



# How Sweet It Is Chemistry 1010



# Introduction

What is the difference between these three products?

**Pepsi**



Ingredients – carbonated water, high fructose corn syrup, caramel color, sugar, phosphoric acid, caffeine, citric acid, natural flavors

**HFCS, sugar**

**Pepsi  
Throwback**



Ingredients – carbonated water, sugar, caramel color, phosphoric acid, caffeine, citric acid, natural flavors

**sugar**

**Diet Pepsi**



Ingredients – carbonated water, caramel color, aspartame, phosphoric acid, potassium benzoate, caffeine, citric acid, natural flavors

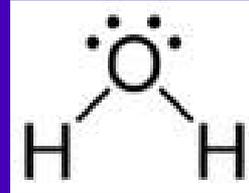
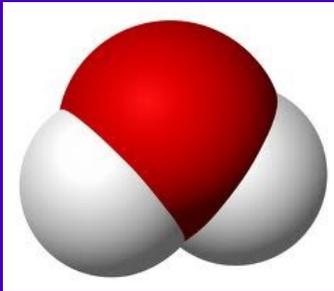
**aspartame, potassium benzoate**

What is the purpose of each of these ingredients?

1) What does carbonated water contain?

water and carbon dioxide

water  
 $H_2O$



Why is water the first ingredient?

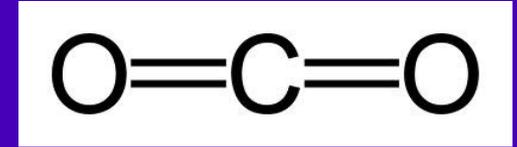
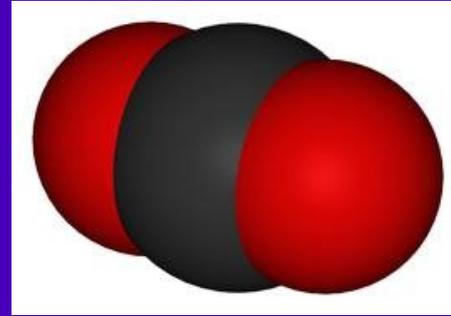
all three products are mostly water

Is this true for other beverages?

yes!

What is the carbon dioxide there for? **makes it fizzy**

**carbon dioxide**  
**CO<sub>2</sub>**



What happens if you leave a soda sitting out?

**it goes flat – all of the CO<sub>2</sub> leaves**

How is Pepsi made in when you buy it at a restaurant?

**carbonated water is added to a syrup**

**even though these are chemically two ingredients,  
they are listed together**

## 2) What is the purpose of these compounds?



**high fructose  
corn syrup**



**sugar**



**aspartame**

**add sweetness**

**What does the Nutrition Facts table say about the amount of sugars in each product?**

**Pepsi – 41 g**

**Throwback Pepsi – 40 g**

**Diet Pepsi – 0 g**

**How much aspartame is found in Diet Pepsi? 118 mg**

### 3) What is the purpose of caramel color?



mostly for color, also flavor, and as an emulsifying agent (helps water and oils stay together)

#### **caramel color**

How is caramel color traditionally made?

by heating sugars to 320°F

How is caramel color made now?

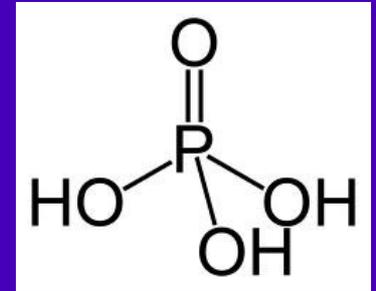
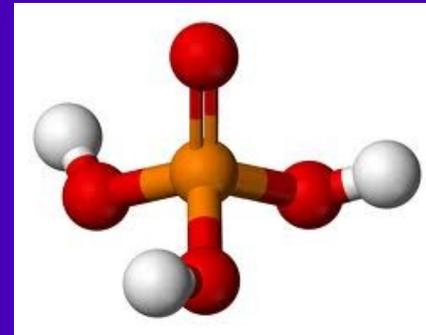
ammonia, sulfites, high pressure are used

What else is caramel color used in?

steak sauce, soy sauce, beer, pancake syrup, rolls, donuts, gravy mixes, etc

#### 4) What is the purpose of adding phosphoric acid?

phosphoric acid  
 $\text{H}_3\text{PO}_4$



tartness, slows growth of molds and bacteria

What concern has been raised by health food advocates?

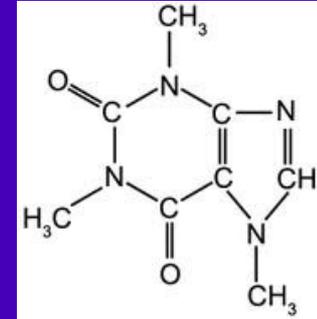
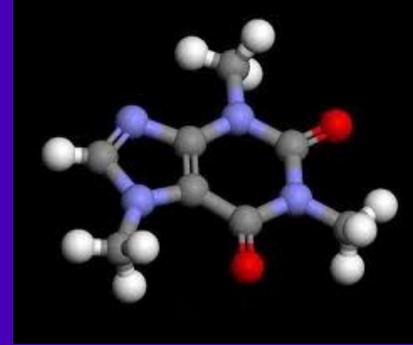
many internet articles claim that phosphoric acid leeches calcium from bones (search for “phosphoric acid in soda”)

Is it justified?

maybe...

## 5) What is the purpose of the caffeine?

**caffeine**  
**C<sub>8</sub>H<sub>10</sub>N<sub>4</sub>O<sub>2</sub>**



**it is a stimulant, and it is habit-forming**

**How much caffeine does a 12 oz can of Pepsi contain?**

**38 mg (a cup of coffee has 150-200 mg)**

**Where does the caffeine come from?**

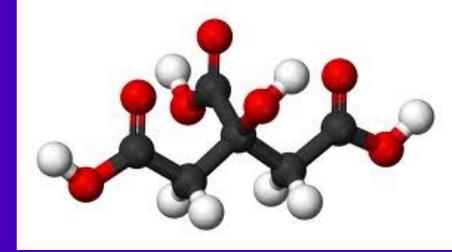
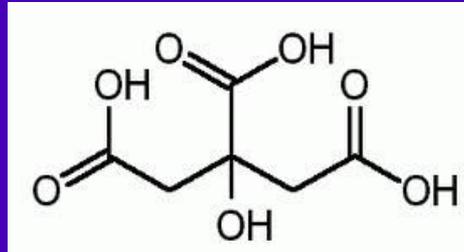
**decaffeinated coffee**

**What is the half-life of caffeine in a healthy adult?**

**about 5 hours**

## 6) What is the purpose of citric acid?

**citric acid**



**adds tartness**

**Is there any truth to the concern that the acid in cola drinks will eat away your tooth enamel?**

**it is possible, but...**

**orange juice is more acidic than cola drinks**

**consider saliva, time factors, etc...**

## 7) What are natural flavors, and what is their purpose?



this is what the company gets to keep secret!

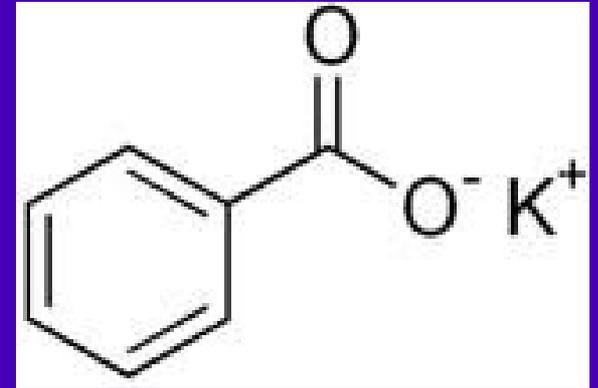
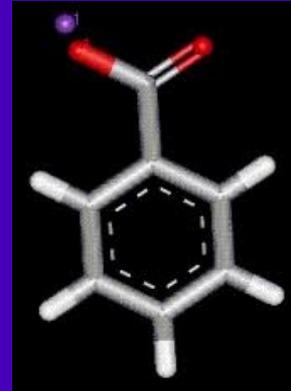
what gives Pepsi its distinct flavor

What are some guesses as to what they may be?

orange oil, lemon oil, vanilla, cola nut

## 8) What is the purpose of potassium benzoate?

potassium benzoate  
 $C_7H_5O_2K$



preservative, prevents growth of fungi, mold, and some bacteria

Why is it found only in Diet Pepsi?

high sugar content acts as a preservative

# So what is Pepsi made of?



=



carbonated  
water

+



high fructose  
corn syrup

+



caramel color

+



sugar

+



phosphoric  
acid

+



caffeine

+



citric acid

+



natural flavors

Which of these are compounds, and which are mixtures?

Now let's focus on the sweeteners.

What are the five tastes that you can detect with your tongue?



**sweet**



**salty**



**sour**



**bitter**



**meaty**

# Sugar

What does “Made with Real Sugar” mean on the Pepsi Throwback can?



table sugar – what we usually think of when we say “sugar”  
also known as granulated sugar (especially in recipes)

# Where does table sugar come from?



**sugar cane**



**sugar beets**

What kind of climates do they grow in?

**tropical climates**

**temperate climates**

How much of the world's sugar comes from each?

**70%**

**30%**

Which has been used for a longer time?

**sugar cane has been known for thousands of years**

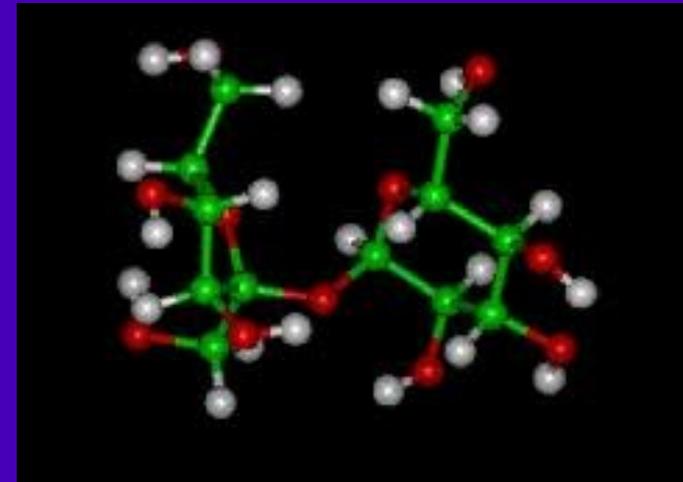
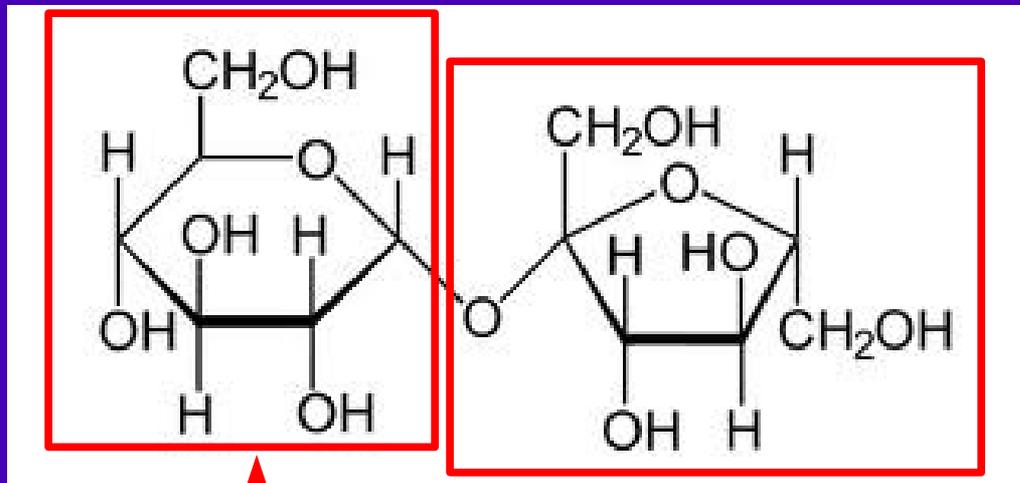
**sugar beets were first used in France in the 1800's**

# What is the chemical structure of table sugar?

chemical name: sucrose

formula:  $C_{11}H_{22}O_{11}$

structure:

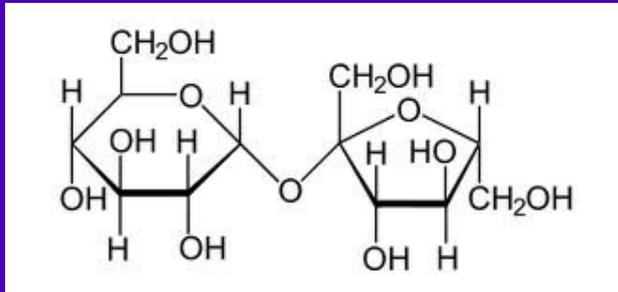


Why is it called a disaccharide?

made of two monosaccharides joined together

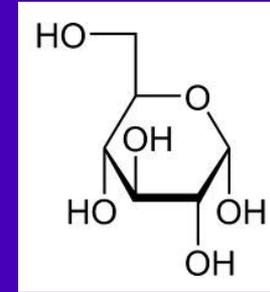
# What happens to sucrose during digestion?

1)



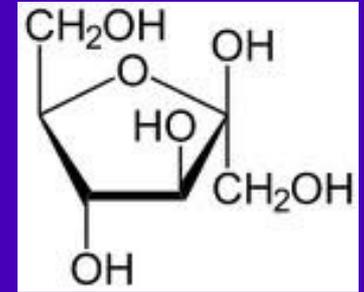
**sucrose**

+ **sucrase** →



**glucose**

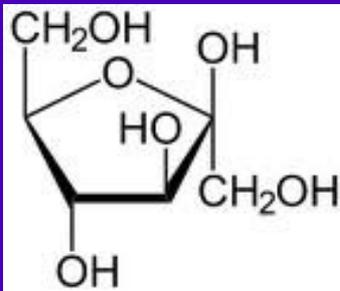
+



**fructose**

**enzymes break up sucrose into glucose + fructose**

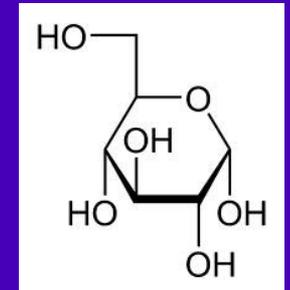
2)



**fructose**

+ **fructose-1-phosphate aldolase**  
+ **aldolase B** →

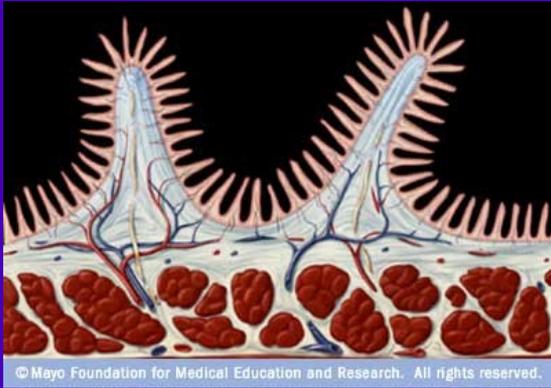
**enzymes**



**glucose**

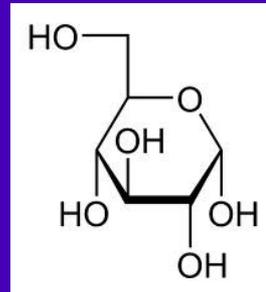
**enzymes convert fructose to glucose**

3)



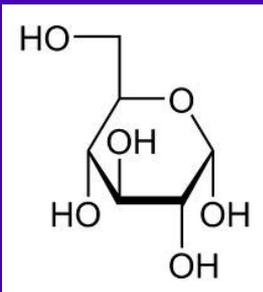
the glucose is absorbed by the bloodstream and carried to your cells

When you test your blood sugar, what compound is being detected?



glucose

4)



glucose + oxygen  $\rightarrow$  carbon dioxide + water + energy

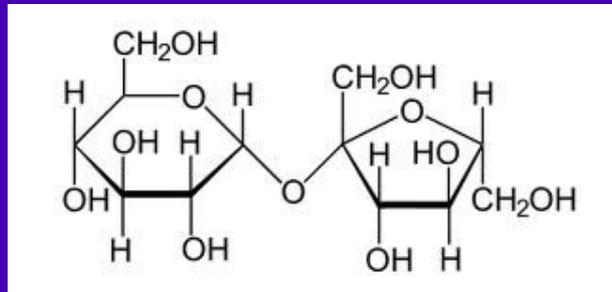
glucose is used by cells to obtain energy in cellular respiration

# High Fructose Corn Syrup (HFCS)

So if Throwback Pepsi contains regular table sugar, what kind of sweetener is in regular Pepsi?



sucrose



HFCS



What can you tell just from the name?

it's a syrup (thick, sweet liquid)  
comes from corn  
has a lot of fructose

How long has HFCS been used in Pepsi?

since the 1070's

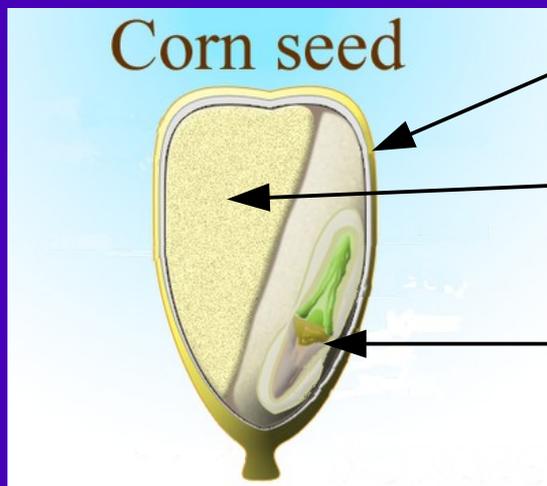
To understand where HFCS comes from, we need to look closely at a grain of corn.



What is the purpose of a grain of corn?

it's a seed – the plant makes it in order to make a new plant

What are the parts of a corn grain?



**bran** – protects the seed, high in fiber

**endosperm** – starch that stores energy for the new plant

**germ** – embryo that grows into a new corn plant; 25% corn oil, 3% protein, vitamins, minerals

# What do you get if you grind up the entire corn kernel?

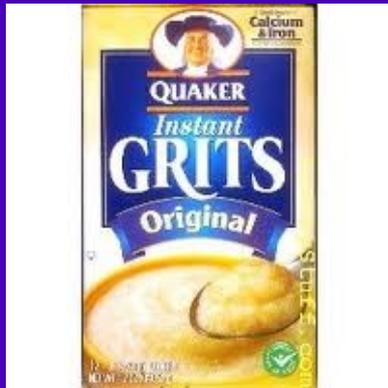
1)



**whole grain cornmeal**  
(similar to whole wheat flour)

the oil can go rancid,  
so store this in the refrigerator

2)



**grits** are coarsely ground corn  
grains (similar to cracked wheat)

3)



**regular cornmeal** (similar to white flour)  
most of the bran and germ have been removed

What do you get if you remove and purify just the endosperm?



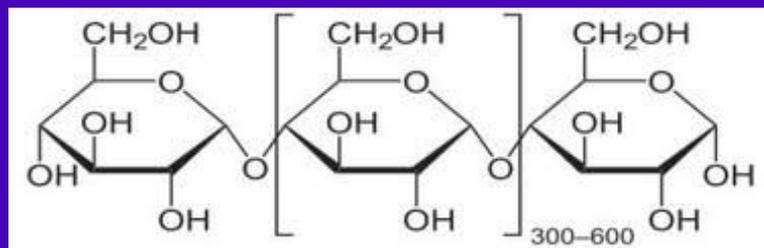
cornstarch

What is cornstarch used for in cooking?

thickening soup, gravy, etc



What is the chemical structure of cornstarch?



big chains of glucose connected together  
can be clipped apart into glucose molecules by the new plant

Does it taste sweet? no

# How is cornstarch made into high fructose corn syrup? **enzymes**

**cornstarch**



**corn syrup**



**HFCS**



**1,2**  
→

**3**  
→

**chains of glucose**

**glucose**

**glucose and  
fructose**

- 1) alpha-amylase breaks long chains of glucose into short ones**
- 2) glucoamylase breaks short chains of glucose into glucose molecules**
- 3) glucose-isomerase converts some glucose to fructose**

**What is corn syrup used for?**

**cooking and candy making  
keeps table sugar from crystallizing**

# What is the 3<sup>rd</sup> step for? Why not just use corn syrup? **sweetness**

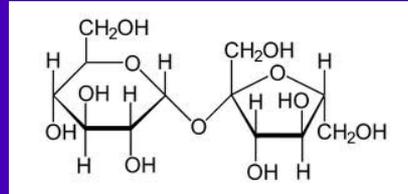
## sweetener

## structures

## sweetness

## comparison

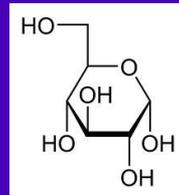
**table  
sugar  
(sucrose)**



**1.0**

**standard that others  
are compared to**

**glucose**



**0.74**

**not as sweet  
as table sugar**

**fructose**



**1.7**

**sweeter than  
table sugar**

**corn  
syrup**



**glucose**

**0.74**

**not as sweet  
as table sugar**

**HFCS**



**45% glucose  
55% fructose**

**1.0**

**about as sweet  
as table sugar**

# What other kinds of foods besides soda contain HFCS?



How do you know? **check the ingredients!**

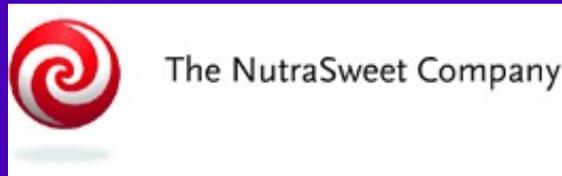
Are there some health concerns that have been raised about HFCS?

**yes! this will be our last group discussion**

## Aspartame

What sweetener is found in Diet Pepsi? **aspartame**

What brand name was aspartame originally known under?



**NutraSweet**

How is it different from the sweeteners in Pepsi and Throwback Pepsi?

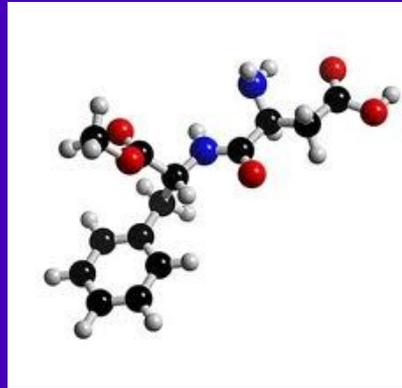
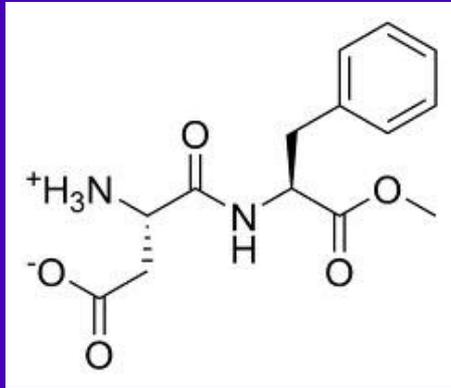
**no calories – it tastes sweet but isn't digested and used for energy like sucrose, glucose and fructose**

What does it look like?



**white powder**

What is its structure?

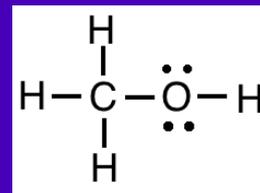
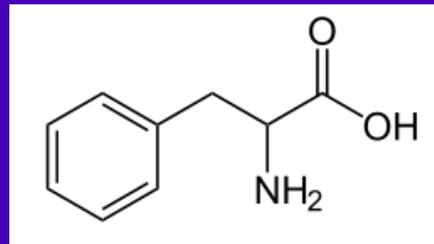
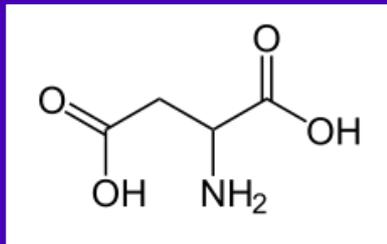


What two amino acids is it made from?

**aspartic acid and phenylalanine**

What happens when it is digested?

**it breaks down to the amino acids and methanol**



## How was it discovered?

In 1965, a chemist was making a potential antiulcer drug, got some on his finger, then licked his finger in order to pick up a piece of paper. He discovered that the compound was very sweet to the taste.

## How does its sweetness compare to sugar?

sucrose = 1.0

aspartame = 200

## What happens to aspartame when it is heated?

it decomposes

it can't be used in baking

diet soda should be stored away from heat

**Are there claims of negative health effects from aspartame?**

**lots and lots! everything from headaches to cancer**

**Have any been proven?**

**studies have failed to prove any of them**

**A 2007 medical review on the subject concluded that "the weight of existing scientific evidence indicates that aspartame is safe at current levels of consumption as a non-nutritive sweetener".**

**Is the customer free to decide?**

**yep! it's always listed on the label**