# CARBOHYDRATES $C_n(H_2O)_m$

**Mono**saccharides have **ONE** sugar: *eg.* glucose, fructose, ribose

**Di**saccharides have **TWO** sugars: *eg.* sucrose, maltose, lactose

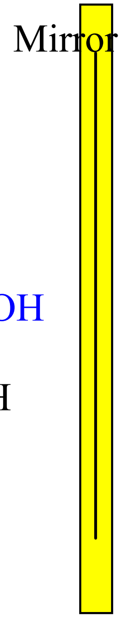
**Oligo**saccharides have a **FEW** sugars: *eg.* raffinose

**Poly**saccharides have **MANY** sugars: *eg.* starch, cellulose

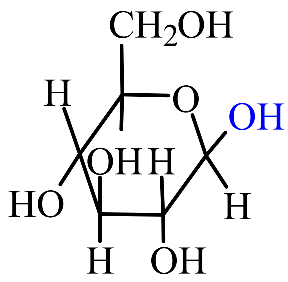
**Carbohydrates store water as well as being an energy source**

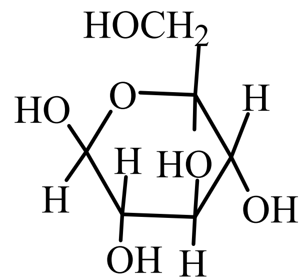
# MONOSACCHARIDES

## GLUCOSE $C_6H_{12}O_6$



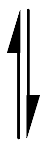

**β-(+)-D-glucose**
**note β = up**



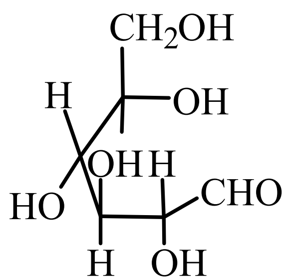




**(-)-L-Glucose**
**(not found in nature)**

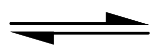
water

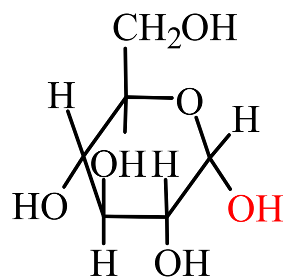


**open form**
**(low conc)**




water

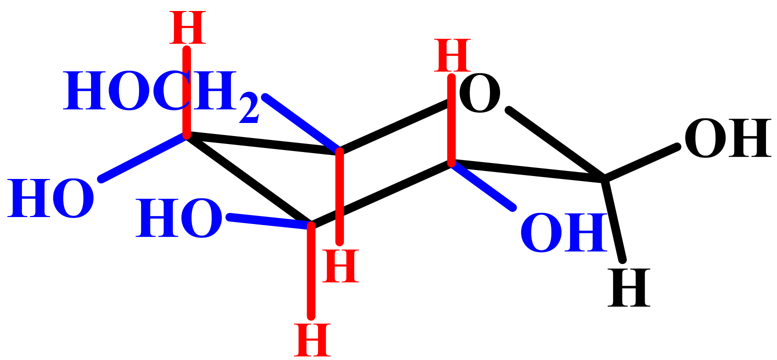





**α-(+)-D-glucose**
**note α = down**

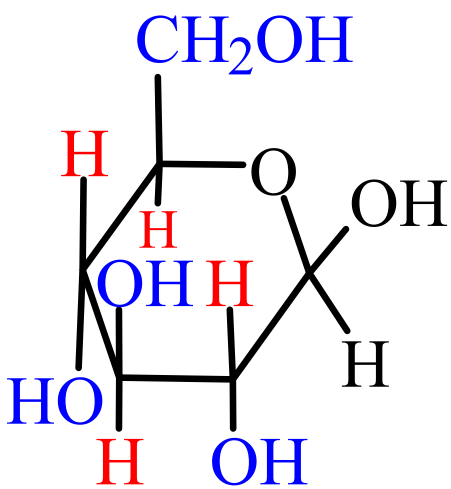
**β and α glucose are two different chemicals**

## Glucose = blood sugar = dextrose: needs no digestion




**Chair structure:**
**bonds are equatorial or axial**

**NOTE: in glucose all the H's are axial, all OH equatorial**

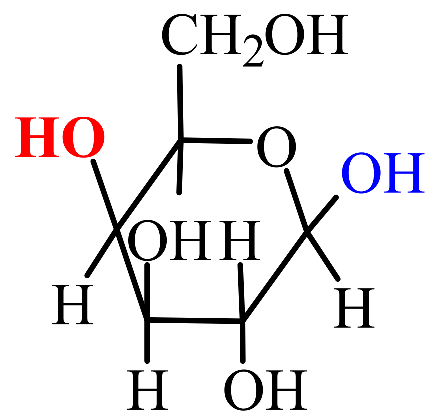



**Flat ring depiction: groups alternate**

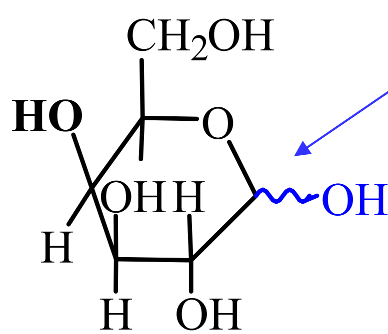
# IF YOU SWITCH AN OH GROUP, YOU CHANGE THE SUGAR

**(+)-D-Galactose**

**has this OH changed** →

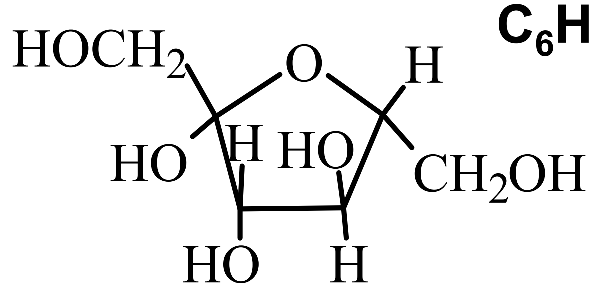



**note: this can still be α or β we show this with a wiggly line:**



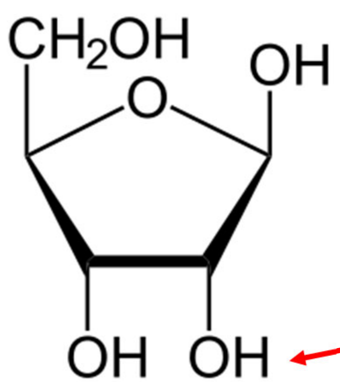

**Found in lactose**

**SOME SUGARS HAVE THE SAME FORMULA BUT MAKE 5-membered rings:** ***eg.*** **FRUCTOSE**




**$C_6H_{12}O_6$**

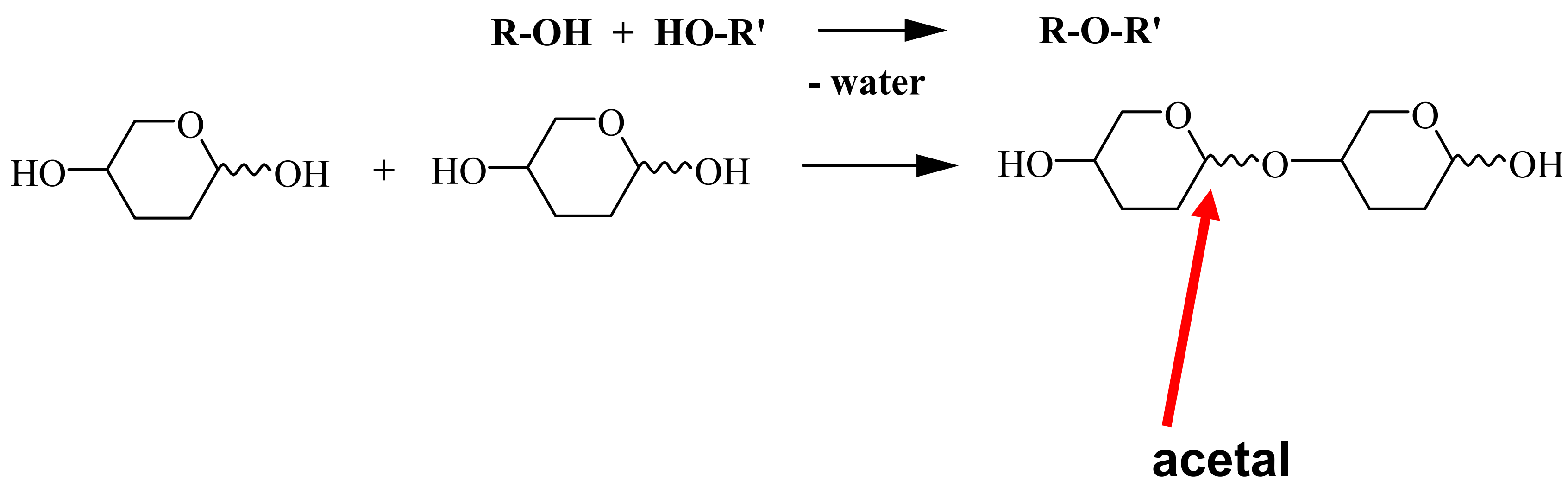
**Sweetest sugar**: ***'high fructose corn syrup'*** **need less to sweeten BUT fructose has been alleged** ***to lead to insulin resistance and promote type II diabetes (this is controversial)***




**(-) - D- Ribose used in RNA**

**(deoxyribose, used in DNA, has H instead of OH)**

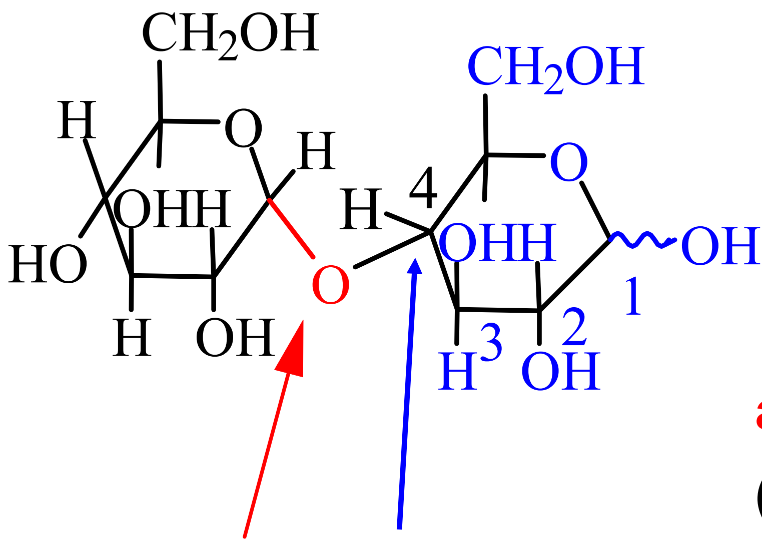
# DI-SACCHARIDES most important in foods




**two molecules of a mono-saccharide can 'condense' with loss of a molecule of water to form a disaccharide:**

$$2\ (C_6H_{12}O_6) - H_2O = C_{12}H_{22}O_{11}$$

## **MALTOSE** uses two glucose molecules, (+) sugar




**α-Glu-4-Glu**

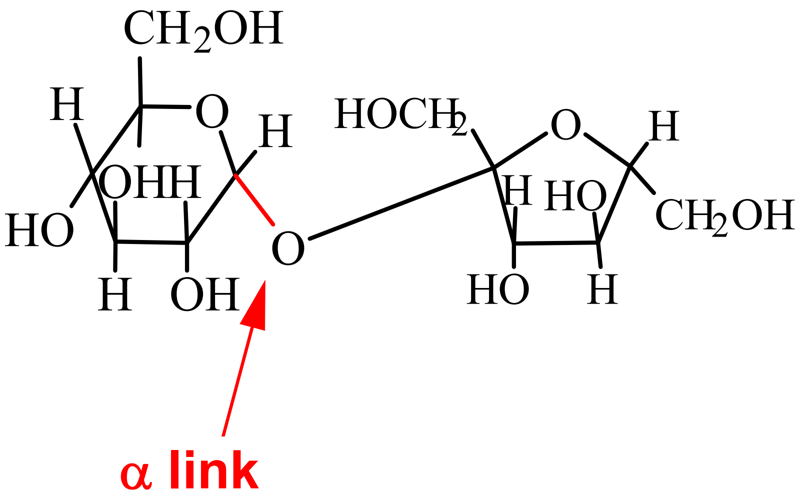
**animals can easily cleave α links (eg. salivary enzymes) to (in this case) 2 glucoses**

**α link** **4-link**

**Other salivary enzymes cleave starch to maltose: try chewing some bread: it gets sweeter as you chew**

**Note: this link is not interconvertible once formed,**
*i.e.* **α stays α, β stays β**

# SUCROSE: Table sugar (>80M tons/y)




α-Glu-(2)-Fru

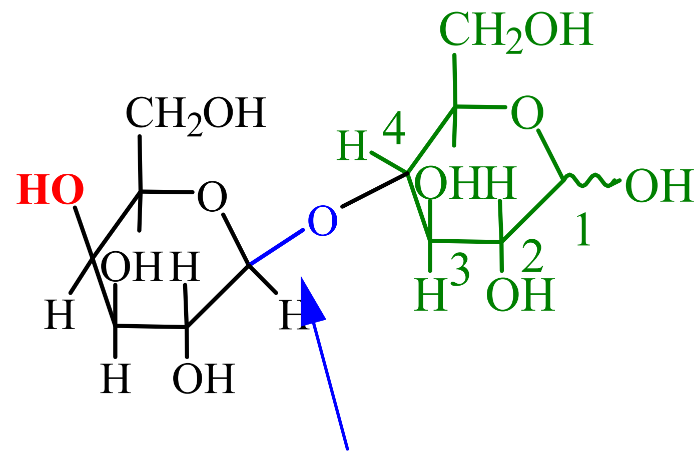
(+) sugar

So we can split this to glucose and fructose – we can only directly metabolize monosaccharides

The liver can inter-convert glucose and fructose as needed but as before too much fructose is not good!

# LACTOSE, Milk sugar (+)

Galactose →




β-Gal-4-Glu

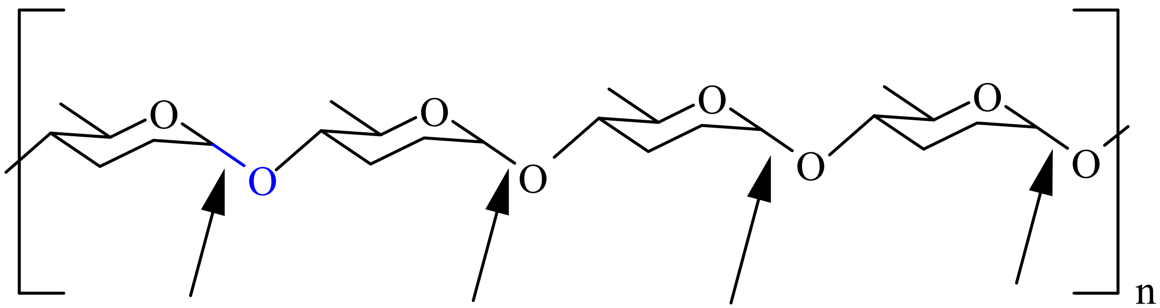
β link

**Babies have *lactase* which can cleave the β-link but many humans and all other animals LOSE this enzyme on weaning and so do not tolerate lactose well**

**Sweetness (relative): Fructose 1.7; Sucrose 1; Lactose 0.16**

# POLYSACCHARIDES

**STARCH, Amylose = water soluble portion of starch (20-25%)**



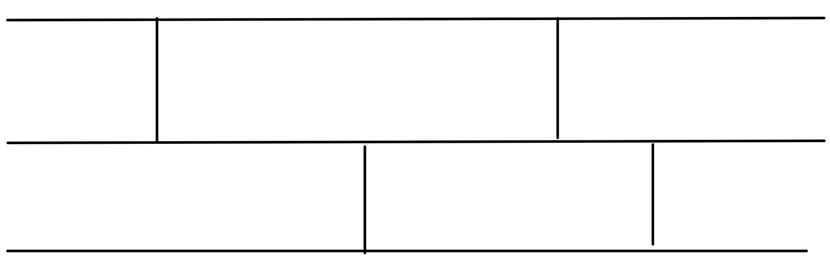

**AMYLOSE**

**$-[\alpha$-Glu-4-Glu-$]_n$-**

**ALL $\alpha$-links**

**n = 15-250**

**rest is AMYLOPECTIN**



**1000-5000 Glu units (3D) cross-linked using the $CH_2OH$**

**Plants store STARCH for energy usage**

**(plus a lot of water - they do not have to move!)**

**Animals use GLYCOGEN: stored in liver and muscles:**

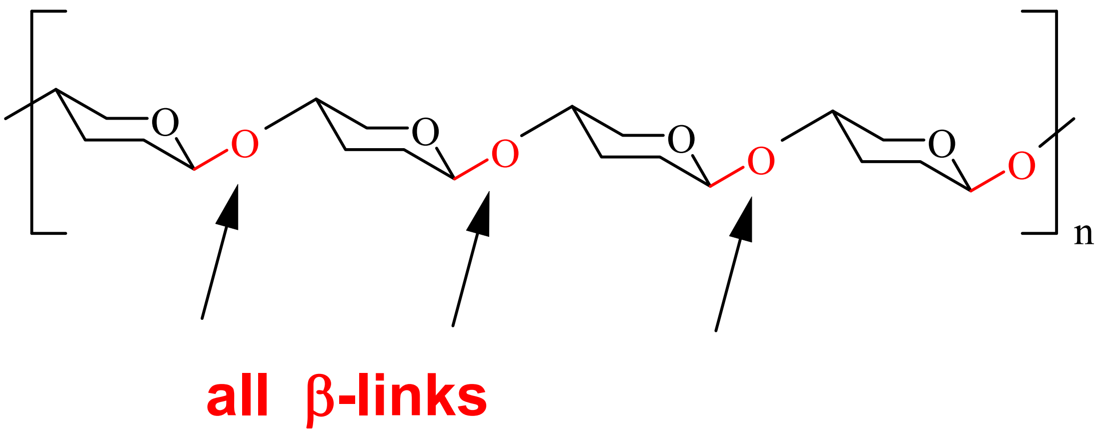
**branched/cross-linked but $\alpha$-links for fast breakdown to glucose**

**Starch cannot pass thru intestine, so to be absorbed, it is broken down by maltase into MALTOSE**

**Amylose when heated & cooled sets to gel: PUDDINGS, CANDIES**

**Amylopectin goes more pasty: GRAVIES, SAUCES**

# CELLULOSE




-[-β-Glu-4-Glu-]$_n$-

**Most animals lack cellobiase which can cleave the β-links**

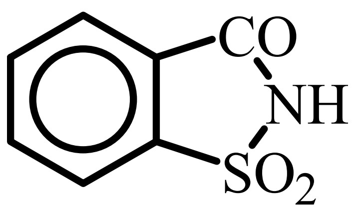
**Cows, goats, horses, termites, etc. have bacteria in their rumens (2nd stomach) which have the enzymes to cleave cellulose**

# SWEETENERS

**Lead acetate is sweet but toxic!! $Pb(OCOCH_3)_2$ - sugar of lead**

**Not much logic as to why things taste sweet**

**SACCHARIN discovered 1879! 300x sweeter than sucrose**






**‘Sweet & Low’ (US): granulated sugar substitute**
**dextrose (3.6%), saccharin (36 mg per 1g packet), cream of tartar and calcium silicate (an anti-caking agent)**

**Banned in Canada since 1977 for causing cancer in rats BUT**

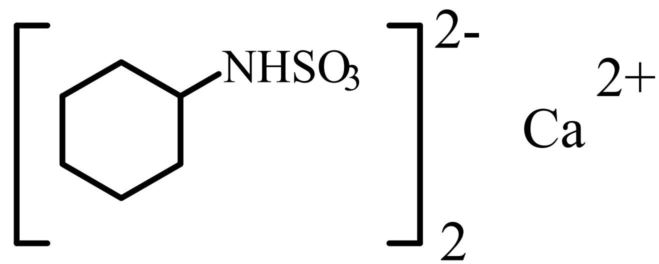
**Study used saccharin as 5% of diet (equiv to 800 cans/pop per day!)**

**Use was >200,000 kg/year in Canada in soft drinks at time of ban**

**Not banned in US (already had banned cyclamates)**

**Some get a *very bitter after-taste !***

**CYCLAMATE (1930)**
**30x sweeter than sucrose,**
**but no after-taste**




**Reached peak in 1969 with 7 Mkg /y (US) soft drinks**

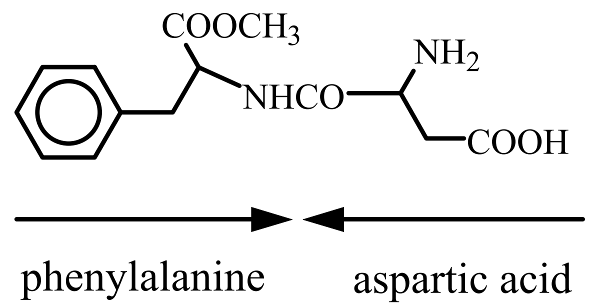
**Banned in US (1969) but not in Canada**

**Still approved in Canada, though not used in soft drinks**
**Sugar Twin = sodium cyclamate in Canada BUT saccharin in US**

# ASPARTAME (1965)

180x sweeter than sucrose,

texture of sugar




Peptide of amino acids phenylalanine and aspartic acid:

Use ~ 100mg (4 kcal/g) so about 0.4 kcal

Some (1 in 10,000) cannot metabolise phenylalanine:
(phenylketonuria) high levels of neurotransmitters, headaches

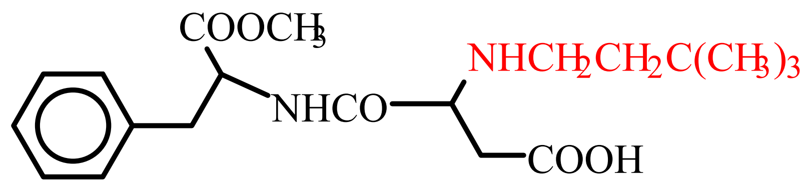
Use: 10 Mkg/yr in NA, 80% of NA market (70% in soft drinks)

Not so useful in cooked goods

*100's of web sites with 'information'!*

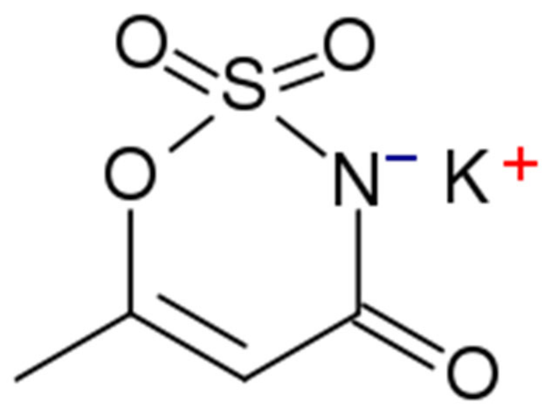
BEWARE SOURCES!!!

## NEOTAME (made by NutraSweet, 2002) ~$10^4$ x sweeter than sugar




**HEAT STABLE:**
**useful in baking**
*http://www.cfsan.fda.gov/~lrd/tpneotam.html*

## ACESULFAME-K (1967) 200 x sweeter than sugar (Sunett)

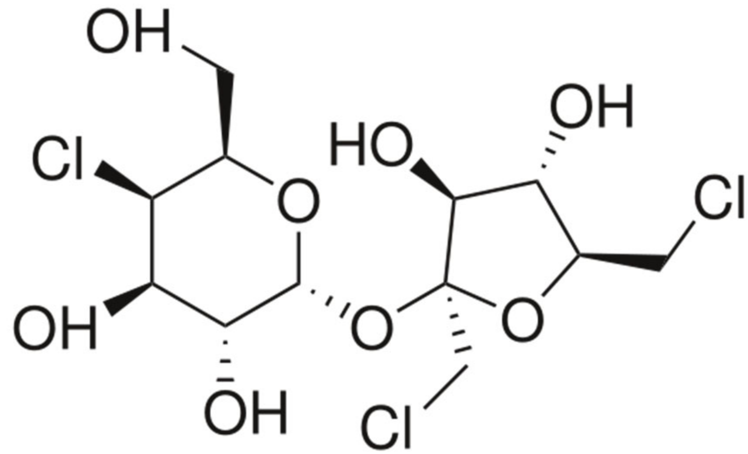



**Used in drugs, toothpaste, mouthwashes...**
**approved for foods, HEAT STABLE**

**popular in Europe for decades but only approved for general use in US in 2003**
*http://www.caloriecontrol.org/acesulf.html*

# SUCRALOSE 600 x sweeter than sugar

**Can (91) FDA (98) WHO (91)**

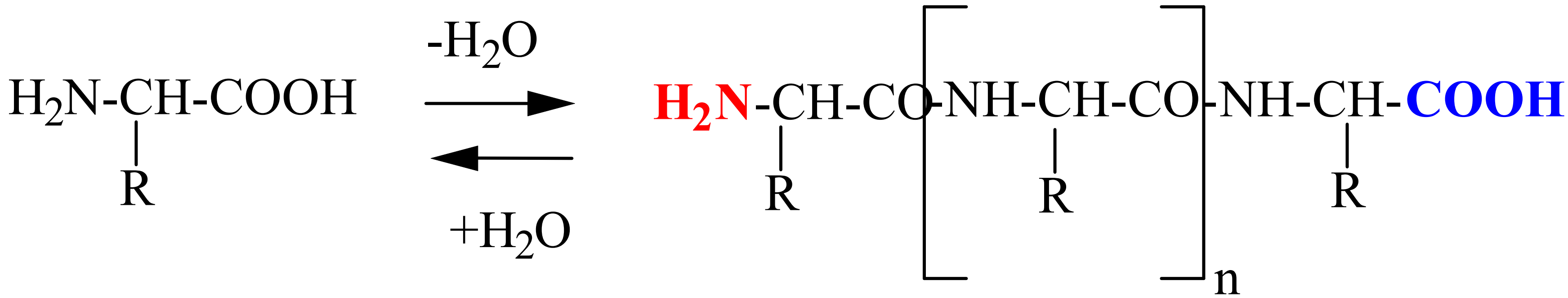

**'Chlorinated galacto-sucrose'** *i.e.* **Gal-Fru**

**More than 100 studies indicate no adverse affects:**
**Can. Diabetes Assoc. guidelines 1.65 g/d for life with no adverse effects *(equivalent to 1 kg sugar/d)***

**Fat insoluble: does not bio-accumulate**

# PROTEINS

**Proteins are polyamides (like nylon below) are made from amino acids:**

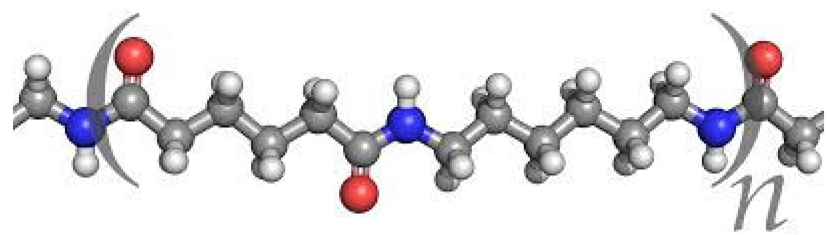



**aminoacid**

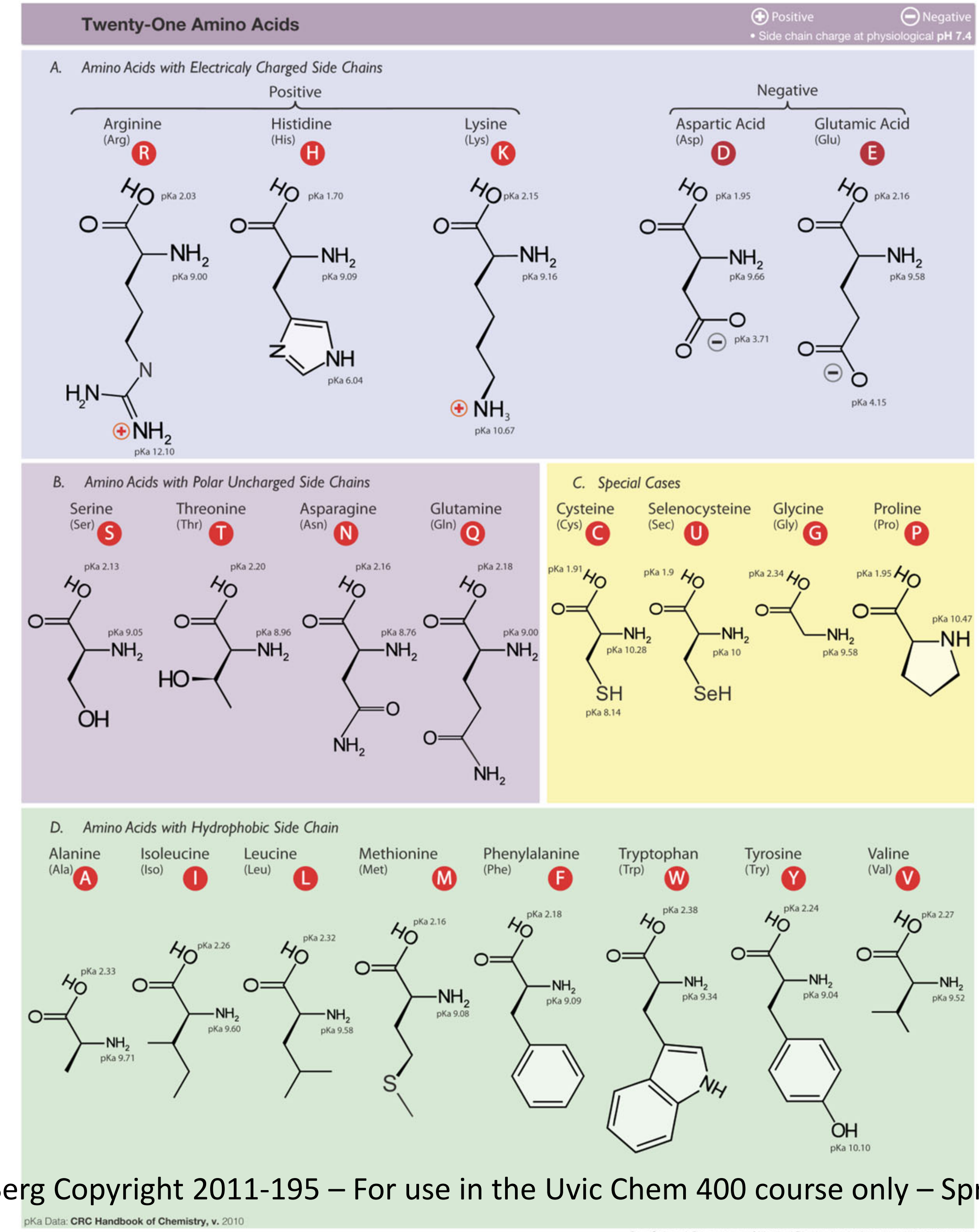
**protein (n=large),**
**peptide (n=small);**
**R’s are different**

**proteins and peptides have an AMINE END** **ACID END**

**Nylon-6,6**


**Proteins are not stored like fat and carbohydrates: constant breakdown and synthesis**


Twenty-One Amino Acids
Positive
Negative
• Side chain charge at physiological pH 7.4
A. Amino Acids with Electricaly Charged Side Chains
Positive
Negative
Arginine (Arg) R
Histidine (His) H
Lysine (Lys) K
Aspartic Acid (Asp) D
Glutamic Acid (Glu) E
B. Amino Acids with Polar Uncharged Side Chains
Serine (Ser) S
Threonine (Thr) T
Asparagine (Asn) N
Glutamine (Gln) Q
C. Special Cases
Cysteine (Cys) C
Selenocysteine (Sec) U
Glycine (Gly) G
Proline (Pro) P
D. Amino Acids with Hydrophobic Side Chain
Alanine (Ala) A
Isoleucine (Iso) I
Leucine (Leu) L
Methionine (Met) M
Phenylalanine (Phe) F
Tryptophan (Trp) W
Tyrosine (Try) Y
Valine (Val) V
pKa Data: CRC Handbook of Chemistry, v. 2010
Dan Cojocari, Department of Medical Biophysics, University of Toronto 2009

***wikipedia***

## PROTEINS IN THE DIET

| | |
|---|---|
| Humans have about | 10 kg protein, |
| need to replace about | 300 g daily; |
| recycle | ~230 g |
| so need to eat | ~30 g meat/fish/egg protein |
| and | ~40 g grain protein per day |

Most of us >100g/day

## CONTENT OF FOODS

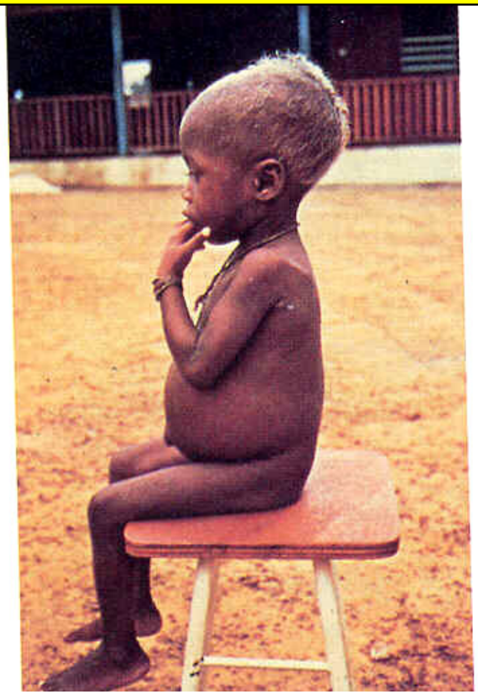
| FOOD | WATER | PROTEIN | FAT | CARBs. | kcal/100g |
|---|---|---|---|---|---|
| *Meats* | | | | | |
| Beef, broiled | 62 | 32 | 5 | 0 | 180 |
| Lamb, broiled | 61 | 28 | 9 | 0 | 200 |
| Chicken, broiled | 71 | 24 | 4 | 0 | 140 |
| Salmon, broiled | 64 | 27 | 7 | 0 | 180 |
| Oysters, raw | 85 | 8 | 2 | 3 | 66 |

| FOOD | WATER | PROTEIN | FAT | CARBs. | kcal/100g |
| --- | --- | --- | --- | --- | --- |
| *Grains* | | | | | |
| Bread | 36 | 10 | 3 | 50 | 250 |
| Rice (cooked) | 70 | 2-3 | 0-1 | 26 | 120 |
| Wheat flour | 12 | 14 | 2-3 | 68 | 360 |
| *Dairy* | | | | | |
| Milk | 87 | 3-4 | 3-4 | 5 | 65 |
| Cheese (cheddar) | 37 | 25 | 32 | 2 | 400 |
| Eggs | 74 | 13 | 11 | 1 | 160 |
| *Fruits* | | | | | |
| Apples | 84 | 0.2 | 0-1 | 15 | 60 |
| Banana | 76 | 1 | 0.2 | 22 | 85 |
| Almonds | 5 | 19 | 54 | 20 | 600 |
| *Vegetables* | | | | | |
| Potatoes | 75 | 2-3 | 0.1 | 21 | 90 |
| Corn | 74 | 3-4 | 1 | 21 | 90 |
| Cabbage | 94 | 1 | 0.2 | 4-5 | 20 |
| Tomatoes (raw) | 94 | 1 | 0.2 | 5 | 22 |
| Soybeans (cooked) | 74 | 10 | 5 | 10 | 120 |

## Some grains lack some aminoacids

| | |
|---|---|
| **CORN lacks** | **lysine and tryptophan** |
| **RICE** | **lacks lysine and threonine** |
| **WHEAT** | **lacks lysine** |
| **SOY** | **lacks methionine (need 2g/day of this one)** |

**KWASHIORKOR (= red boy) is common in Africa where corn is major food. Bloated, swollen belly, scaly skin, retarded growth, mental apathy**



**From an efficiency standpoint, consuming animal proteins is not necessarily the best option:**

**To produce 1kg of animal protein requires the following kg of feed:**

| | | | |
|---|---|---|---|
| Beef | 20 | Pork | 8 |
| Chicken | 5 | Eggs | 4 |
| Catfish/Carp | 2.5 | | |

**Animal protein sources have changed a lot over the last few decades (chicken was ~ equal to mutton in 1950):**

| | 1990 (M tons) | 2003 | Growth/y World |
|---|---|---|---|
| Beef | 53 | 59 | 0.8 |
| Pork | 70 | 96 | 2.5 |
| Mutton | 10 | 12 | 1.6 |
| Chicken | 41 | 76 | 4.9 |
| Ocean Fish | 85 | 93 | 0.8 |
| Farm Fish | 13 | 40 | 9.7 |

## High protein – low carb diets (Atkins, Paleo, Protein Power…)

**Result in *quick weight loss* because eliminating carbohydrates results in loss of body fluids, but…**

***according to the American Heart Association, are not effective long term:***

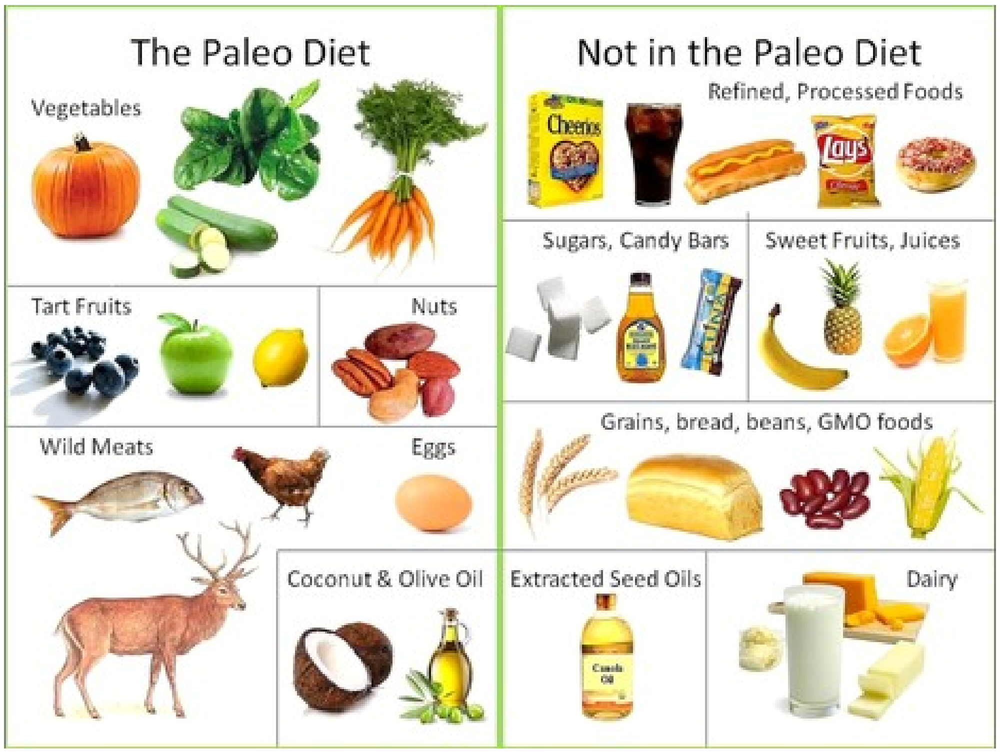
- **impede fat metabolism**
- **generally substitute carbohydrates with fats**
- **restricts mineral intake**
- **causes ketosis (and nausea)**
- **uremia (ammonia on breath)**
- **some cannot metabolize excess: liver/kidney disorders**

## Plenty of controversy here:

**USC longitudinal study over 18 years found high protein-low carb diet equivalent to smoking a pack of cigarettes/day and increased likelihood of early death 74%**

***but…***

**Proponents claim no account was taken to control lifestyle or starting fitness level**



**2002: Acrylamide, a potent carcinogen, identified in many popular foods such as fries, potato chips, cakes, bread, coffee, cookies** *See: http://www.who.int/foodsafety/publications/chem/en/acrylamide_summary.pdf*

**Comes from carb rich foods that are fried or baked**

**Source identified from amino acid asparagine + dicarbonyl compound from browned sugars**

$$H_2N\text{-}CO\text{-}CH_2CH<^{COOH}_{NH2} \quad + \quad R\text{-}CO\text{-}CHO$$

$$\downarrow \text{heat}$$

**Is this a risk?** $H_2N\text{-}CO\text{-}CH{=}CH_2$

**Maybe not: NOAEL *(no observed adverse affect limit)* is 500x higher at 0.5 mg/kg body weight than the amount in a normal portion of the worst offender, french fries (*ca.* 1.3 mg/kg or 25 mcg/server)**