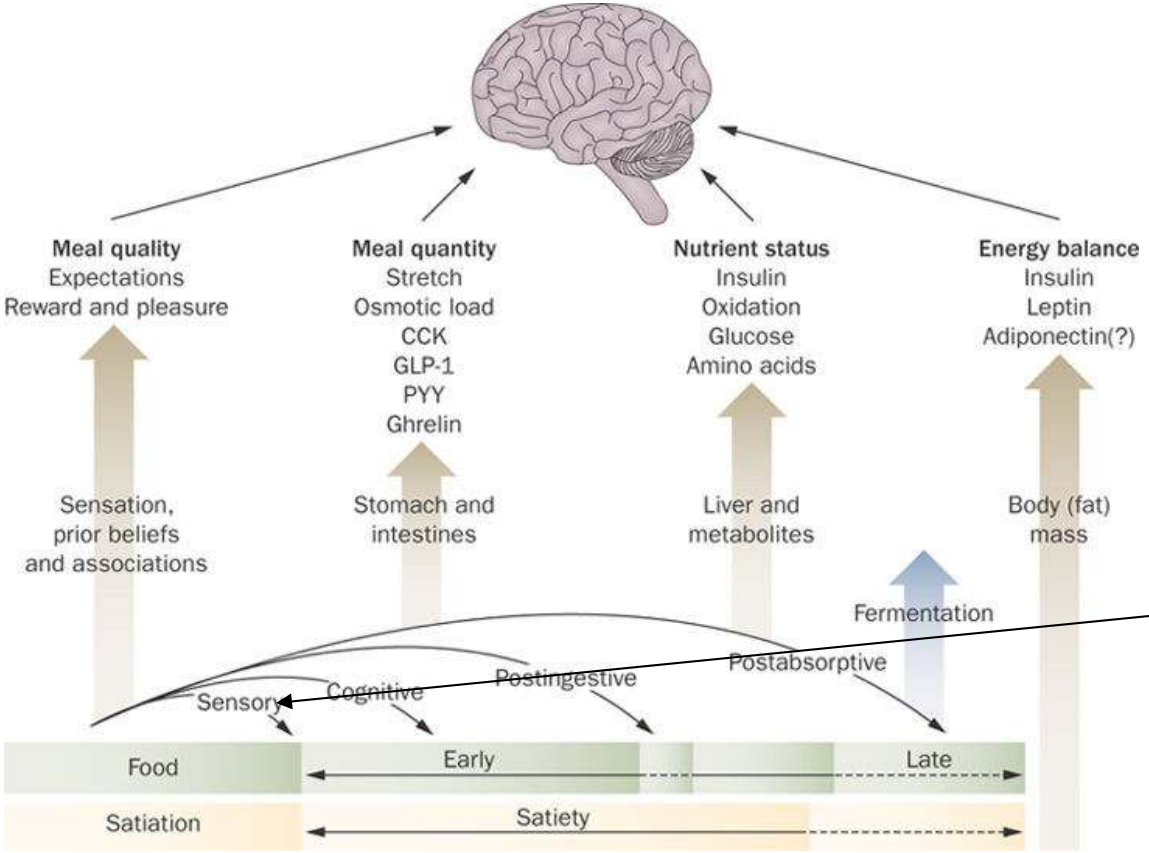
Satiety Cascade



Palatability: Sensory characteristics of food antagonizes satiation

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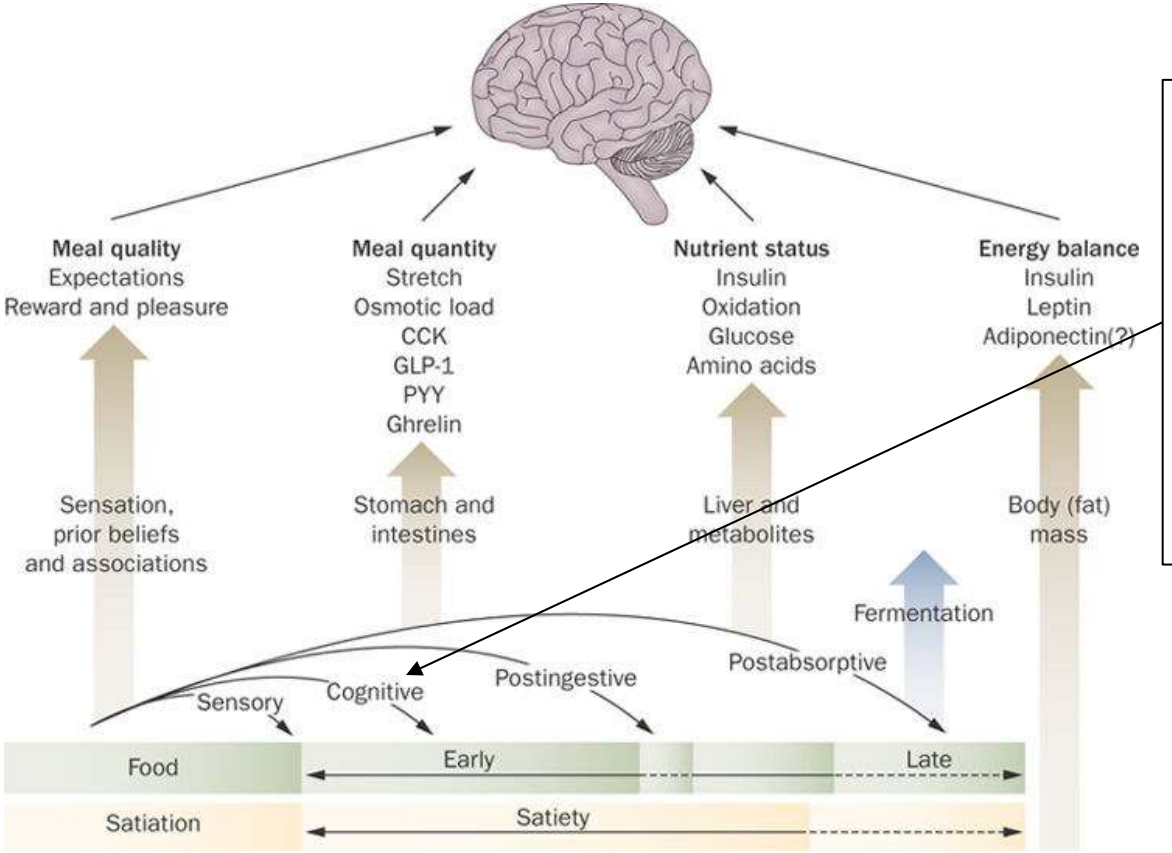

Cognitive Influences: Individual expectations of foods, beliefs, attention or distraction while eating

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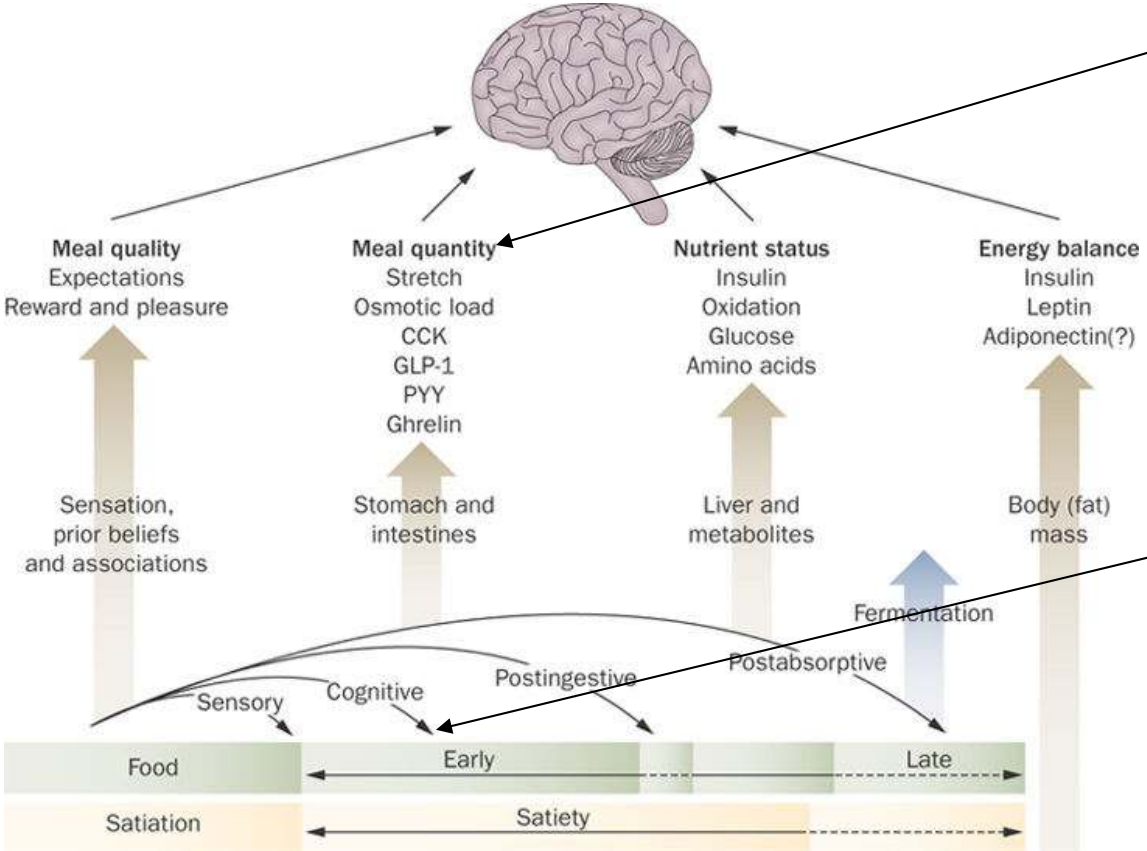

Post Meal: weight, volume, energy and nutrient content of meal contribute to satiety

Cognitive Factors: beliefs about the last meal also contribute

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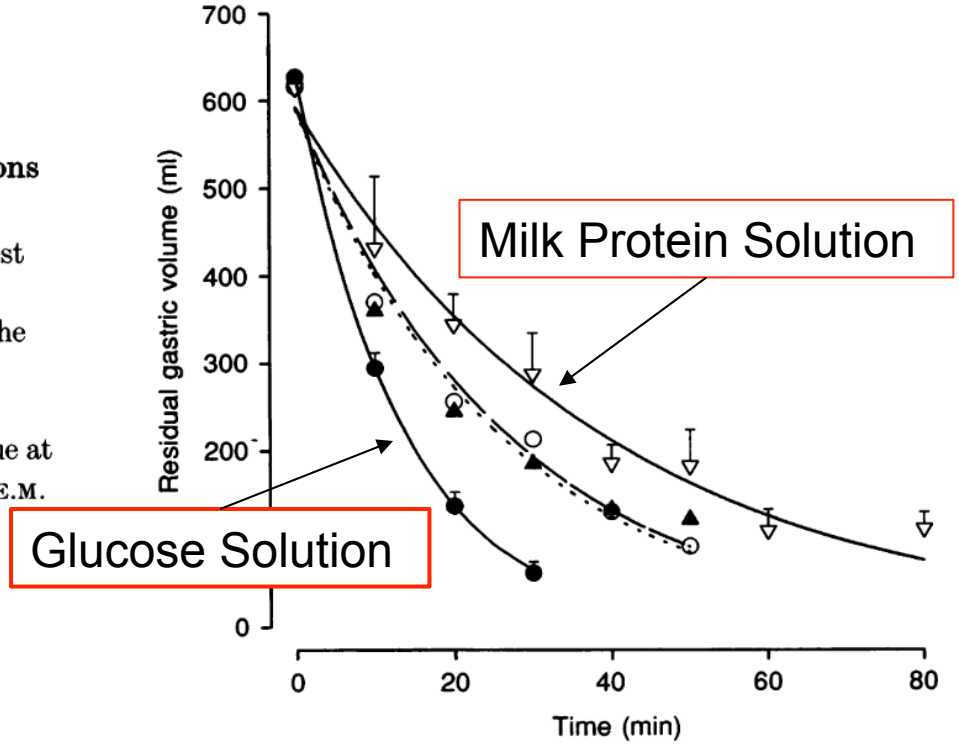
Nutrients & Gastric Emptying

Figure 1. The rate of gastric emptying of the test solutions
The rate of gastric emptying for all solutions was exponential ($r = 0{\cdot}86–0{\cdot}99$). The glucose (●) solution was emptied the fastest (half-emptying time, $9{\cdot}4 \pm 1{\cdot}2$ min; $P < 0{\cdot}05$) and the milk protein (▽) solution the slowest ($26{\cdot}4 \pm 10{\cdot}0$ min; $P < 0{\cdot}05$); the pea peptide hydrolysate (○) and whey peptide hydrolysate (▲) solutions had half-emptying times of $16{\cdot}3 \pm 5{\cdot}4$ and $17{\cdot}2 \pm 6{\cdot}1$ min, respectively. Symbols represent the mean value at each sampling time when $n = 6$, and vertical bars represent S.E.M.

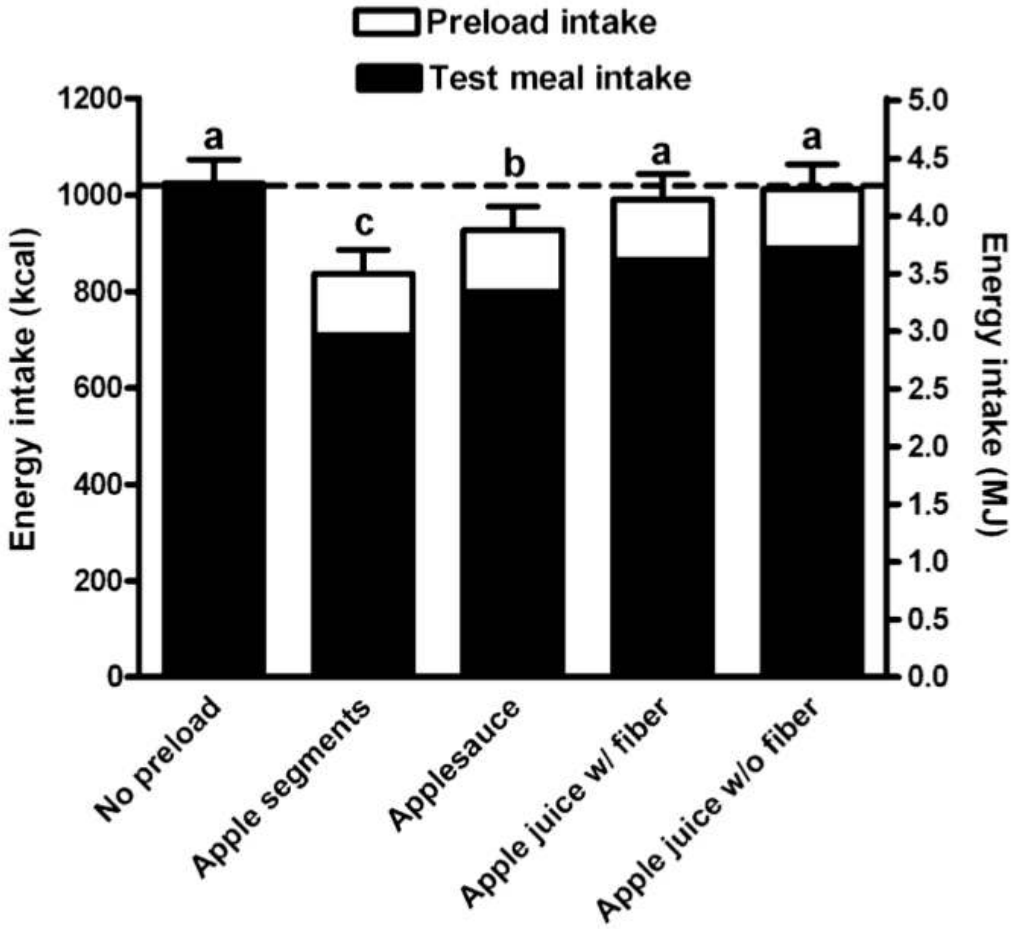


- Milk protein solution- includes fat, carbohydrate, and protein yields slowest gastric emptying
- Stomach “stretched” potentially yielding longer satiety

Nutrient Sources Effects on Satiety and Intake

- Apple study *(Flood-Obbagy and Rolls, Appetite, 2010)*
  - 58 healthy subjects
  - Pre-Meal provided all with the same weight, calories, time to eat
    - Apple segments
    - Applesauce
    - Apple juice w/ fiber
    - Apple juice w/o fiber
  - Test Meal provided for individuals to eat lunch ad lib

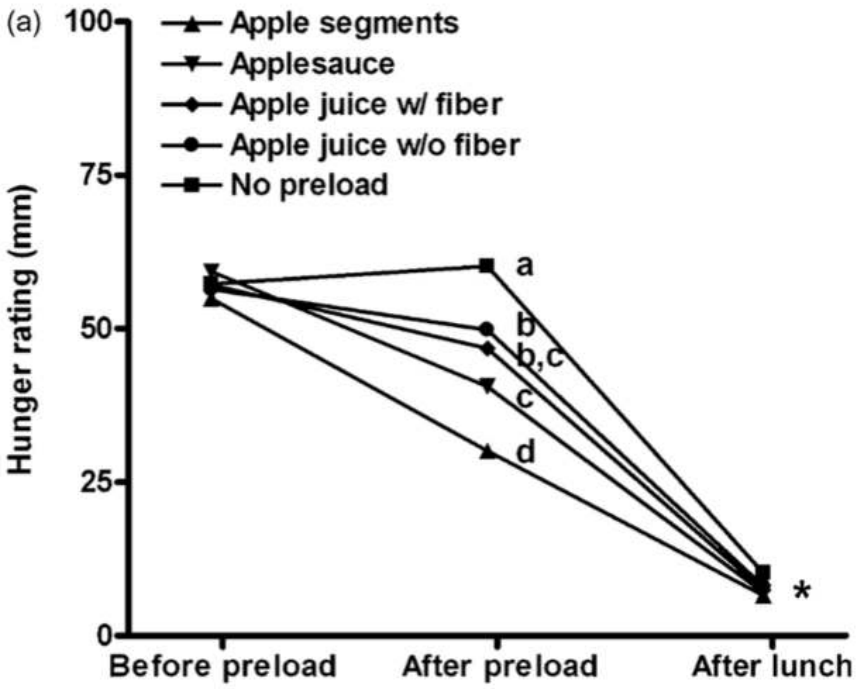
Apple Study Findings

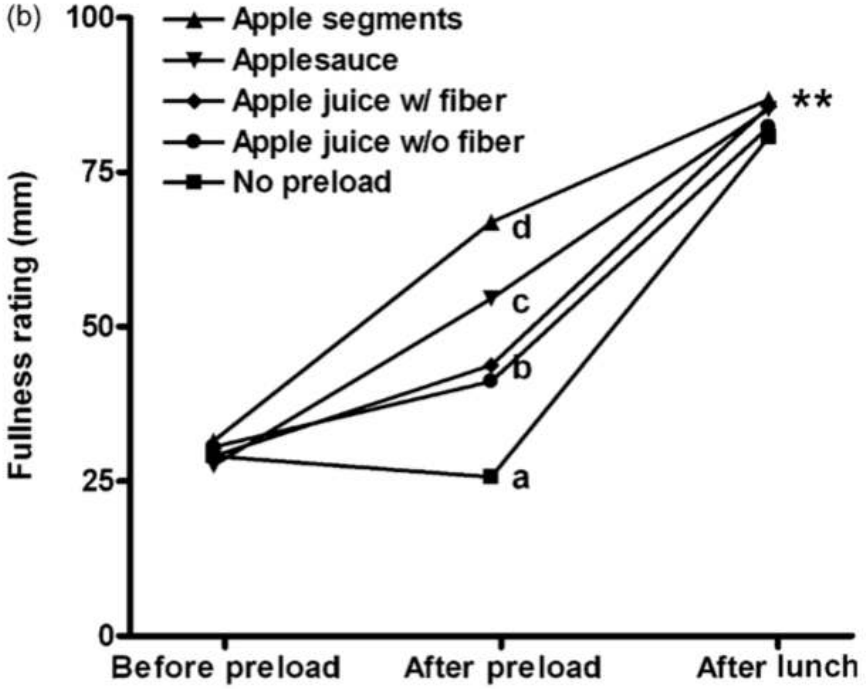


**Means with different letters are significantly different based on missed linear model with repeated measures. (Flood-Obbagy & Rolls, 2010)*

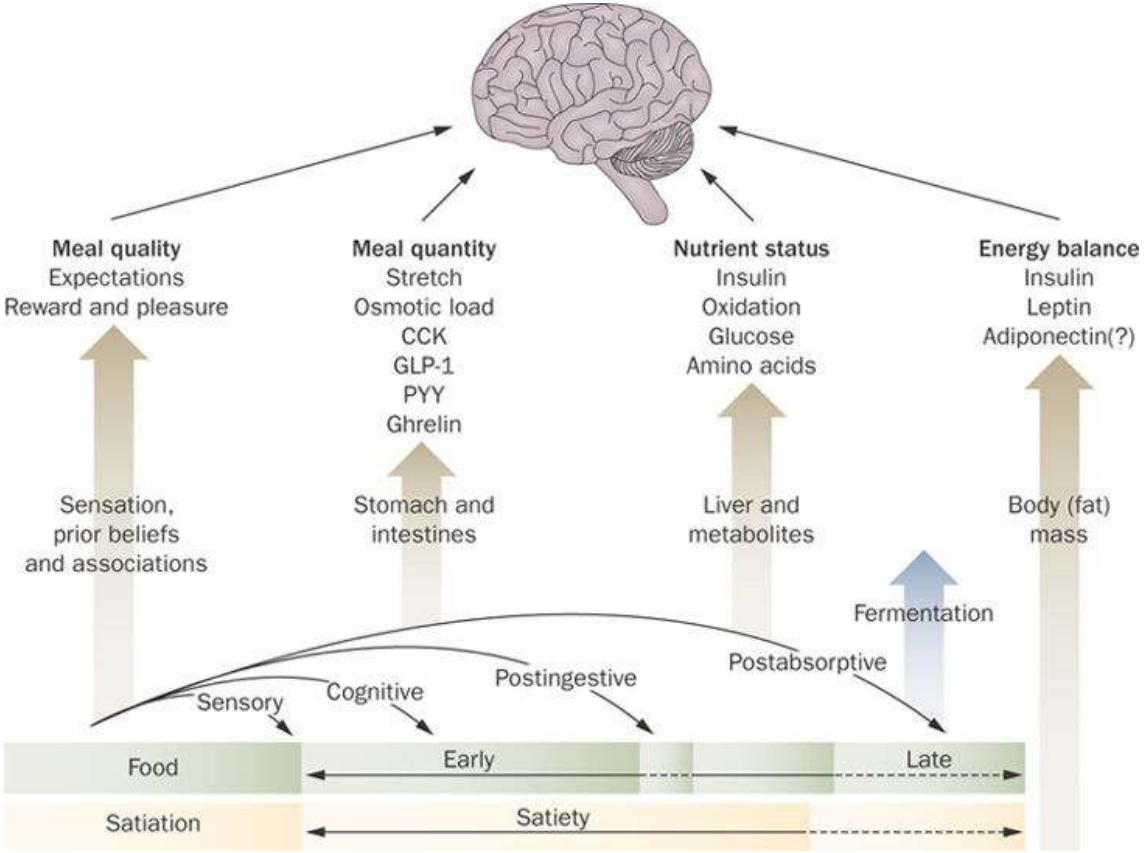
Apple Study Findings

- After eating apple segments or applesauce
- Hunger ratings were lower
- Fullness ratings were higher





Satiety Cascade



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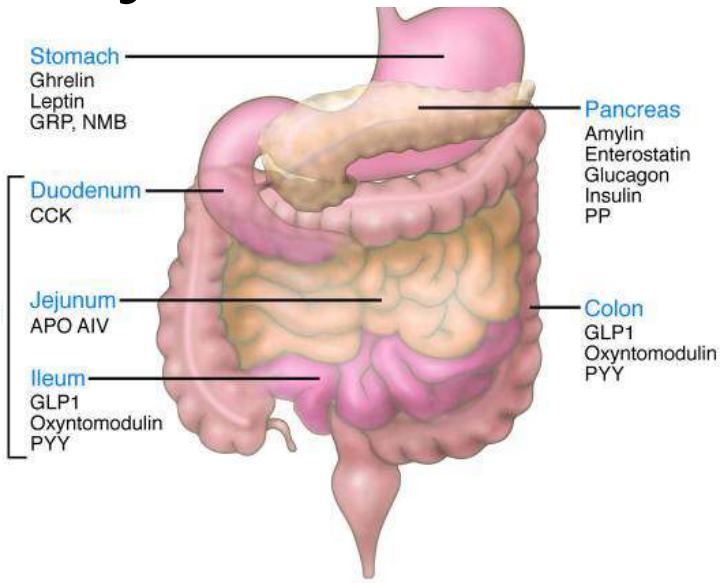
GI Peptides and Satiety

Table 1

Selected GI and pancreatic peptides that regulate food intake

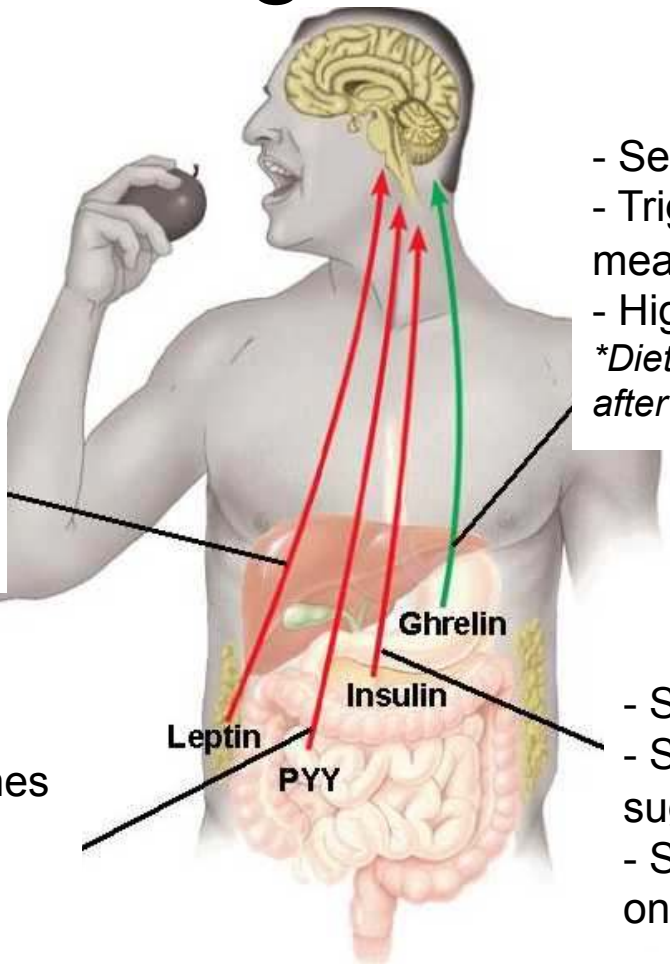
Peptide	Main site of synthesis	Receptors mediating feeding effects	Sites of action of peripheral peptides germane to feeding			Effect on food intake[A]
			Hypothalamus	Hindbrain	Vagus nerve	
CCK	Proximal intestinal I cells	CCK1R	X	X	X	↓
GLP1	Distal-intestinal L cells	GLP1R	X?	X?	X	↓
Oxyntomodulin	Distal-intestinal L cells	GLP1R and other	X			↓
PYY_{3-36}	Distal-intestinal L cells	Y2R	X		X	↓
Enterostatin	Exocrine pancreas	F1-ATPase β subunit			X	↓
APO AIV	Intestinal epithelial cells	Unknown	X		X	↓
PP	Pancreatic F cells	Y4R, Y5R		X	X	↓
Amylin	Pancreatic β cells	CTRs, RAMPs	X	X		↓
GRP and NMB	Gastric myenteric neurons	GRPR		X	X	↓
Gastric leptin	Gastric chief and P cells	Leptin receptor	?	?	X	↓
Ghrelin	Gastric X/A–like cells	Ghrelin receptor	X	X	X	↑

CTRs, calcitonin receptors; RAMPs, receptor activity–modifying proteins; GRP, gastrin-releasing peptide; NMB, neuromedin B; GRPR, GRP receptor. X? indicates that it is unclear whether physiologically relevant quantities of GLP1 from the gut evade DPP4-mediated degradation in blood to activate GLP1 receptors in the brain, although these receptors might interact with CNS GLP1 to regulate food intake. ? indicates that it seems very unlikely that gastric leptin interacts in a physiologically meaningful way with leptin receptors in the hypothalamus or hindbrain, which are important targets of leptin secreted from adipocytes. [A]Effect of peripheral peptides on food intake. In some cases, central administration yields opposite results.



J Clin Invest DOI: 10.1172/JCI30227

Who's in charge of satiety?



Ghrelin

- Secreted by stomach wall
- Triggers feelings of hunger as mealtimes approach
- High Ghrelin = ↑ Hunger

**Dieters have high levels of ghrelin after weight loss*

Leptin

- Produced by fat tissue
- Suppresses appetite
- High Leptin = ↓ Hunger
- Low Leptin = ↑ Hunger

Insulin

- Secreted by pancreas
- Stimulated after rise in blood sugar from meals
- Suppresses appetite by acting on brain

PYY Hormone

- Secreted by small intestines after meals
- Suppresses appetite
- High PYY = ↓ Hunger
- Counteracts Ghrelin

Macronutrients & Satiety

- Macronutrients
- Provide energy:
  - Carbohydrates: 4 calories per gram
  - Fat: 9 calories per gram
  - Protein: 4 calories per gram

Carbohydrates & Satiety

- Broken down in GI to glucose
- Absorbed into blood stream
- Rises in blood sugar after eating carbohydrates induce satiety
  - Due to insulin production
- Blood sugar decreases satiety is diminished
- Food sources with simple carbohydrates may lead to rapid rise and fall of blood sugar→ increase hunger
- Presence of soluble and insoluble fiber may improve satiety

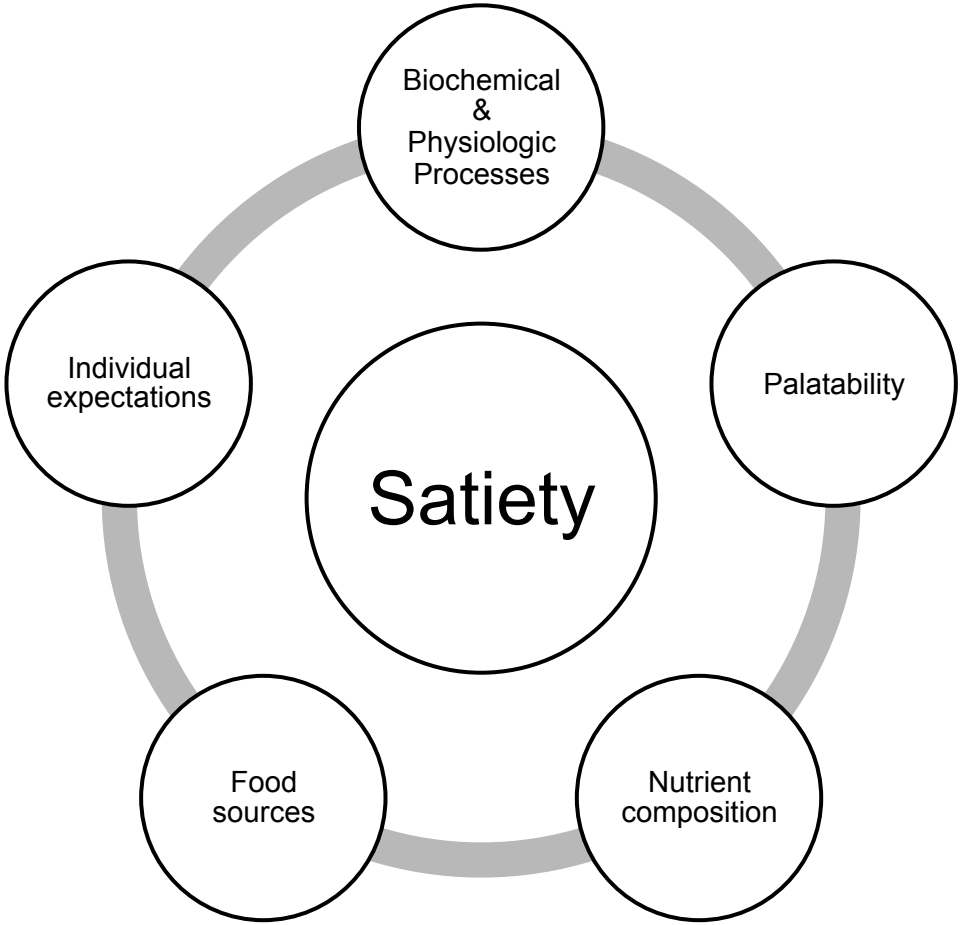
Dietary Protein & Satiety

- Protein broken down into amino acids and absorbed
- Increased amino acids in blood stream may reduce hunger sensations
- Amino acid presences in GI track also increase CCK to induce satiety

Dietary Fat & Satiety

- In hierarchy of “satiety” fat shows the lowest effect
- High-fat meals lead to over consumption of energy compared with high-carbohydrate meals
- Theories:
  - High energy density= lowered satiety
  - Palatability-enhancing: stimulates overconsumption
- Ghrelin levels drop more following carbohydrate rich meal vs. high-fat meal

Summary


Biochemical & Physiologic Processes
Palatability
Nutrient composition
Food sources
Individual expectations
Satiety

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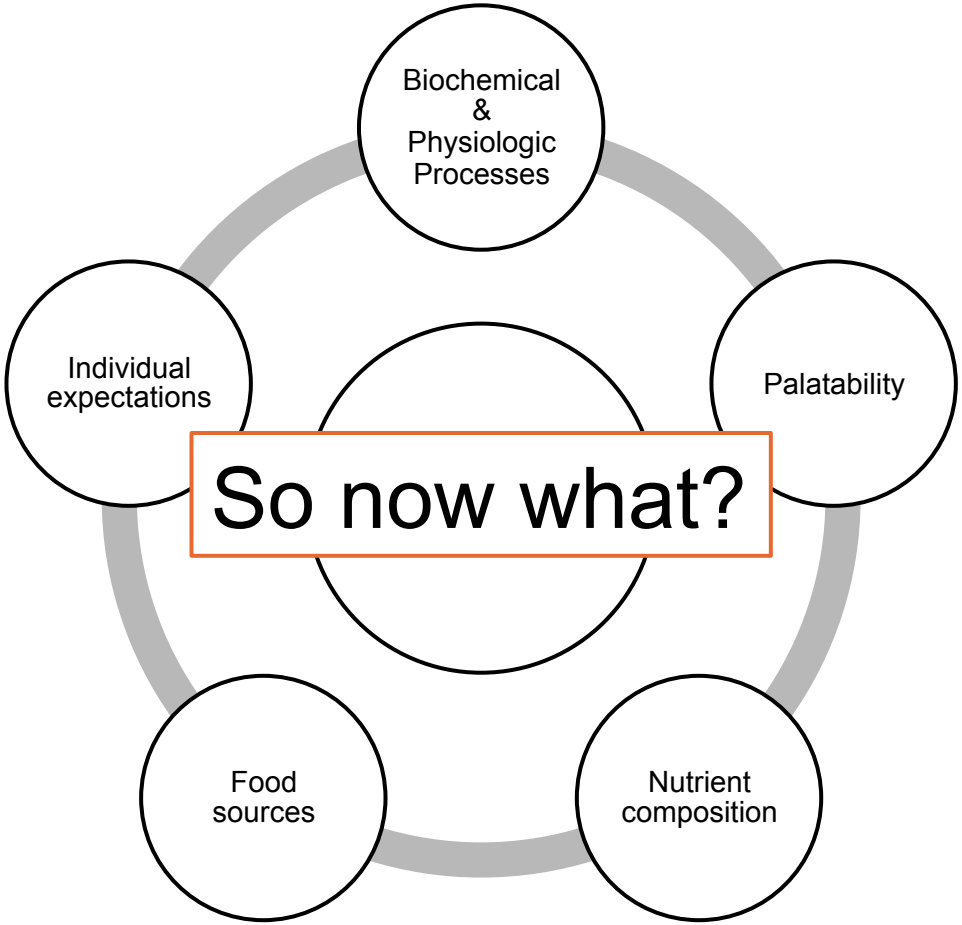
Biochemical & Physiologic Processes
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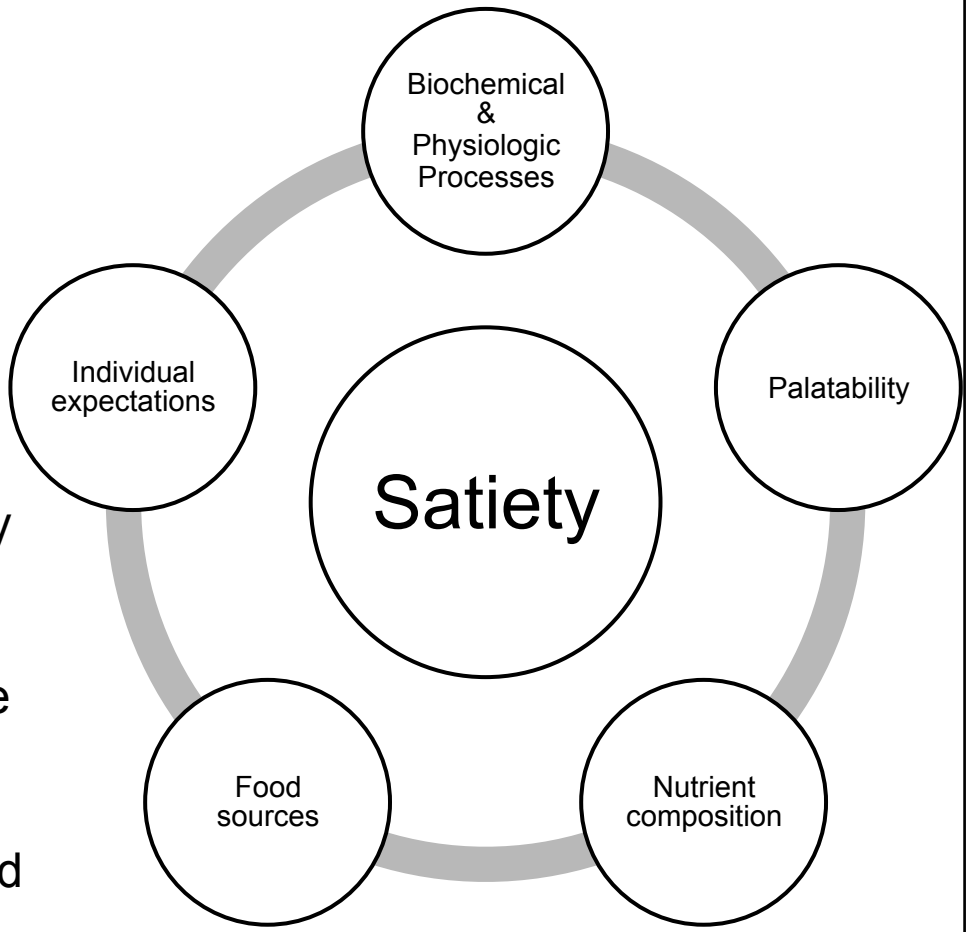
So now what?

Practice Points

- Improving satiety may support weight loss or weight management
  - Hunger management
  - Compliance with diet-related goals
- Optimize Meals to Support the Satiety Cascade:
  - Balanced with fiber-rich carbohydrates, protein and a little bit of fat
  - Non-nutrient related factors also influence satiety, subsequent food intake



Nutrition Recommendations

- Dietary Fiber:
  - 25-30 grams per day
    - Soluble fiber should be 7-13 g/day
- Protein
  - 15-20% of total calories
- Fat
  - About 30% daily intake
  - Avoid trans-fat
  - Select more poly-and mono-unsaturated types
- Physical Activity
  - 50 minutes of moderate-intensity aerobic activity/week
  - Resistance or strength training 3x/week
- Limited Sugar-Sweetened Beverages
  - 2-2.5% weight loss in 6 months by replacing with water

Academy of Nutrition and Dietetics Evidence Analysis Library

Potential Interventions

- Nutrition Education & Meal Composition alone not enough
  - Food choices: liquid calories vs. solid food
  - Fiber-rich vs. simple carbohydrates
  - Lean protein sources
  - Limited fat
- Behavioral Modifications
  - Sleep
  - Stress
  - Eating slowly: shown to decrease food intake
    - Mindful eating
  - Minimized distractions
  - Large vs small plates, bowls, etc

Potential Interventions con't

- Identifying already "acceptable" foods and providing strategies to increase nutrient density of those foods
  - Addition of vegetables to common dishes
    - Kalua pig with cabbage
    - Adding vegetables to soups
  - Choosing brown rice
- Stay mindful of limited resources
- Balance palatability, food preferences, nutrient density

Questions

Expected Satiety?

- Consumers have preconceived expectations of a food's ability to provide:
  - Fullness (satiation)
  - Absence of hunger between meals (expected satiety)
- Expectations are learned over time
- Eating behaviors affect them
  - Ex: eating and chewing slowly predicts post-meal satiation

Nutrient Profile & Gastric Emptying

- Gastric emptying and volume

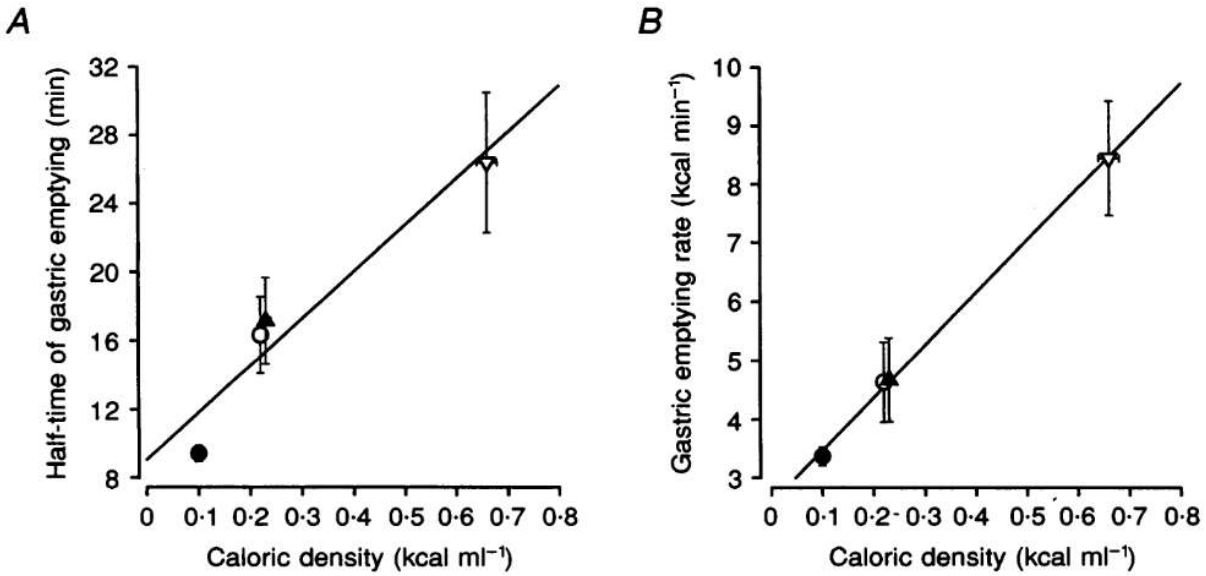


Figure 2. The relationship between caloric density and the rate of gastric emptying

A, the half-time of the gastric emptying process was closely related to the caloric density of the test solution ($r = 0{\cdot}96$, $P < 0{\cdot}05$). *B*, the rate of caloric delivery to the duodenum during the first half of the gastric emptying process was also closely related to the caloric density of the test solution ($r = 0{\cdot}99$, $P < 0{\cdot}001$). Symbols represent mean values ($n = 6$), and vertical as well as horizontal bars represent the S.E.M. values. Solutions: ●, glucose; ○, pea peptide hydrolysate; ▲, whey peptide hydrolysate; ▽, milk protein.