Sugar — the bitter truth

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• No disclosures

Venus von Willendorf, Vienna Museum of Natural History
Dated to 22,000 BCE, unearthed in 1908

Obesity has been part of the human condition since there were humans

But something’s happened—
How did the world get so obese?
And how so fast?

The First Law of Thermodynamics

The total energy inside a closed system remains constant.

Two interpretations:

Fat for Life?
Six Million Kids Are Seriously Overweight—What Families Can Do

The First Law of Thermodynamics

The total energy inside a closed system remains constant.
The First Law of Thermodynamics

In Calories

Out Calories

Weight Gain

Obesity is the result of two aberrant behaviors

Total Caloric Intake

↑ 275 kcal in teen boys

Children 2-17 yrs, CSFII (USDA) 1989-91 vs. 1994-95
Fat Intake: Grams

†5 g (45 cal) in teen boys

Prevalence of Obesity Compared to Percent Calories from Fat Among US Adults

Carbohydrate Intake: Grams

†57 g (228 cal) in teen boys

Secular trends in specific food intake 1989-1996

Beverage Intake

†41% soft drinks

†35% fruit drinks
Beverage Intake

- 41% soft drinks
- 35% fruit drinks

Children 2-17 yrs, CSFII (USDA) 1989-91 vs. 1994-95

One can of soda/day = 150 cal x 365 d/yr ÷ 3500 cal/lb = 15.6 lbs/yr

High Fructose Corn Syrup

- Current US annual consumption of HFCS
- 63 pounds per person

High Fructose Corn Syrup is 42-55% Fructose; Sucrose is 50% Fructose

10 Most Obese States

- > 30% obese

10 Laziest States

- < 63% active
**Secular trend in fructose consumption**

Natural consumption of fruits and vegetables
• 15 gm/day

Prior to WWII (estimated):
• 16-24 gm/day

1977-1978 (USDA Nationwide Food Consumption Survey):
• 37 gm/day (8% of total caloric intake)

1994 (NHANES III):
• 54.7 gm/day (10.2% of total caloric intake)

Adolescents:
• 72.8 gm/day (12.1% of total caloric intake)
• 25% consumed at least 15% of calories from fructose


**The perfect storm from three political winds**
The perfect storm from three political winds

1. Richard Nixon and USDA Secretary Earl Butz (1973)
   • food should never be an issue in a presidential election
2. The advent of High Fructose Corn Syrup
   • invented in 1966 in Japan
   • introduced to the American market in 1975

Percent of Gross National Product spent on food, by country

Influence of corn sweeteners on the price of sugar

Juice is sucrose:
Change in BMI z-score in lower socioeconomic status children versus number of fruit juice servings per day
The perfect storm from three political winds

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3. The USDA, AMA, and AHA call for dietary fat reduction
   - Early 1970's: discovery of LDL
   - Mid 1970's: Dietary fat raises LDL (A → B)
   - Late 1970's: LDL correlated with CVD (B → C)
   - 1982: If A → B, and B → C, then A → C,
     therefore no A, no C

The macronutrient wars 1970-1980

Seven Countries
Correlation of CHD with dietary fat

Seven Countries
Correlation of CHD with dietary fat

The lipoprotein continuum

"Total LDL" won’t tell you particle number -
There’s more LDL↓ than LDL↓ at the same total concentration
**TG and HDL change with LDL sizing**

**The low-fat craze**

The content of low-fat *home-cooked* food can be controlled

But low-fat *processed* food means substitution with carbohydrate

Which carbohydrate?

Either

- High fructose corn syrup (55% fructose)
- Sucrose (50% fructose)

  e.g. Nabisco Snackwells® Oreos
  (−2g fat, +13g CHO (+4g sugars))

**Adulteration of our food supply**

Addition of fructose

- palatability (esp. with decreased fat)
- browning agent

Removal of fiber

- shelf life
- freezing

Substitution of trans-fats

- hardening agent, shelf life
- now being removed due to CVD risk

**Fructose is not glucose**

- Fructose is 7 times more likely than glucose to form Advanced Glycation End-Products (AGE’s)
- Fructose does not suppress ghrelin
- Acute fructose does not stimulate insulin (or leptin)
- Hepatic fructose metabolism is different
- *Chronic* fructose exposure promotes the Metabolic Syndrome

**Metabolism of Glucose**

Hepatocyte

- Glucose (80%)
- 96 kcal
- Insulin

Muscle

- Glucose (20%)
Ethanol is a carbohydrate

CH₃-CH₂-OH

But ethanol is also a toxin

<table>
<thead>
<tr>
<th>Acute ethanol exposure</th>
<th>Acute fructose exposure</th>
</tr>
</thead>
<tbody>
<tr>
<td>• CNS depression</td>
<td>• Hypothermia</td>
</tr>
<tr>
<td>• Vasodilatation, decreased BP</td>
<td>• Tachycardia</td>
</tr>
<tr>
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<td>• Myocardial depression</td>
</tr>
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<td>• Tachycardia</td>
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<td>• Diuresis</td>
<td>• Hypoglycemia</td>
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<td>• Loss of fine motor control</td>
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Relations between fructose, uric acid and hypertension in NHANES IV adolescents


Relations between fructose, uric acid and hypertension in NHANES IV adolescents

Fructose increases de novo lipogenesis in normal adults

Fructose increases de novo lipogenesis, triglycerides and free fatty acids in normal adults

Faeh and Schwarz, Diabetes 54:1907, 2005

Sugar sweetened beverages (kcal/day)

Associations between sugar sweetened beverage consumption and ALT in obese children

African American (n = 80)

Caucasian (n = 163)

r = 0.22

P = 0.049

r = 0.20

P = 0.119

 отметить певчего
Protein Glycation and the Metabolic Syndrome

The furan ring of fructose is more unstable, so at equilibrium, fructose exists in the linear form.

Generation of reactive oxygen species by carbohydrate

Non-enzymatic glycation: fructose >> glucose

Serum fructose levels after 75 gm (300 kcal) oral bolus
**Serum fructose levels after 75 gm (300 kcal) oral bolus**

![Graph showing serum fructose levels over time][1]


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**Hepatocyte death in vitro upon fructose exposure (after generation of H₂O₂)**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>ED₅₀</th>
<th>ED₅₀ (with H₂O₂)</th>
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<tbody>
<tr>
<td>Fructose</td>
<td>1.5 ± 0.13 M</td>
<td>12 ± 2 mM</td>
</tr>
<tr>
<td>Glucose</td>
<td>&gt;1.5 M</td>
<td>1.5 M</td>
</tr>
<tr>
<td>Glycoaldehyde</td>
<td>20 ± 2 mM</td>
<td>0.5 ± 0.1 mM</td>
</tr>
<tr>
<td>Glycerol</td>
<td>5 ± 0.5 mM</td>
<td>0.02 ± 0.002 mM</td>
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Prevented by addition of:
- Antioxidant vitamins (VitB₁, VitB₆, VitC)
- P₄₅₀ inhibitors
- Hydroxyl radical and carbonyl scavengers
- Heavy metal chelators

Lee et al. Chemico-biological Interactions 178:332, 2009

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**Chronic ethanol exposure**
- Hematologic disorders
- Electrolyte abnormalities
- Hypertension
- Cardiac dilatation
- Cardiomyopathy
- Dyslipidemia
- Pancreatitis
- Malnutrition
- Obesity
- Hepatic dysfunction (ASH)
- Fetal alcohol syndrome
- Addiction

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1st pass GI metabolism 0% 10%
Calories reaching liver 90 92

**Calories**
- Alcohol: 90 kcal (7 kcal/gm)

**Percent CHO**
- Sugar: 10.5% (sucrose), 3.6% (alcohol)
- Alcohol: 3.6% (alcohol)

**Calories from**
- Fructose: 75 kcal (4.1 kcal/gm)
- Other carbs: 75 kcal (glucose), 60 kcal (maltose)
- Alcohol: 75 kcal (4.1 kcal/gm)
- Alcohol: 60 kcal (maltose)
**What's the difference?**

| Calories | 150 | 150 |
| Percent CHO | 10.5% (sucrose) | 3.6% (alcohol) |
| Calories from | | |
| fructose | 75 (4.1 kcal/gm) |
| other carbs | 75 (glucose) | 60 (maltose) |
| alcohol | 90 (7 kcal/gm) |
| 1st pass GI metabolism | 0% | 10% |
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**Recognition at the American Heart Association**

**AHA Scientific Statement**

*Dietary Sugars Intake and Cardiovascular Health*  
*A Scientific Statement From the American Heart Association*  
Rachel K. Johnson, PhD, MPH, RD, Chria Lawrence J. Appel, MD, MPH, FAHA;  
Michael Brains, PhD, FADA, Barbara V. Howard, PhD, FADA;  
Michael Letts, PhD, FADA, Robert J. Lavelle, MD; Frank Sacks, MD, FASA;  
Lyne M. Stetten, PhD, MPH, RD, FADA; Daniel W. Wirtz-Kerstel, PhD, RD  
on behalf of the American Heart Association Nutrition Committee of the Council on Nutrition, Physical Activity, and Metabolism and the Council on Epidemiology and Prevention

Recommends reduction in sugar intake from 22 tsp/day to 9 tsp/day (males) and 6 tsp/day (females)

**The First Law of Thermodynamics**

Obligate weight gain

**Calories Out**

**Calories In**

**Weight Gain**

**Recognition at the American Heart Association**
The First Law of Thermodynamics

Obligate weight gain

The two aberrant behaviors are a result of our biochemistry
Our biochemistry is a result of our environment

Collaborators

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