DTN2PNU Principles of Human Nutrition
Lecture: Carbohydrates

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Today

- Types of dietary carbohydrate
- Sugars and starch
- Common food sources
- Artificial sweeteners
- Digestion and absorption
- Metabolism of dietary CHO
- Endogenous CHO production
- Fibre
- Carbohydrates & Disease: possible health risks associated with excess CHO intake
- Glycaemic response (GI & GL)

Required readings

- Whitney, E., Rolfes, SR, Crowe, T., Cameron-Smith, D. & Walsh, A. (2011). Understanding Nutrition: Australia and New Zealand Edition. South Melbourne, Australia: Cengage Learning Australia.
  - CHAPTER 4

What are carbohydrates?

Diverse group of substances

Varied chemical and physiological properties

Available CHO

- sugars
  - monosaccharide (glucose, fructose, galactose)
  - disaccharides (sucrose, maltose, lactose)
- starches
  - polysaccharides

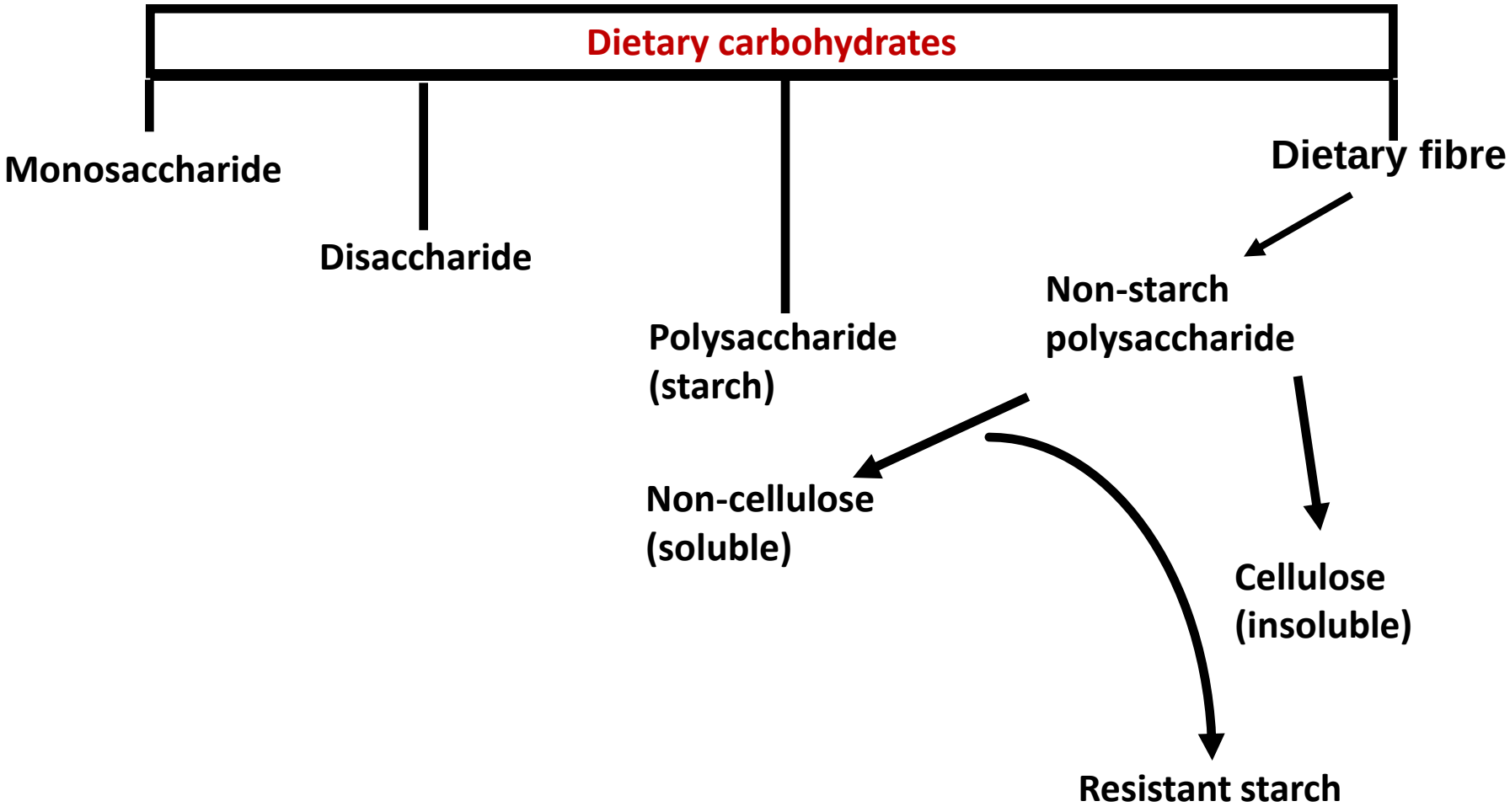
Non available CHOs

- resistant starch*
- dietary fibre (some types are available)

Reference:

**Baghurst PA, Baghurst KI, Record SJ. Dietary fibre: Non-starch polysaccharides and resistant starch: A review. Supplement to Food Aust 1996:48(3);S1-S36.*

What are carbohydrates?



Sugars/Monosaccharides

- 3 Principal Monosaccharides:
  - Glucose
  - Fructose
  - Galactose
- Building blocks of naturally occurind di-, oligo- and poly- saccharides
- Fructose is the sweetest of all the carbohydrates
- Free glucose and fructose occur in cooked/dried fruit and small amounts in raw fruit, berries and veggies

Disaccharides

Principal disaccharides:

- Sucrose (sugar)- found widely, in fruit, berries, vegetables, sugar cane, beets
- Lactose- main sugar in milk/dairy products

Other disaccharides:

- Maltose- sprouted wheat, barley
- Trehalose- yeast, fungi

Total CHO content of food

Food	*CHO (%)*	*Protein (%)*	*Fat (%)*
Flour (raw)	*72*	*11*	*1.2*
Bread (cooked cereal)	*47*	*10*	*4*
Fruit	*25*	*Neg*	*neg*
Green leafy vegs	*1-7*	*1*	*neg*
Root vegs	*10-20*	*1-2*	*neg*
Pulses or legumes (cooked)	*5-15*	*7-10*	*2-5*
Nuts	*5-20*	*15*	*50-60*
Milk (cows)	*3-4*	*3-4*	*3-4*

NUTTAB95

Artificial sweeteners

Nutritive (16 kJ/g)

- polyhydric alcohols or polyols (sorbitol, mannitol, xylitol)
- properties
  - absorbed more slowly than sugars
  - converted to fructose
  - associated with decreased cariogenicity

Non-nutritive

- saccharin
- aspartame *(Nutrasweet)*
  - aspartic acid + phenylalanine
- acesulfame-K *(Sunette /Sweet One)*
- cyclamate
- sucralose *(Splenda)*

Polyols/ Sugar-Alcohols

- Alcohols of glucose and other sugars eg. Sorbitol
- Found naturally in some fruits
- Made commercially- using aldose reductase to convert the aldehyde group of the glucose molecule to alcohol
- Used as a sucrose replacement to make “sugar free” products

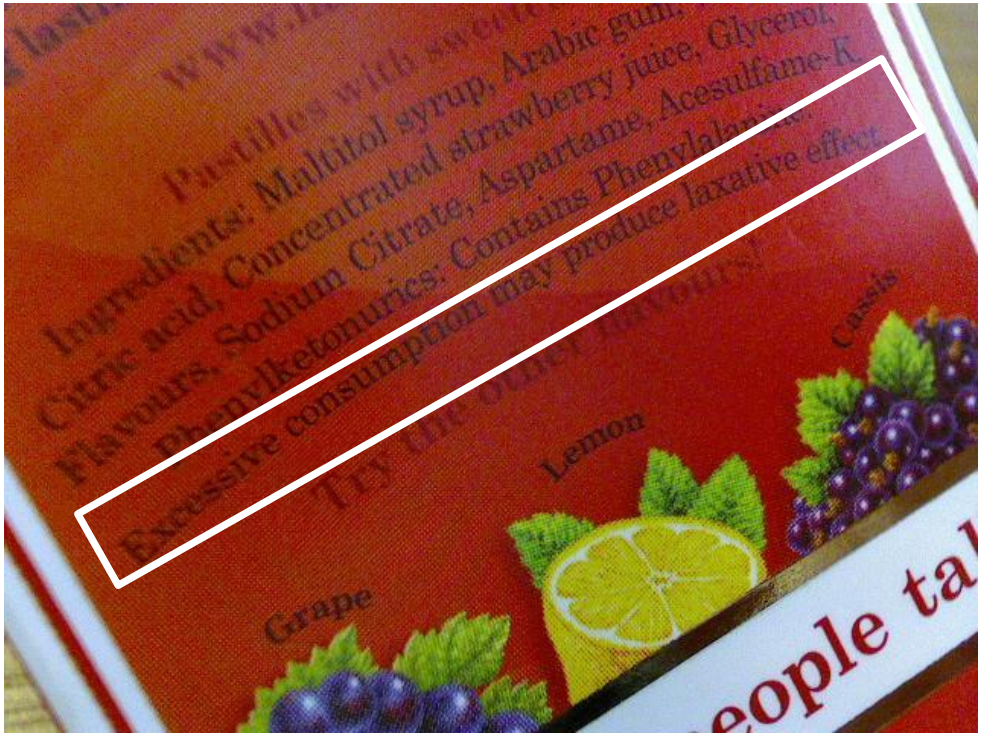
Polyols

- Sugar alcohols are neither sugars nor alcohols
- They are carbohydrates with a chemical structure that partially resembles sugar and partially resembles alcohol, but they don’t contain ethanol as alcoholic beverages do
- They are incompletely absorbed and metabolized by the body, and consequently contribute fewer calories

Relative sweetness of sugars/artificial sweeteners

sucrose	100
lactose	16
maltose	33
Sorbitol (artificial sweetener)	50
glucose	70
fructose	120
sodium cyclamate	3,000
Aspartame (artificial sweetener)	18,000
Saccharin (artificial sweetener)	40,000

Example- Malitol



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Why ‘Laxative Effect’?

- Polyols can have an osmotic effect- they attract and bind water
- The undigested polyols may be gut microbes producing gas as well as short chain fatty acids which can also have osmotic effects
- There is a lot of individual variation

Oligosaccharides

- Short-chain carbohydrates
- Degree of polymerisation 2-10, but more commonly >2 &<10
- Maltodexrins
- Other oligosaccharides:
  - Raffinose,verbacose eg. in lentils/beans
- Non-digestible oligosaccharides:
  - Not susceptible to brush-border enzyme breakdown
  - Fructans-Inulin, fructo-oligosaccharides eg. in artichokes
  - Become known as prebiotics

Polysaccharides

2 categories

- Starch polysaccharides (α-glucans)
- Non-starch polysaccharides (non-α-glucans)

Starch- storage carbohydrate of plants

- Granules comprised of 2 polymers- amylose and amylopectin
- Digestion depends on type A/B/C
- Starch not digested in the small intestine = resistant starch

Non-starch polysaccharides- mostly from plant cell walls

- Cellulose represents 10-30% NSP in foods
- Hemicellulose
- Pectins
- Gums & Mucilages
- Algal polysaccharides eg. Gennan, agar
- Fermented in the large intestine

Carbohydrates- Availability

Major sources worldwide are:

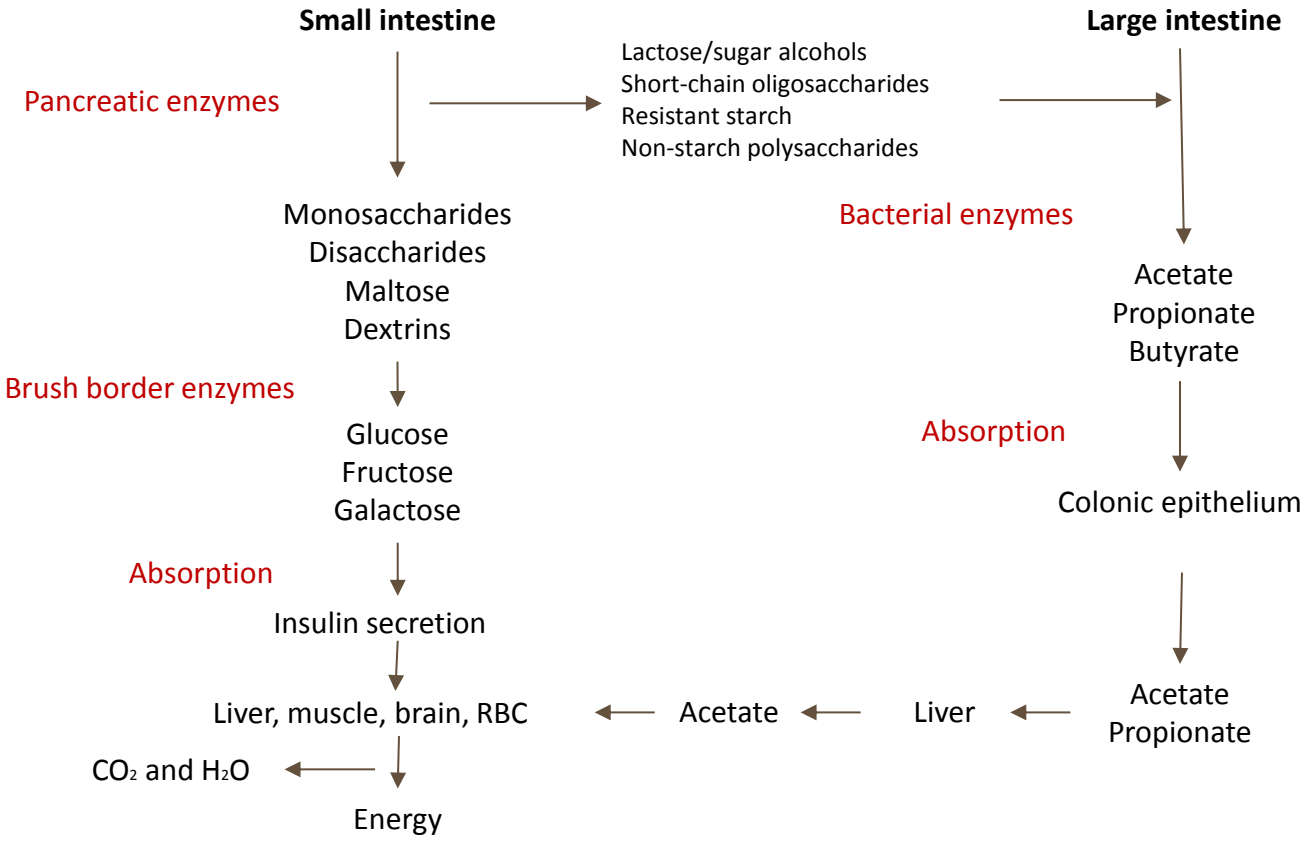
- Cereals
- Root crops
- Sugar cane & beet
- Pulses
- Vegetables
- Fruit
- Milk products

Carbohydrates- Digestion & Absorption

- CHO digestion starts in mouth
- Most absorbed in the upper part of small intestine, hydrolysed to monosaccharides prior to absorption
- Some CHO eg. Most oligos (except maltodextrins), some starch and all NSP, resist digestion and pass into the large bowel where they are fermented

Carbohydrates- Digestion & Absorption

Adapted from: Fig 2.4 pg.17 Mann & Truswell, 2007



Carbohydrates- Metabolism

- Concentration of blood glucose in humans is carefully controlled- insulin key player
- But these can rise and fall depending on eating/fasting
- Careful control is maintained through processes of:
  - Glycolysis- breakdown of glucose
  - Gluconeogenesis- conversion of non-carbohydrates to glucose
  - Glycogenolysis- conversion of stored glycogen to glucose
  - Glycogenesis- synthesis of glycogen from glucose

CHO Dependent Tissues

The following tissues are dependent on glucose as fuel:

- Red blood cells
- Brain
- Nervous system

How much glucose is stored as glycogen?

Blood glucose

- continually replenished by liver glycogen
  liver glycogen stores (85g)
- used for various functions (nervous system, blood)
  anywhere in the body

Muscle glycogen

- used only in the muscular site
  - approx 6000 kJ of stored energy

Recommended CHO intake

- No RDI/EAR or AI for carbohydrate (except in infants (<12 months)
- FAO/WHO
  - Recommends a minimum of 180g/d to prevent ketosis (FAO 1998)
- AMDR (Acceptable Macronutrient Distribution Range)
  - 45-65% of energy from CHO to total energy in the diet
  - From low energy density, low GI foods (Dept of Health and ageing et al. 2006, p. 77)
- Dietary guidelines for Australian adults relating to CHO (NHMRC et al. 2013) to eat:
  - Plenty of vegetables of different types and colours, and legumes/beans
  - Fruit
  - Grain (cereal) foods, mostly wholegrain and/or high cereal fibre varieties, such as breads, cereals, rice, pasta, noodles, polenta, couscous, oats, quinoa and barley
  - Limit intake of foods and drinks containing added sugars such as confectionary, sugar-sweetened soft drinks and cordials, fruit drinks, vitamin waters, energy and sports drinks.

Carbohydrate needs

- Glucose is an essential energy source for the brain, red blood cells and renal medulla- daily requirement about 180g/d
- Body can make up to 130g/d from non-CHO sources
- So minimum amount dietary CHO required per day to avoid ketosis = 50g/d (pregnancy 100g/d)
- kJ Value of Carbohydrates
  - 17kJ/g
  - Monosaccharides 15.7 kJ/g
  - CHO that reach the colon 6-8kJ/g

Fibre

History of Fibre

- 1937 Dr Dymock findings '*breakfast cereal all bran improved constipation in 90% cases studies in hospital environment*'
- Cleave introduced bran on ships in WWII as regulation of diet to treat constipation
- Dennis Burkett and Trowell investigated link between fibre (in diet) and bowel cancer in 1960s

5 serves of vegetables/salads a day = 2½ cups

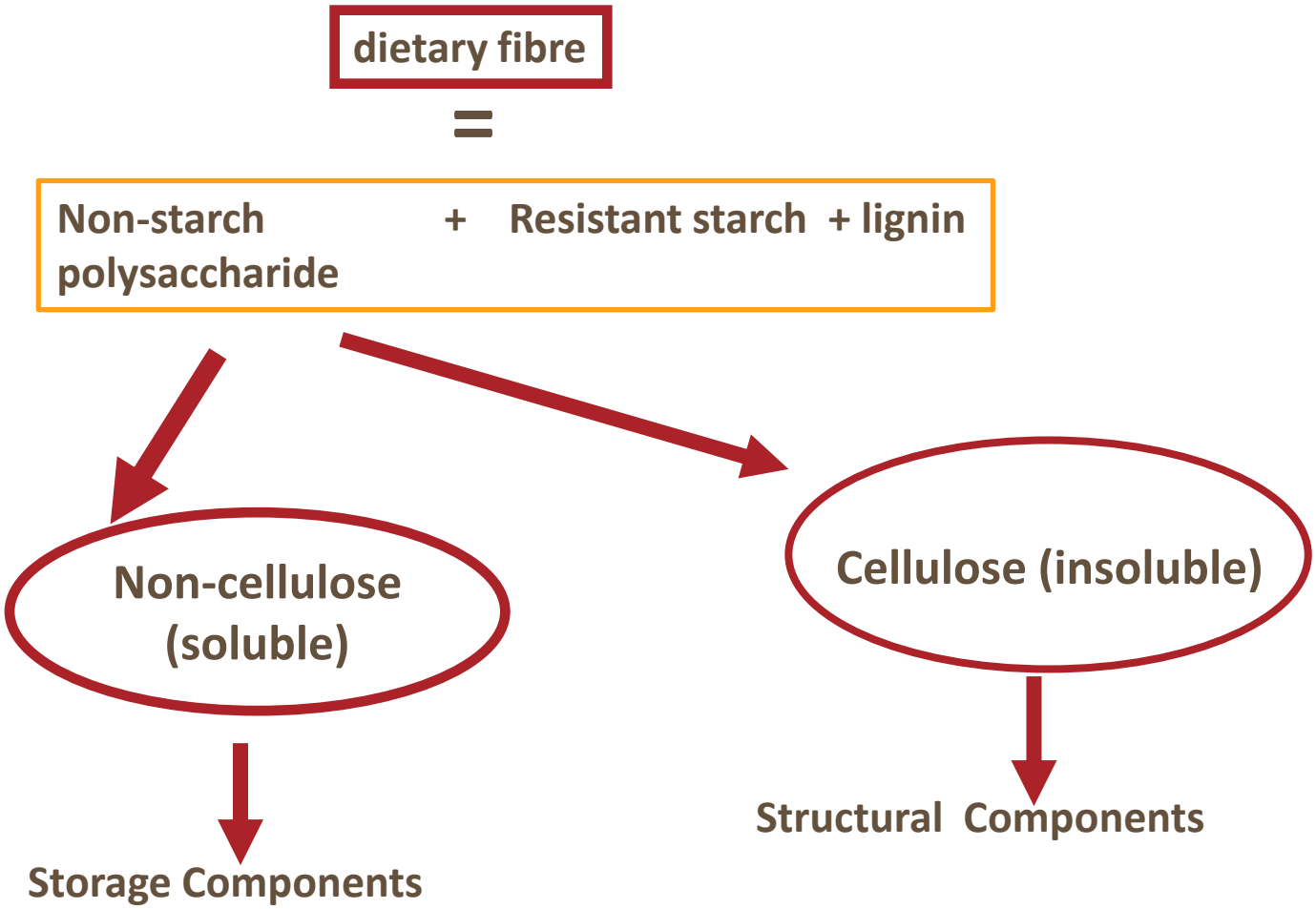
What is plant/dietary fibre?

Definition: resistant to hydrolysis by enzymes of stomach & small intestine

Chemically very complex

- includes resistant starch
- includes non-starch polysaccharides
  - soluble (non-cellulose) = all vegetable tissue gums, mucilage (eg oats and legumes, guar gums, pectin (fruit)
    - **Comprises 25-30% of 'fibre' in total diet**
  - Insoluble (cellulose) = lignin, woody vegetables
    - **Comprises 70-75% of 'fibre' in total diet**

What is dietary fibre?



Dietary fibre content (g/serve) in commonly consumed foods

Bread (average slice)

- white (0.6), multigrain (2.0), wholemeal (2.4)

Breakfast cereals (average serve)

- Cornflakes (negligible), Weetbix (2.8), muesli (8.0), All bran (9.5)

Vegetables and legumes (g fibre/100g food)

- peas (7.5), potato with skin (3.0) without skin (1.5) green beans (3.0), kidney, soy beans (9.5), corn (6.5)

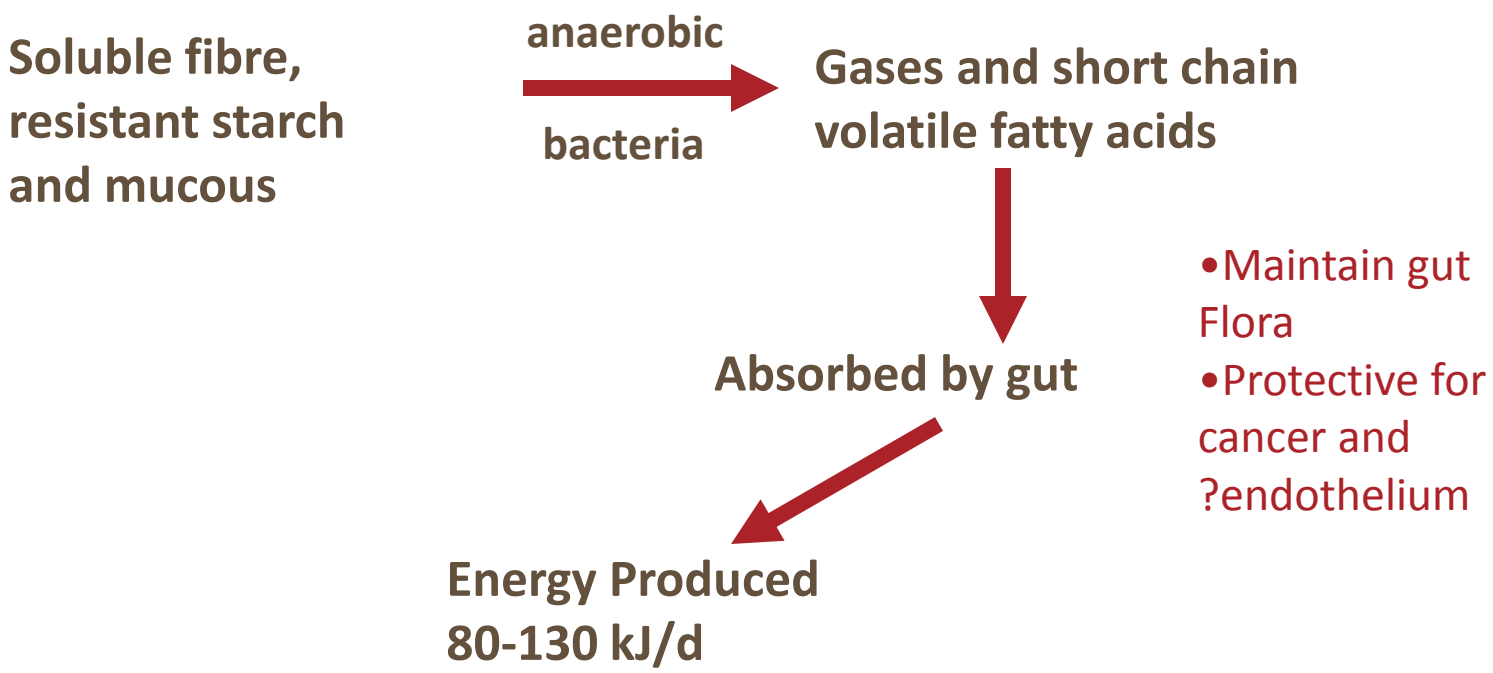
Fruit and nuts (average serve)

- apple (3.3), prunes, (6 medium (8.0), nuts (2-3g fibre for 30g of nuts)

Source: NUTTAB95

Digestion of fibre

- Human enzymes cannot digest fibre but some bacteria in the gut can



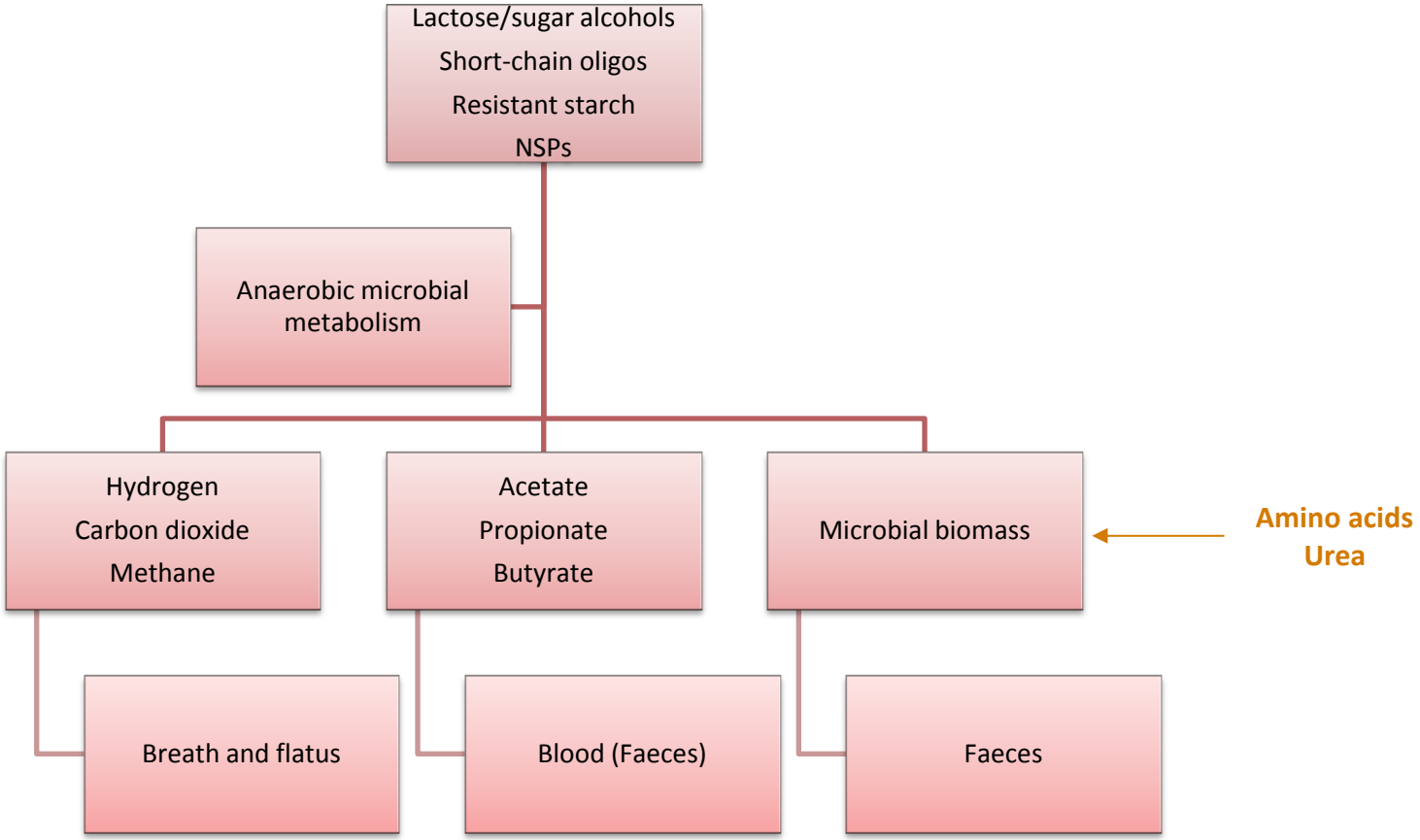
Fate of fibre in the colon

Three major events occur

- Bacterial growth
- Gas production (flatus)
  - CO_2, hydrogen, methane
- Production of short chain fatty acids
  - Acetic (60%)
  - Proprionic (25%)
  - Butyric (15%)

Fermentation of carbohydrates in the large intestine

Adapted from: Fig 2.5 pg. 19 Mann & Truswell, 2007



What causes flatus?

Swallowing air

- Oxygen and nitrogen swallowed when we eat – some exerted ‘burping’, reabsorbed from stomach or passes to bowel ‘flatulence’

Foods

- Undigested starch and foods high in fibre, particularly beans and cruciferous vegetables (cauliflower, cabbage, broccoli)
- Lactose intolerance or disaccharide malabsorption
- CHO modified artificial sweetener (e.g. sorbitol has high degree of intolerance ~50%)

Why offensive?

- Mostly odourless carbon dioxide, methane, nitrogen
- Butyric acid (offensive), hydrogen sulphides “rotten egg gas”, indoles, skatoles, methyl sulphides.

Properties of dietary fibre

Soluble

- absorbs water into the GI tract
  - increases the faecal bulk
  - softens the stool
- binds with bile salts
  - therefore promotes elimination of cholesterol
- affects the rate of digestion
  - slow, decreased transit time in gut
- produces low molecular weight organic acids

Insoluble

- affects the rate of digestion
  - increases transit time in the gut
- increases the bulk of the stool

Potential clinical uses of fibre

Weight control

- Satiety, reduced energy density, slows gastric emptying

Diabetes Mellitus (Type II)

- High fibre low GI diet improves BGL

? Prevention of cancer

- Hypothesised – epidemiological studies

Bowel diseases e.g. diverticulitis

- Prevents constipation which can cause diverticulae + infection -> perforation!

Fibre and cardiovascular disease

Soluble fibre has cholesterol-lowering properties

- 90g oat bran/day decreased serum cholesterol by 14%, LDL by 13% (Kirby & Anderson 1981)
- Similar effects seen with soybeans (Anderson 1984)
  - In normo-cholesterolaemic uni students, 400g baked beans/d for 23 day decreased serum cholesterol (Shuller et al. 1989)

Mechanism: faecal loss of bile acids and short chain FFA inhibit endogenous Cholesterol synthesis

Bulking (fibre supplements)

Wheat, rice and oat bran

- Added to many food products (e.g. cereals)

Bran fibre supplements

- Can cause ++ discomfort and flatulence

Psyllium

- Extract from seeds and husks of plantango plant – main component in laxatives “Metamucil, Fybogel”

Methyl cellulose

- Bulking agent in foods

Problem with too much fibre?

Inhibits mineral absorption

- Binds calcium and iron forming insoluble compounds

High in bulk

- Reduces energy density – problem with young children and elderly getting enough Energy

?uncomfortable side effects

- Sudden increase in fibre causes discomfort, pain, flatulence +++

? increases requirement for fluid

- Absorbs fluid in gut so increases requirement for soft stool

50g/d – no serious health effects *(Lancet 1993)*

Carbohydrates & Disease

Carbohydrates & Disease

- Blood glucose & diabetes
- Dental caries
- Lactose intolerance/malabsorption
- FODMAPs (Fermentable Oligo-, Di-, Mono-Saccharides and Polyols)

Are any health effects associated with CHO intake?

High sugar intake

- ?direct link with aetiology of chronic lifestyle diseases
    - Does too much sugar cause diabetes?
    - Does too much sugar cause hyperactivity
- ?risk of overweight
- ?poor nutrition (nutrient dilution)
- dental caries (cariogenic effect)

Low CHO diet

- Ketosis

High CHO diets

- Improvement in weight control
- High intakes of cereals, grains, legumes, fruits, starchy vegetables - protective to heart disease, cancer and diabetes. These foods are high in phytochemicals and anti oxidants and other vitamins and minerals
- Beware sugars in drinks

Total sugars content of some common foods

Foods	Total sugars (%)
Porridge, boiled	0%
Puffed Rice, choc	40%
Cornflakes, plain	9%
Wheat biscuit	3%
Fruit juice (unsw)	8-10%
Soft drink/senergy drinks	10-11%
Cordial (diluted)	9%

Source: NUTTAB 2006

Sources of added sugar

Foods	Number of teaspoons (approx)
bar of chocolate (50g)	8 teaspoons
hard sweets (50g)	8 teaspoons
one cupcake or doughnut	6 teaspoons
ice cream	4 teaspoons
ice block	6 teaspoons

How much sugar are Australians consuming*?

- Contribution of sugar to the total energy in the diet *(from the NNS 1995)*
  - Total sugar (22%), added sugar (11.2%), natural sugar (10.5%) – average values for the whole population.
- Effect of sugar intake on nutrient adequacy
  - Higher intakes of total and added sugar increased the proportion of people below 70% of the RDI for some nutrients.
  - High natural sugar intake – higher density of other micronutrients
  - High total sugar intake = lower total fat (but not necessarily saturated fat) and higher total CHO intake

**Cobiac et al. 2003*

Carbohydrates- Glycaemic Response

Plasma glucose levels:

- Rise 5-45 minutes after any meal that contains sugar or digestible starch = Glycaemic response
- Return to fasting levels 2-3 hrs later

Glycaemic Index- " Incremental area under the blood glucose response curve following a 50g carbohydrate portion of a test food, expressed as a % of the response to the same amount of carbohydrate from a standard food eg. Glucose/white bread taken by the same subject" http://www.glycemicindex.com/

Glycaemic index

The glycemic index (GI) is a ranking of carbohydrates on a scale from 0 to 100 according to the extent to which they raise blood sugar levels after eating.

- Determined by feeding >10 healthy people food containing 50g CHO and measuring BGL rise over time and comparing to 50G CHO from glucose
- most important factor is physical state of the starch – processed starches are digested very quickly
- starch in intact wholegrains/legumes digested slowly
- added sugars in foods mostly sucrose - moderate
- Always check GI of specific foods

Glycaemic Index

Source: http://www.glycemicindex.com/

Glycaemic index symbol on Australian foods

Approved for labelling in 2002

Source: http://www.gisymbol.com.au

Criteria for approval

- Good source of CHO - around 10g CHO per serve
- Healthy choice within food category - criteria for energy, total & saturated fat, sodium (if appropriate fibre, calcium)
- Foods tested by an approved independent laboratory (e.g. Sydney University GI Research Service (SUGiRS))
- Food retested to ensure quality control

The GI represents a relative ranking of different foods, irrespective on an individuals unique blood glucose responses or profile

See http://www.gisymbol.com.au and www.glycemicindex.com

Glycaemic Response

- Influenced by:
  - Level of processing
  - Other components of food eg fat/protein
- Total Glycaemic Response also influenced by amount/quantity
  - Glycaemic load (GL)= Amount available CHO x GI/100
- GL
  - Low GL <10
  - Medium GL 11-19
  - High GL 20+

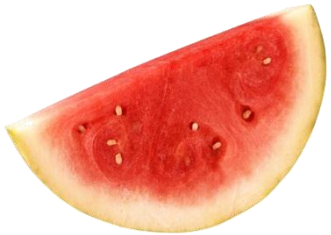
Activity

Calculate GL of the following products

Glycaemic load= Amount available CHO x GI/100

Al dente
Cooked Pasta 180g
GI: 43
Available CHO: 44g

LOW GI



Watermelon 120g

GI: 72
Available CHO: 6g

HIGH GI

Banana Raw 120g

GI: 47
Available CHO: 24g

LOW GI

Couscous rehydrated with water 150g
GI: 65
Available CHO: 14 g

MEDIUM GI

Activity

Calculate GL of the following products

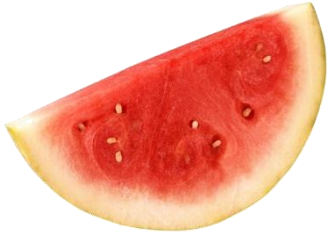
Glycaemic load= Amount available CHO x GI/100

Al dente
Cooked Pasta 180g
GI: 43
Available CHO: 44g

LOW GI

GL 19

Medium GL



Watermelon 120g

GI: 72
Available CHO: 6g

HIGH GI

GL 4

Low GL

Banana Raw 120g

GI: 47
Available CHO: 24g

LOW GI

GL 11

Medium GL

Couscous rehydrated with water 150g
GI: 65
Available CHO: 14 g

MEDIUM GI

GL 9

Low GL

Summary

- Carbohydrates are an important macronutrient
  - Sugars and starch
  - Fibre
  - Artificial sweeteners
- Digestion and absorption of carbohydrates is complex and starts in the mouth
- Metabolism of dietary CHO involves numerous processes
- There are some possible health risks associated with excess CHO intake
- GI and GL of CHOs may be useful

Back to your friend...

NOW SHE WANTS TO KNOW HOW MUCH PROTEIN SHE SHOULD BE EATING …
NEXT LECTURE

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