Regulation of Human Energy Intake

Emily Dhurandhar, PhD
1/31/14 Energetics Course
Outline

I. Evidence that energy intake is regulated
II. Factors that influence energy intake
   I. Physiological
   II. Environmental
   III. Food
Is Energy Intake Regulated?

Jean Mayer, 1955, describes three types of regulation:

1. Biometric Regulation: maximums and minimums defined by requirements and capacities of cells, organs, and systems.
2. Adaptation of energy intake to energy output.
3. Corrections in errors matching energy intake to output by successive recompenations.

Biometric Regulation

• Is there an upper limit to energy intake?

**Fig. 2**

a. Relationship between mean food intake and day of reproduction for the MFL mouse. Intake increases over days 1–10, but then reaches a plateau at days 10–18.

b. Asymptotic food intake (average over days 10–18) plotted against litter size. Bigger litters require greater energy demands, but for litters of more than ten the total intake is capped at 23 g per day.

c. Pup body mass at weaning in relation to litter size. In all cases, n = 71 unmanipulated litters.

Biometric Regulation

• Is there an upper limit to energy intake?

  – Tour de France Cyclists expend approximately 7,000 kcal/day and maintain energy balance.
  – Metabolic Scope for active wild animals ranges from 1.3 to 7.0 (Hammond & Diamond, Nature 1997).
  • Metabolic Scope = SusMR/RMR
  • Tour de France Athletes = 3.5-5.5 (Westerterp et al J. Appl. Physiol. 61, 2162–2167)
Does Energy Intake Reflect Energy Output?
In adult rats, increasing energy expenditure increases food intake to maintain body weight to a point.

Does Energy Intake Reflect Energy Output? Response to day-to-day variations in expenditure

Does Energy Intake Reflect Energy Output?
Response to day-to-day variations in expenditure

Fig. 3. Relationship between caloric expenditure and intake of the cadets. There is close agreement between the two plots indicating that daily intake of food is affected by the degree of activity 2 days previously.

## Does Energy Intake Reflect Energy Output? Response to exercise

Changes in *ad lib* energy intake over a few days of graded exercise in men & women.

**Men - 9 days** (Stubbs et al. EJCN. 2002. 56:129-140)

<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>0</td>
<td>11.6</td>
<td>-0.1</td>
</tr>
<tr>
<td>1.6</td>
<td>11.8</td>
<td>-1.0</td>
</tr>
<tr>
<td>3.2</td>
<td>11.8</td>
<td>-5.2</td>
</tr>
</tbody>
</table>

**Women - 7 days** (Int J Obes Relat Metab Disord **26**(6): 866-869)

<table>
<thead>
<tr>
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<tr>
<td>0</td>
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<td>-1.3</td>
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<tr>
<td>1.9</td>
<td>9.2</td>
<td>-1.8</td>
</tr>
<tr>
<td>3.4</td>
<td>10.0</td>
<td>-2.9</td>
</tr>
</tbody>
</table>
Compensating during exercise regimen by increased EI, not decreased EE

• **Sample**: 54 middle-aged men with sedentary lifestyles (BMI: 28±3)

• **Methods**: Used synchronized accelerometry and heart rate to observe prescribed and non-prescribed PAEE during an 18-week exercise intervention, plus 2 week “detraining period”

• **Results**: No significant decrease in non-prescribed PAEE to compensate for prescribed PAEE

• **Conclusion**: Losing less weight than predicted by PAEE likely a result of increased energy intake (both groups were allowed to eat *ad libidum*)

**Figure 1.** Physical activity energy expenditure (PAEE) throughout the study, no exercise group vs. prescribed exercise

**PAEE differences between control and exercise groups, across time points**

Does Energy Intake Reflect Energy Output?
Response to exercise

“In conclusion, an exercise-induced increase in energy expenditure induces increased energy intake, thus compensating for the additional requirement, especially at higher exercise loads.”

<table>
<thead>
<tr>
<th>Reference</th>
<th>Subjects</th>
<th>Training mode</th>
<th>Δ Expenditure (MJ/d)</th>
<th>Δ Body weight (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bingham et al. (1989)</td>
<td>2 females, 3 males, normal weight</td>
<td>Jogging for 9 weeks</td>
<td>+2.8*</td>
<td>-0.9**</td>
</tr>
<tr>
<td>Blaak et al. (1992)</td>
<td>10 boys, obese</td>
<td>Cycling for 4 weeks</td>
<td>+1.3*</td>
<td>+0.5**</td>
</tr>
<tr>
<td></td>
<td>5 females, 8 males, normal weight</td>
<td>Jogging for 40 weeks</td>
<td>+2.3***</td>
<td>-0.9ns</td>
</tr>
<tr>
<td>Westerterp et al. (1992)</td>
<td>12 males, normal weight</td>
<td>Weight training for 12 weeks</td>
<td>+0.8**</td>
<td>-1.1*</td>
</tr>
</tbody>
</table>

* P < 0.05; ** P < 0.01; *** P < 0.001, for significant differences with baseline; ns, not statistically significant.
Does Energy Intake Reflect Energy Output?
Response to exercise

  – Decrease in RMR, decrease in non-exercise energy expenditure, increase in lean mass, and increase in energy intake may all be responsible
Evidence for Recovery from Errors in Energy Balance System
Recovery after overfeeding

Short-term studies looking for reduction in ad lib intake following overfeeding have mixed results.
- not long enough to produce substantial weight change

Evidence for Recovery from Errors in Energy Balance System

Recovery after overfeeding

Evidence for Recovery from Errors in Energy Balance System Recovery after underfeeding

The Biosphere 2 experiment (Weyer et al. Am J Clin Nutr October 2000 vol. 72 no. 4 946-953)
Evidence for Recovery from Errors in Energy Balance System Recovery after underfeeding

The Biosphere 2 experiment (Weyer et al. Am J Clin Nutr October 2000 vol. 72 no. 4 946-953)

<table>
<thead>
<tr>
<th>TABLE 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical characteristics of the control subjects and of the subgroup of 5 biospherians in whom 24-h energy metabolism was assessed in a respiratory chamber at within 1 wk and 6 mo after exit from Biosphere 2(^1)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Control subjects (n = 89 M, 63 F)</th>
<th>Biospherians (n = 3 M, 2 F)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age (y)</strong></td>
<td>35.3 ± 16.0</td>
</tr>
<tr>
<td><strong>Height (cm)</strong></td>
<td>170 ± 8</td>
</tr>
<tr>
<td><strong>Body weight (kg)</strong></td>
<td>68.3 ± 8.7</td>
</tr>
<tr>
<td><strong>BMI (kg/m(^2))</strong></td>
<td>23.7 ± 3.4</td>
</tr>
<tr>
<td><strong>Percentage body fat (%)</strong></td>
<td>21 ± 10</td>
</tr>
<tr>
<td><strong>24-h energy expenditure (kJ/d)</strong></td>
<td>8120 ± 990</td>
</tr>
<tr>
<td><strong>Sleeping metabolic rate (kJ/d)</strong></td>
<td>5920 ± 730</td>
</tr>
<tr>
<td><strong>Spontaneous physical activity (%)</strong></td>
<td>7.5 ± 3.2</td>
</tr>
<tr>
<td><strong>24-h Energy intake (kJ/d)</strong></td>
<td>8100 ± 880</td>
</tr>
<tr>
<td><strong>24-h Energy balance (kJ/d)</strong></td>
<td>-20 ± 620</td>
</tr>
<tr>
<td><strong>24-h Respiratory quotient</strong></td>
<td>0.863 ± 0.027</td>
</tr>
</tbody>
</table>

\(^1\)\(\bar{x} \pm SD.\)
\(^2,4,7\) Significant time effect: \(^2 P < 0.001, ^4 P < 0.01, ^7 P < 0.05.\)
\(^3,5,6\) Significantly different from control subjects after adjustment for age and sex: \(^3 P < 0.01, ^5 P < 0.001, ^6 P < 0.05.\)
\(^8\) The 24-h respiratory quotient 1 wk after exit was measured under different dietary conditions (see Methods).
Is Energy Intake Regulated?

Summary

• There is a lower limit to energy intake.
• Theory and animal evidence supports an upper limit to energy intake.
• Energy intake is adjusted to output, but there is a time lag in response and output dose may matter.
• Correction for perturbations in energy balance by long-term successive compensations does occur.
Factors that influence energy intake: Physiological

• Glucostatic & Lipostatic Hypothesis
• Central Control of Intake
• Control of Meal Intake Through Signals from the G.I. Tract
Factors that influence energy intake: Physiological Glucostatic Theory

• One of the first theories to explain short-term regulation of food intake
• Proposed by Jean Mayer, 1955
• Based on four observations:
  1. Glucose required for nerve cell activity.
  2. Neurons with glucose receptors in hypothalamus are particularly active in hungry mice.
  3. Preferential use of carbohydrates as energy source in fed state.
  4. Low blood glucose associated with hunger, high blood glucose with meal cessation
Factors that influence energy intake: Physiological Lipostatic Theory

- One of the first theories to explain long-term regulation of food intake
- Proposed by Jean-Mayer, 1955
- Proposes that energy intake is regulated over the long-term by body fat stores
Factors that influence energy intake: Physiological Central Control of Food Intake

- The brain integrates many signals to regulate feeding behavior (reviewed in Morton et al. *Nature* 443, 289-295 (21 September 2006))
  - Adiposity signals
  - Food reward
  - Signals from the G.I. Tract
Factors that influence energy intake: Physiological Central Control of Food Intake

Factors that influence energy intake: Physiological Central Control of Food Intake

Negative feedback from adipose tissue

Schwartz et al. Nature 404, 661-671(6 April 2000)
Factors that influence energy intake: Physiological Central Control of Food Intake

Negative feedback from adipose tissue

<table>
<thead>
<tr>
<th>Molecule</th>
<th>Regulation by adiposity signals</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Orexigenic</strong></td>
<td></td>
</tr>
<tr>
<td>NPY*†</td>
<td>⊖</td>
</tr>
<tr>
<td>AGRP*†</td>
<td>⊖</td>
</tr>
<tr>
<td>MCH</td>
<td>⊖</td>
</tr>
<tr>
<td>Hypocretin 1 and 2/orexin A and B</td>
<td>⊖</td>
</tr>
<tr>
<td>Gelanin</td>
<td>?</td>
</tr>
<tr>
<td>Noradrenaline</td>
<td>?</td>
</tr>
<tr>
<td><strong>Anorexigenic</strong></td>
<td></td>
</tr>
<tr>
<td>α-MSH*</td>
<td>⊖</td>
</tr>
<tr>
<td>CRH*</td>
<td>⊖</td>
</tr>
<tr>
<td>TRH*</td>
<td>⊖</td>
</tr>
<tr>
<td>CART*</td>
<td>⊖</td>
</tr>
<tr>
<td>IL-1β*</td>
<td>⊖</td>
</tr>
<tr>
<td>Urocortin*</td>
<td>?</td>
</tr>
<tr>
<td>Glucagon-like peptide 1</td>
<td>?</td>
</tr>
<tr>
<td>Oxytocin</td>
<td>?</td>
</tr>
<tr>
<td>Neurotensin</td>
<td>?</td>
</tr>
<tr>
<td>Serotonin</td>
<td>?</td>
</tr>
</tbody>
</table>

Orexigenic refers to molecules that promote increased energy intake; anorexigenic implies the opposite. An asterisk designates documented, coordinated effects on both food intake and energy expenditure that promote a change in energy stores; arrows designate direction of effect exerted by one or both of the adiposity signals, leptin and insulin.

Schwartz et al. Nature 404, 661-671 (6 April 2000)
Factors that influence energy intake: Physiological Central Control of Food Intake

Negative feedback from adipose tissue

“Hunger center” “Satiety center”

Schwartz et al. Nature 404, 661-671(6 April 2000)
Factors that influence energy intake: Physiological Central Control of Food Intake

Food Reward

Perception of pleasure associated with consumption of a palatable food involves neuronal activation in the NAc and striatum, which through activation of opiate peptide receptors disinhibits the lateral hypothalamic area and thereby stimulates feeding.

Schwartz et al. Nature 404, 661-671 (6 April 2000)
Factors that influence energy intake: Physiological
The Role of Digestion and Gastrointestinal Factors in Controlling Meal Intake

Without feedback signals from the G.I. tract (sham feeding), meals are considerably larger.

Factors that influence energy intake: Physiological
The Role of Digestion and Gastrointestinal Factors in Controlling Meal Intake

• Mechanical sensing from the enteric nervous system of digestive tract sends feedback to CNS food intake centers
• G.I. secretes hormones with receptors in the CNS that induce satiety and slow feeding
• Nutrient absorption sensed by CNS
Factors that influence energy intake: Physiological
The Role of Digestion and Gastrointestinal Factors in Controlling Meal Intake

<table>
<thead>
<tr>
<th>Reduce Meal Size</th>
<th>Increase Meal Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>CCK</td>
<td>Ghrelin</td>
</tr>
<tr>
<td>Bombesin family</td>
<td></td>
</tr>
<tr>
<td>Glucagon</td>
<td></td>
</tr>
<tr>
<td>Glucagon-like-peptide-1</td>
<td></td>
</tr>
<tr>
<td>Glucagon-like-peptide-2</td>
<td></td>
</tr>
<tr>
<td>Apolipoprotein A-IV</td>
<td></td>
</tr>
<tr>
<td>Amylin</td>
<td></td>
</tr>
<tr>
<td>Somatostatin</td>
<td></td>
</tr>
<tr>
<td>Enterostatin</td>
<td></td>
</tr>
<tr>
<td>Peptide-YY-(3-36)</td>
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</tr>
</tbody>
</table>

Factors that influence energy intake: Physiological
The Role of Digestion and Gastrointestinal Factors in Controlling Meal Intake

• Cholecystokinin (CCK)
  – Secreted from the duodenum in response to nutrients
  – Intravenous administration reduces meal size
  – CCK receptors on vagal nerve send signal to NTS in hindbrain
Factors that influence energy intake: Physiological
The Role of Digestion and Gastrointestinal Factors in Controlling Meal Intake

- If CCK reduces meal size, can it change overall energy intake and body weight? (West et al. Am J Physiol 246(5 Pt 2): R776-787.)
Factors that influence energy intake: Physiological
The importance of oral, olfactory and visual cues

- Initiation of meal intake, motivation to continue eating
- Sensory specific satiety

Factors that influence energy intake: Physiological

The importance of taste, smell and sight

-Sensory Specific Satiety
- Eating a single food decreases food intake relative to eating a variety of foods

Factors that influence energy intake: Physiological

The importance of taste, smell and sight

• Flavor-Nutrient Learning:
  – Flavor-nutrient hedonic learning: linking a flavor (Conditioned stimulus) with its postingestive effects (unconditioned stimulus)
  – Flavor-nutrient satiety learning: linking a flavor (conditioned stimulus) with its energy value (unconditioned stimulus)
Factors that influence energy intake: Physiological
The importance of taste, smell and sight


<table>
<thead>
<tr>
<th>Day 1</th>
<th>Day 2</th>
<th>Day 3</th>
<th>Day 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>25% CHO both grape and orange</td>
<td>10% CHO (1/2 grape, 1/2 orange) OR 45% CHO (1/2 grape, 1/2 orange)</td>
<td>10% CHO (1/2 grape, 1/2 orange) OR 45% CHO (1/2 grape, 1/2 orange)</td>
<td>25% CHO both grape and orange</td>
</tr>
</tbody>
</table>

Trained with orange
- Intake reflects chow intake
- Intake reflects chow intake
- Intake of 10% increases, Intake of 45% increases
- If trained with 10% CHO increased intake of orange flavor, If trained with 45% decreased intake of orange

Trained with grape
- Intake reflects chow intake
- Intake reflects chow intake
- Intake of 10% increases, Intake of 45% increases
- If trained with 10% CHO increased intake of grape flavor, If trained with 45% decreased intake of grape
Factors that influence energy intake: Physiological
The importance of taste, smell and sight

Flavor-nutrient satiety learning: flavor is crucial

Flavors of LED and HED different
No flavor to HED or LED

Open bars before training, filled bars after training
Factors that influence energy intake: Physiological
The importance of taste, smell and sight

Implications of learned flavor-nutrient satiation for low calorie foods

**Snack (kcal)**

<table>
<thead>
<tr>
<th></th>
<th>Hi-Cal</th>
<th>Lo-Cal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Day 1**

<table>
<thead>
<tr>
<th></th>
<th>Hi-Cal</th>
<th>Lo-Cal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Other food T1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total T1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**After 4 days of consumption**

<table>
<thead>
<tr>
<th></th>
<th>Hi-Cal</th>
<th>Lo-Cal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Other Food T2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total T2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Appetite, 1989, 12, 95–103*

**Learned Caloric Adjustment of Human Intake**

JEANINE LOUIS-SYLVESTRE, ALAIN TOURNIER, PHILIPPE VERGER, MICHELE CHABERT and BRIGITTE DELORME

Laboratoire de Neurobiologie de la Nutrition E.P.H.E., Université Paris 6

JOSEPH HOSSENLOPP

Ecole Nationale des Sciences de l’Industrie Alimentaire
Factors That Regulate Energy Intake: Physiological Summary

• The physiological system that regulate energy intake is complex and has many redundant pathways.
• Nutrients play a critical role in stimulating this system, and their effects on energy stores are likely mediated by it.
• Learning mechanisms are in place to link the flavor of a food with its energy content.
• The systems that regulate longterm energy intake are distinct from those that regulate meal intake, but the two systems talk to each other.
Factors that influence energy intake: Environmental

Factors that influence energy intake: Environmental Portion Sizes

A 30% (161 kcal) increase in intake occurred between the largest and smallest portion.

Rolls et al. 2002 AJCN. vol. 76 no. 6:1207-1213.

Open circles = serving dish with plate, closed circles = plate only
Factors that influence energy intake: Environmental Visual Cues & Estimation of Portion Sizes

• Plate, bowl, or glass size:
  – Serves as an anchor for judging portion size
  – Smaller plate sizes mean less food is taken and consumed without the perception of less (Wansink et al. J Exp Psychol Appl. 2013 Dec; 19(4):320-32)
  – Height of fill of a glass is reference- tall, thin glass with the same amount of liquid as a short, stout glass will be perceived to contain more liquid (Wansink. Annu. Rev. Nutr. 2004. 24:455–79)
Factors that influence energy intake: Environmental Visual Cues & Estimation of Portion Sizes

“Bottomless” bowls increase soup intake, but not perceived soup intake.

Factors that influence energy intake: Environmental Temperature, lighting, odors, social factors

• Cold environments increase energy intake
• Bright, harsh lighting decreases intake; soft lighting increases it
• Odors have quick sensory specific satiety, but can initiate eating episodes

Factors that influence energy intake: Environmental Variety and choice structure

The *perception* of variety is sufficient to increase intake (M&M’s test the same, but increasing color variety increases consumption).

Factors that influence energy intake: Environmental Variety and choice structure

• Consistent exposure to variety increases energy intake and weight gain in rats
• Effect wears off for a single set of food options; new varieties must be introduced to produce consistent increases in EI
• (Le Magnen J. Hunger. Cambridge (UK): Cambridge Univ. Press; 1985.)
Factors that influence energy intake: Environmental Effort

• In-shell pistachios reduce consumption by 86 kcal (41%) compared to shelled nuts during an ad libitum snack. (Honselman CS. Appetite. 2011 Oct;57(2):414-7.)
Factors that influence energy intake: Environmental Preordering

Avoiding environmental cues that stimulate intake may reduce “unhealthy” choices

<table>
<thead>
<tr>
<th></th>
<th>%</th>
<th>Change</th>
<th>Odds Ratio (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Selected a healthy entrée</td>
<td>29.4</td>
<td>-48.0</td>
<td>0.55 (0.35-0.86)</td>
</tr>
<tr>
<td>Selected a less healthy entrée</td>
<td>70.8</td>
<td>21.0</td>
<td>1.81 (1.14-2.87)</td>
</tr>
</tbody>
</table>

From: Preordering School Lunch Encourages Better Food Choices by Children
Factors That Regulate Energy Intake: Environmental 

Summary

• Energy availability (portion sizes) and the way food is presented visually can influence energy intake of a meal.

• Atmosphere cues like social influences, temperature, and lighting can influence energy intake of a meal.

• Increasing variety can increase energy intake and weight gain
Factors that influence energy intake: Food Energy Density

• Key factors influencing energy density are water and fat content
• Covert manipulation of energy density (no chance for learning) greatly effects energy intake
  – Increasing ED increases EI
  – Decreasing ED decreases EI
• Consumption of higher energy density foods are associated with higher energy intake and body weight
Factors that influence energy intake: Food

Energy Density

There is an interaction between portion size and energy density. (Kral et al. Am J Clin Nutr 2004;79:962–8.)
Animals do reasonably well at self-selection of a “balanced diet”

Macronutrient self-selection is relatively consistent within species, and highly consistent day-to-day for a given animal

(Ritcher et al. Amer. J. Physiol., 1938, 122, 734-744.)
Factors that influence energy intake: Food Macronutrients

- “High fat” (low carb, similar protein) diets increase energy intake

Factors that influence energy intake: Food Macronutrients

- The effect of fat on energy intake is diminished when energy density is controlled for.

Factors that influence energy intake: Food Macronutrients

• Protein is consistently more satiating than carbohydrate and fat in the short-term (Poppitt et al. Physiol Behav 64(3): 279-285.)

• Rats compensate well for dilutions in protein, but not for dilutions in carbohydrate (Rozin J Comp Physiol Psychol 65(1): 23-29.)
Factors that influence energy intake: Food Macronutrients

Figure 3. Energy intake at an ad lib. lunch 120 min after ingestion of 1-MJ preload supplements of protein, carbohydrate (CHO) and fat (mean ± sd) alcohol.

(Poppitt et al. Physiol Behav 64(3): 279-285.)
Factors that influence energy intake: Food Macronutrients

*Ad libitum* high protein diets reduce calorie intake and the effect is persistent for 90 days.

Factors that influence energy intake: Food Macronutrients

High levels of protein suppress food intake, but lower levels may not increase it. (Martens et al. Am J Clin Nutr 97(1): 86-93.)
Factors that influence energy intake: Food Form: Liquid vs. Solid

- Some evidence suggests liquids may not be compensated for as well as solids (keep in mind these are self-report data)

![Graph showing energy intake comparison between Soda and Jelly Beans](image-url)

*Figure 1* Mean reported energy intake (s.e.) prior to and at the end of both intervention periods.
Factors that influence energy intake: Food Form: Liquid vs. Solid

Regardless of food being high in protein, carbohydrate, or fat, liquid calories lead to imperfect compensation over 1 day compared to solid calories.

<table>
<thead>
<tr>
<th></th>
<th>Beverage</th>
<th>Solid</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Protein</td>
<td>-54 ± 102</td>
<td>127 ± 58</td>
<td>0.02</td>
</tr>
<tr>
<td>High Carbohydrate</td>
<td>-8 ± 77</td>
<td>152 ± 52</td>
<td>0.006</td>
</tr>
<tr>
<td>High Fat</td>
<td>-179 ± 97</td>
<td>42 ± 48</td>
<td>0.016</td>
</tr>
</tbody>
</table>

Units are % total daily compensation. 0 indicates perfect compensation, negative indicates eating more food than baseline, and positive indicates eating less food than baseline. (Mourao et al. International Journal of Obesity (2007) 31, 1688–1695)
Factors that influence energy intake: Food

Food Form: Liquid vs. Solid

- Meta-analysis of RCTs that added nutritively sweetened beverages to diet suggest they may lead to some weight gain (Mattes et al. 2011 *Obes Rev.* 2011 May;12(5):346-65)
Factors that influence energy intake: Food Summary

• We can make conclusions about diets of a particular macronutrient composition:
  – Diets with high levels of protein tend to suppress energy intake
  – Diets high in fat/energy density tend to increase energy intake

• High calorie liquid added to the diet may not be well compensated for, increase energy intake, and lead to a small amount of weight gain
Conclusions

• What is something new that you learned today?

• What overarching conclusions & principles did you draw from this lecture?