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Calling All Female Postdocs!

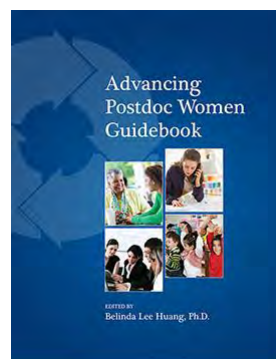


## NPA Advancing Postdoc Women Guidebook

**Tuesday, October 13, 2015**

**Webinar: 12PM – 1PM ET**

**Register: <http://bit.ly/1GsgdAZ>**



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Todd Smeltz, Math & Chemistry Teacher,  
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### “Halloween Candy Chemistry: Caramels, Gummies, Jellies, and Candy Corn”



**Silvana Martini**  
Associate Professor,  
Utah State University



**Rich Hartel**  
Professor of Food Engineering,  
University of Wisconsin-Madison

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## Halloween Candy Chemistry:

Caramel, Gummies, Jellies, and Candy Corn



Dr. Rich Hartel  
UW-Madison

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## Favorite Halloween Candy?



- Tootsie Roll
- Halloween taffy
- Lollipops
- Smarties
- Caramel
- Skittles
- Licorice cats
- PB cups
- Gummi bears
- Chocolate bars
- Nerds
- Oozing eyeballs
- Orange slices
- Skittles
- Jelly beans
- Candy pumpkins



**Any candy bar?**

[www.candywarehouse.com/halloweencandy.html](http://www.candywarehouse.com/halloweencandy.html)

## Audience Survey Question

ANSWER THE QUESTION ON BLUE SCREEN IN ONE MOMENT



**Name that candy bar?**

- Kit Kat
- Snickers
- 100 Grand
- Bar None
- Whatchamacallit

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## Name that candy bar?



Enrobed with  
chocolate

Caramel  
with peanuts

Nougat



[www.sci.mus.mn.us/sln/tf/c/crosssection/cbk.html](http://www.sci.mus.mn.us/sln/tf/c/crosssection/cbk.html)

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## Caramel

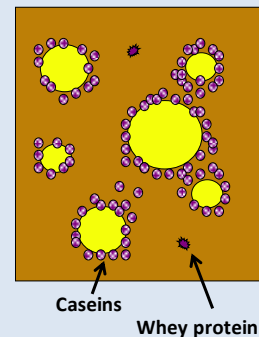
- Chewy candy made with sugars and milk ingredients
  - Brown color, caramel flavor
- Soft to runny or firm to hard
  - Water content of amorphous phase
- Texture
  - Chewy (no grain)
  - Short ( $\approx 10\%$  crystals)
  - Fudge ( $\approx 30\text{-}40\%$  grained)



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## Microstructure

- Amorphous phase
  - The glue that holds it all together
  - Water content, sugar type and content, milk, etc.
- Emulsification
  - Amount of fat, type of fat and its distribution
- Protein structure and distribution
  - Type and amount of protein;
  - Protein's initial state
- Graining
  - Amount and type of crystalline phase



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# Ungrained Caramel

Continuous phase  
- dissolved sugars and proteins

Fat globules

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# Grained Caramel

Continuous phase  
- dissolved sugars and proteins

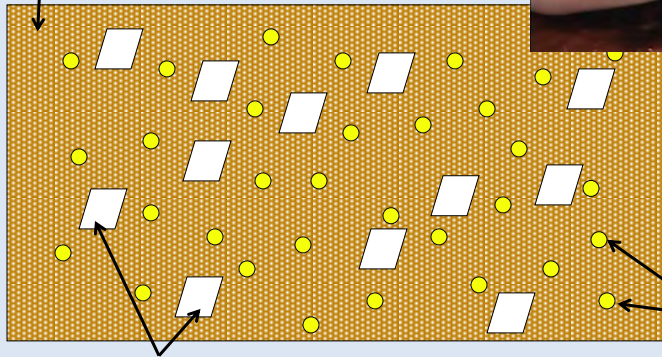
Sugar crystals

Fat globules

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## Fudge

Continuous phase  
- dissolved sugars and proteins



Fat globules

Sugar crystals  
(lots of them)



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## Cold Flow

- One of the primary concerns of caramel
- Cold flow is defined as gradual flow of the candy mass at room temperature
  - A product will gradually deform due to the force of gravity
  - Caramel is an amorphous material that slowly flows under its own weight
  - The structures within caramel (fat globules, protein aggregates, sugar crystals, etc.) help provide yield stress to prevent cold flow



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## Cold Flow

- Identical samples, except one has evaporated milk added
  - Cooked to 252° F (122° C)



1 day



2 day



5 day



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## Cold Flow



10 days



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## Gummy and Jelly Candies

- Sweetened candies that owe their firm texture to the solidification of the hydrocolloid
  - Color, flavor and acid for sour kick
- Water content is high: 18-25%
  - Without the hydrocolloid, the sweeteners would be in liquid form at this water content
  - Gelation of the hydrocolloid gives the structure to hold the fluid sweetener base in place



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## Gummy and Jelly Candies

Gummies - made with gelatin



Jelly Candies - made with other stabilizers

- starch (from various plant sources)
- pectin (from fruits)
- agar-agar (gelatin from seaweed or red algae)
- gum arabic (from trees)



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## Hydrocolloids Used

Type	Usage	Candies
Starch	11-15%	Jelly beans, sugar sanded, jujubes, etc.
Gelatin	6-8%	Gummies, marshmallow
Pectin	2-4%	Jelly beans, fruit slices
Gum arabic	20-40%	Cough drops, coatings
Agar	2%	Fruit slices
Flour	30%	Licorice



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## Hydrocolloid Comparison

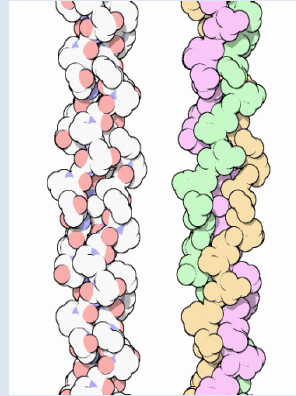
Stabilizer	Texture	Appearance
Starch	short easy to chew	cloudy opaque
Gelatin	elastic chewy, gummy	translucent
Pectin	short, tender brittle	transparent clear
Gum arabic	hard	translucent



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## Gelatin - Collagen

- Protein derived from collagen, found in the connective tissue and muscles of animals
- Collagen monomer
  - Long cylindrical protein
    - 2800 Å long, 14-15 Å diameter
  - Three chains wound together in a helix



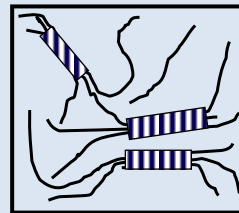
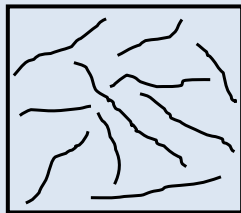
Source: [www.rcsb.org/pdb/molecules/pdb4\\_1.html](http://www.rcsb.org/pdb/molecules/pdb4_1.html)

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## Gelation Mechanism

- Gelation (sol-gel transition) occurs upon formation of junction zones by formation of intermolecular triple helices



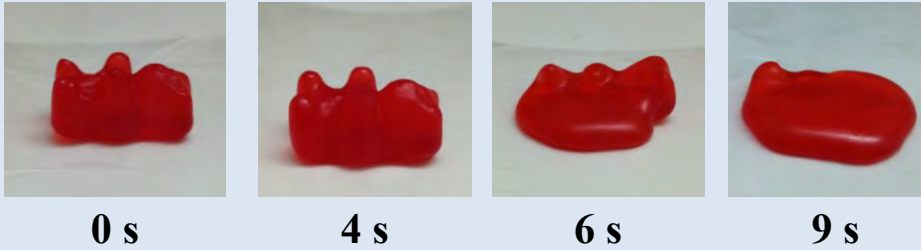
- Number density and size of these junction zones determines gel properties
  - Elasticity of gummy bears



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## Thermoreversibility

- Gelatin gel melts when temperature goes above melting point
- When cooled, gelatin gels once again
  - But usually not in the same shape



0 s

4 s

6 s

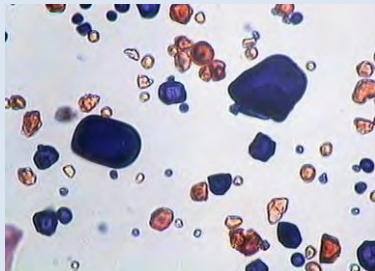
9 s



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## Starch Granules

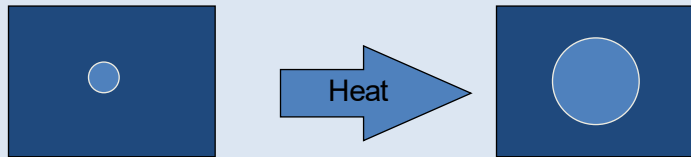
- Energy storage in plants
- Partially crystalline arrangement of glucose polymers amylose and amylopectin
- Vary in size and composition among plants



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## Starch Cooking

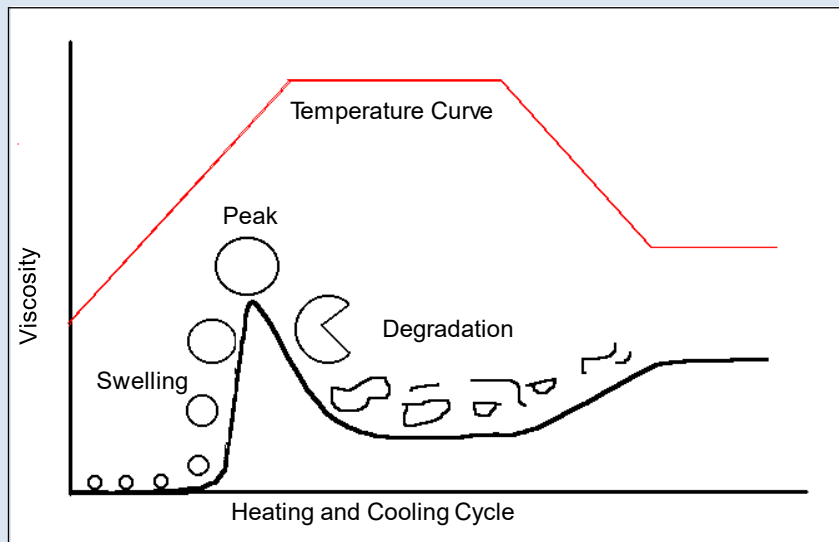


- Granule swells and takes in water when sufficient heat is added to the system
  - Need minimum water content (>30% in open kettle)
- The temperature at which the starch starts to thicken is called the ‘Pasting Temperature’
  - Typically, 60-70° C
- Pasting temperature increased by addition of sugars



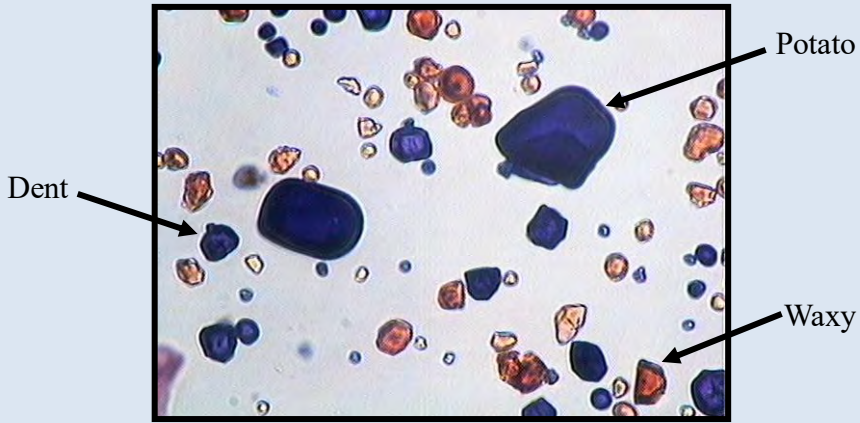
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## Starch Cooking Curve



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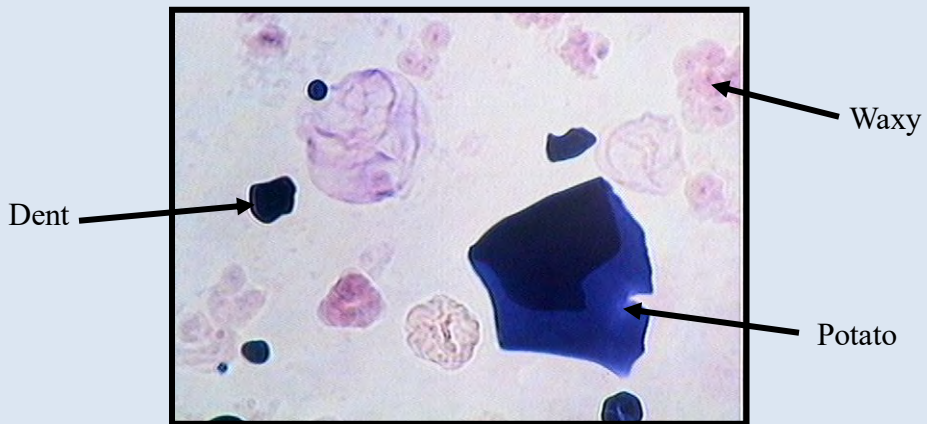
## Intact Granules



Picture Courtesy of M. Schwenk



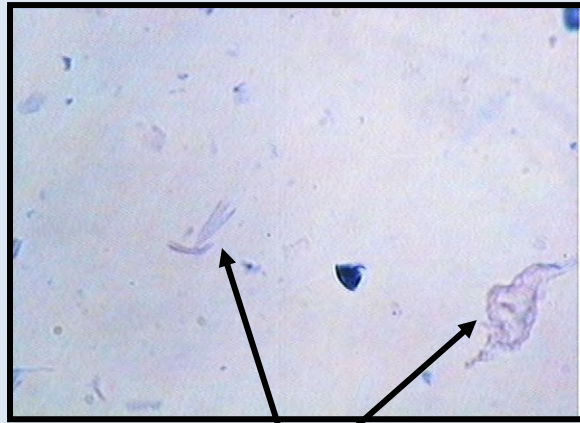
## Swollen Granules



Picture Courtesy of M. Schwenk



## Pasted Granules



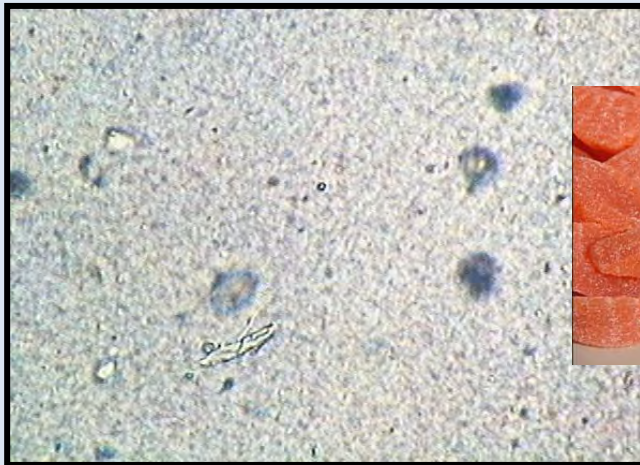
Starch Fragments

Picture Courtesy of M. Schwenk



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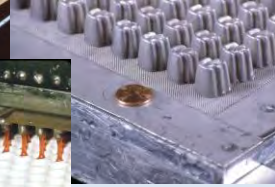
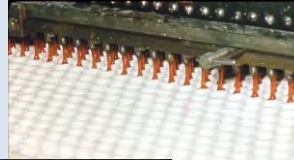
## Commercial Starch Jelly Candy



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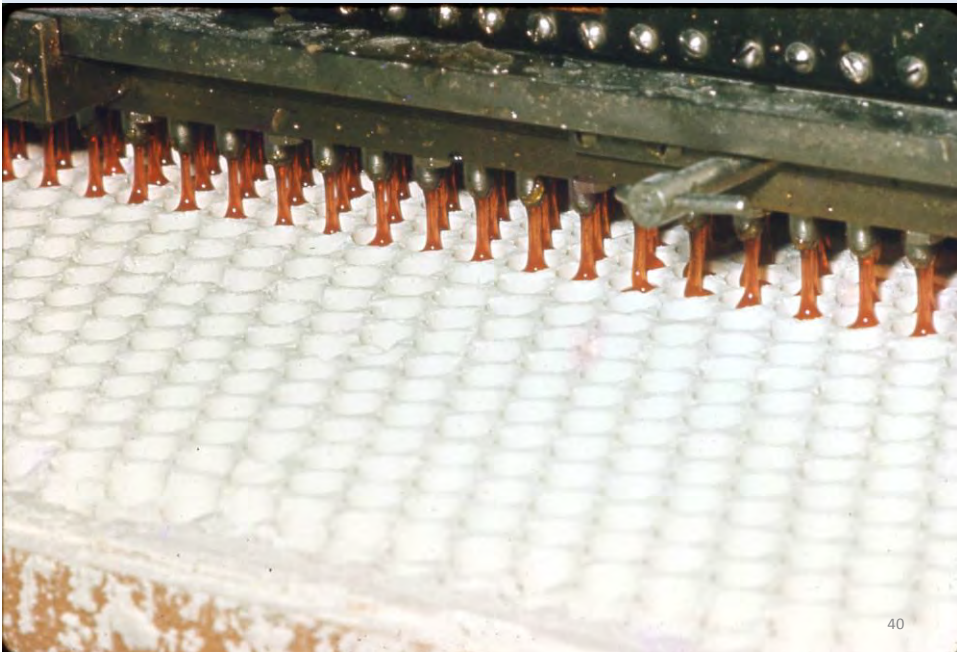
## Starch Mogul

- Depositing fluid candy into starch molds
  - Fill tray with corn starch
  - Press board makes depressions in starch
  - Depositor fills molds
  - Mogul stacks trays, stores overnight, and empties the next day



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## Depositing Candy Into Starch



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## Candy Corn

### Ingredients:

- Sugar
- Corn syrup
- Salt
- Honey
- **Soy protein**
- **Gelatin**
- Confectioner's glaze
- Dextrose
- Artificial flavor
- Titanium dioxide (color)
- Artificial colors



[www.candywarehouse.com](http://www.candywarehouse.com)



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## Mallow Creams

- Typical Recipe:
 

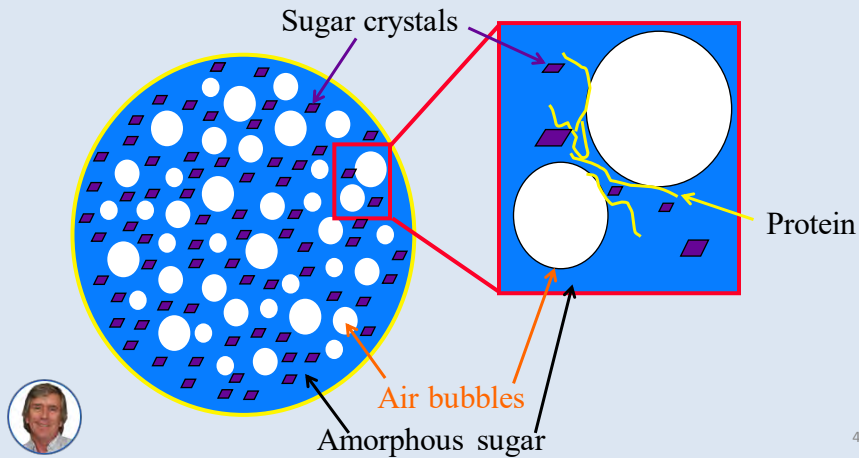
– Fondant (sugar crystals)	54%
– Frappé (air bubbles)	10%
– Thinning syrup	36%
– Color and flavor as desired	
- These would be deposited in molds, typically formed in molding starch, to form desired shapes
- Cooled and demolded for further process
  - Coating with wax/polish



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## Mallow Creams

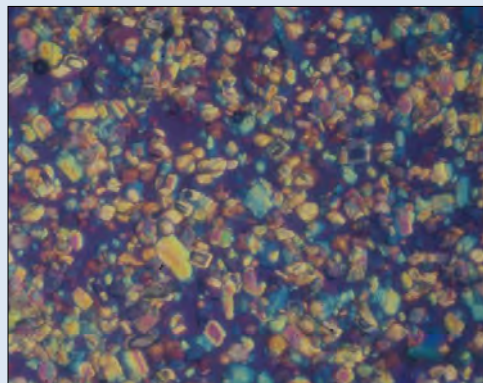
- Particles and bubbles packed tightly to give semi-solid (soft solid) characteristics



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## Fondant Crystalline Structure

- Crystal mass
  - 50 - 60%
- Number of crystals:
  - $360 \times 10^9$  #/mL
- Mean size:
  - 5 - 10  $\mu\text{m}$
- Size distribution:
  - none over 15 - 20  $\mu\text{m}$



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## Audience Survey Question

ANSWER THE QUESTION ON BLUE SCREEN IN ONE MOMENT



### What is the smallest sized particle that can be detected in the mouth?

- 100 microns
- 50 microns
- 20 microns
- 5 microns

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## Candy Corn Manufacture

- Mallow cream
  - Made by mixing fondant, frappé, thinning syrup
    - Fondant: highly crystallized sugar matrix
    - Frappé: marshmallow-like base, protein stabilizer
- Deposited into starch in 3 different layers to get multi-colored piece
- Dry/set overnight
- Remove and apply glaze



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## Candy Corn Manufacture

- If too few crystals remain when deposited, the seeds melt initially, but then recrystallize uncontrolled to give white spots.



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### Audience Survey Question

ANSWER THE QUESTION ON BLUE SCREEN IN ONE MOMENT



**Final Exam:** What's your favorite type of candy discussed today?

- Chocolate candy bars
- Caramels
- Gummies and Jellies
- Candy Corn

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## Lessons Learned

- Chemistry in your Halloween Candy Bag
  - Reaction chemistry
  - Phase behavior
  - Rheology
  - Sugar chemistry
    - Phase transitions/crystallization/amorphous
  - Hydrocolloid/protein chemistry
  - Enzyme chemistry – invertase in Cordial cherries
  - Water chemistry
  - Flavor and color chemistry
  - Many others



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