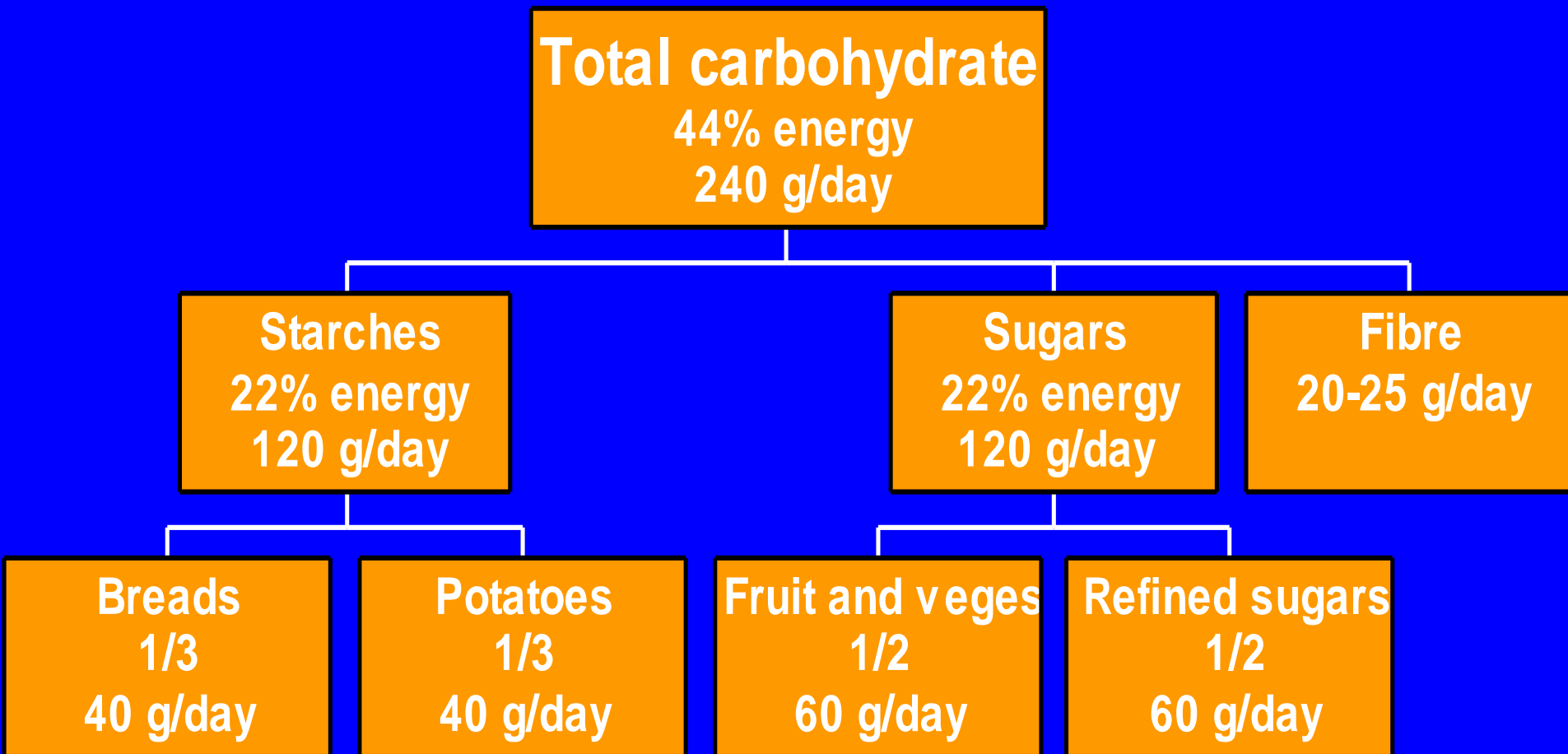


Starches

- **How much do we eat?**
- **Where does it come from?**
- **Characteristics of starch**
- **Starch digestion - rate and extent**
- **Starch gelatinisation**
- **Glycaemic index of starchy foods**
- **Resistant starch**
- **Conclusions**

Starch in western diets



Where does it come from?

g starch per 100 g

• Flour, white	73	• Cake, plain	30
• Rice Bubbles	71	• Pasta, cooked	25
• Cracker biscuits	70	• Corn, sweet	17
• Scone	51	• Potatoes, boiled	13
• Sweet biscuits	49	• Sweet potato	13
• Bread, white	45	• Baked beans	11
• Bread, wh'meal	38	• Porridge	9
• Crumpet	38	• Bananas	3-7
• Rice, white, cooked	28	• Pumpkin	3

Starch characteristics

- **Plant energy reserve**
- **Storage organs:**
 - seeds (cereals and legumes), tubers, unripe fruit (esp. banana)
- **Starch granules**
 - **Unique in shape and size to each plant**
 - Rice starch: small and angular
 - Potato starch: large and more spherical

Starch digestion

Three phases

1. Intraluminal phase

- Starts in the mouth with salivary α -amylase, continues in the stomach, despite low pH (15% total)
- Pancreatic α -amylase secreted into duodenum
- Products are maltose, maltotriose and α -limit dextrans

2. Brush border phase

- isomaltase, maltase, glucoamylase, dextrinase

3. Phase of glucose absorption

- Glucose actively absorbed across enterocytes
- Enters portal blood, then liver, then circulation

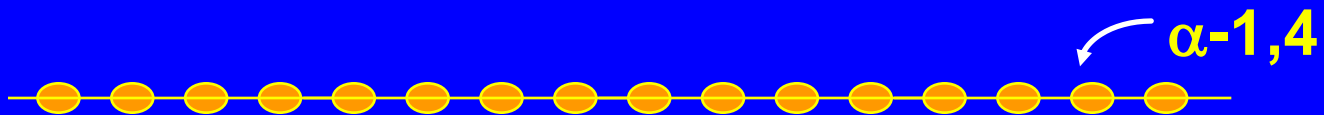
Rate of starch digestion

Depends on:

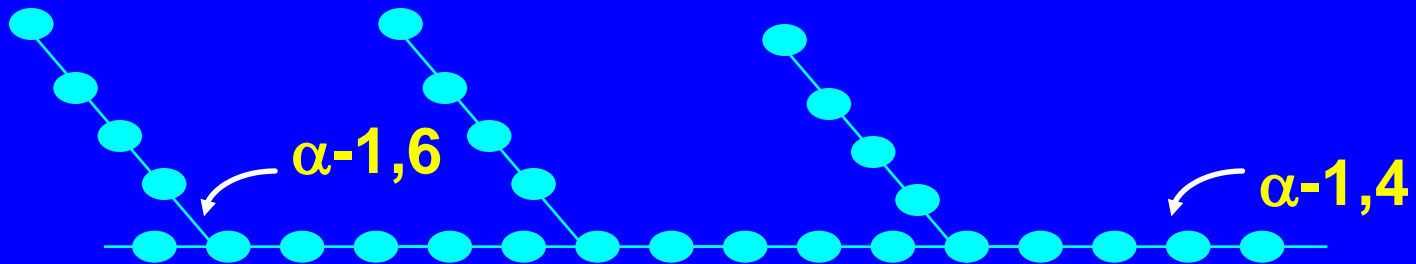
- **rate of stomach emptying rate**
 - Fat and protein slow it down
- **susceptibility of starch to α -amylase**
 - Degree of gelatinisation
 - Amylose content
 - Physical entrapment in fibrous cell walls
- **viscosity of luminal contents**
 - More viscous means slower

Amylose and amylopectin

amylose - linear molecule



amylopectin - highly branched



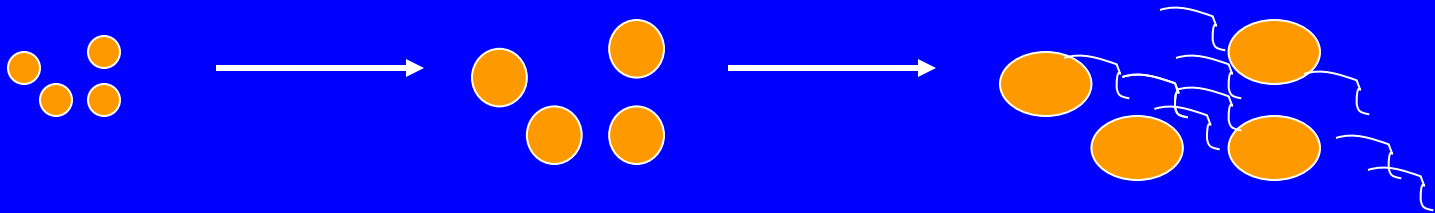
(~ 20 residues)

Amylose and amylopectin

- **Most plants contain starch ratio of**
 - 80% amylopectin / 20% amylose
- **More amylose (ie 30-60% of starch) in:**
 - Legumes, Basmati rice, Hi-Maize™
- **Amylose tends to line up in rows**
- **Amylose gelatinises at a higher temp.**
- **Amylose is digested more slowly**

Gelatinisation

- **Starch granules swell in presence of water and heat = gelatinisation**



- **Causes increase in viscosity**
- **If starch conc'n is high, a gel will form**
 - Gravies, soups, custards, instant desserts
- **Temp of gelatinisation depends on;**
 - size of granule, amylose content

Physical state of starch in foods

Determines rate of starch digestion *in vivo*

Slower

Raw starch

raw
cereals

Swollen

cooked
legumes

Gelatinised

cooked
grains,
pasta

Disrupted

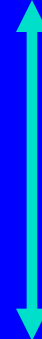
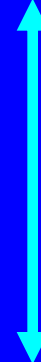
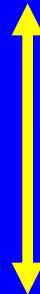
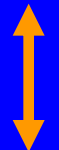
bread,
scones

Dispersed

extruded
products,
popped
cereals

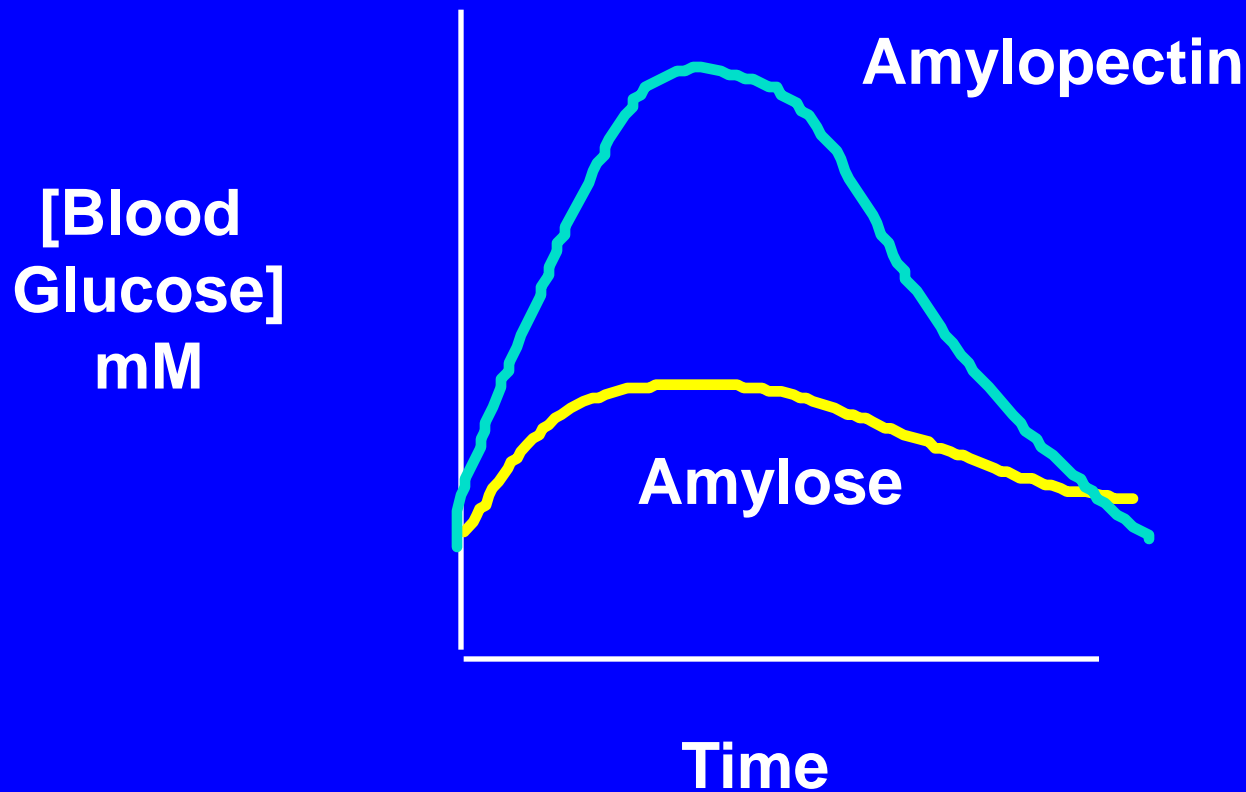
Enzymatically
degraded

Faster

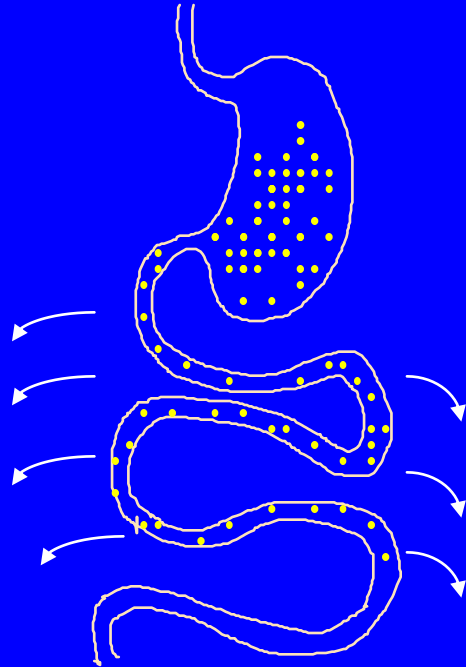


Blood glucose responses

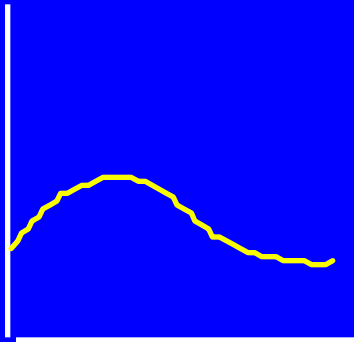
50 g carbohydrate portions



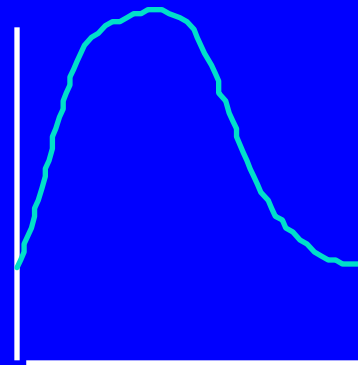
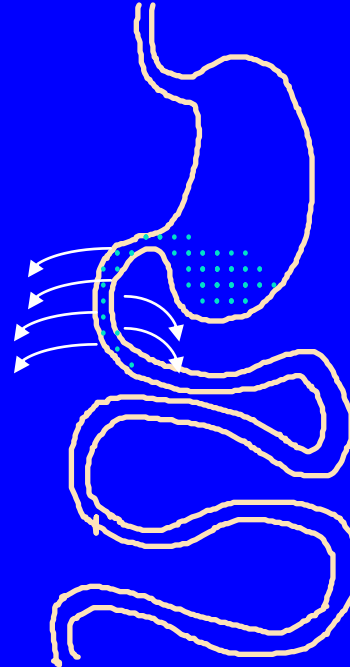
**Starch
Slowly digested**



**Blood
glucose
rise**



**Starch
Rapidly digested**



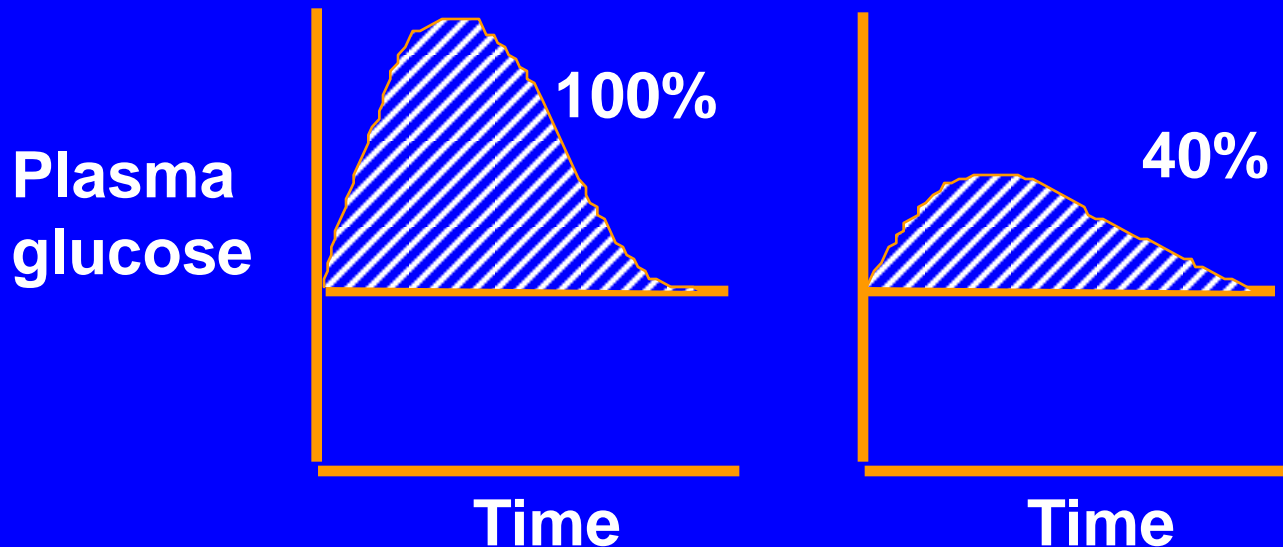
Glucose and insulin responses

Why are they relevant?

- **Treatment of diabetes**
 - hyperglycaemia and hypoglycaemia
- **Prevention of type 2 diabetes**
- **Prevention of coronary heart disease**
- **Satiety, appetite control, weight reduction**
- **Sporting performance**

What is the glycaemic index?

- A ranking of carbohydrates in foods based on the blood glucose response to equivalent carbohydrate portions
- The reference food has by definition a GI of 100



Most starchy foods have a high glycaemic index

Glucose = 100

- White bread 70
- Whole meal bread 69
- Dark rye bread 86
- Potatoes (boiled) 88
- Cornflakes 84
- Rice (Calrose brown) 87
- Crumpets 69
- Wheatbix 69

Relatively few starchy foods have a low GI

(Glucose = 100)

- Barley 25
- Legumes 30's
- Pastas 40's
- Heavy grain breads 40's
- Allbran™ 42
- Porridge oats 50

Resistant starch

- Originally considered that cooked starch was completely digested in the small intestine
- But certain starch fractions can pass through the small intestine intact
- Some of it undergoes microbial fermentation in the large intestine
- Resistant starch is that portion of starch that escapes digestion in the small intestine
- Up to 20% of starch in white bread is resistant starch

RS content of starchy foods

% total starch

- **Legumes** 10
- **Pumpernickel bread** 10
- **White bread** 5
- **Cornflakes** 3
- **Potatoes**
 - freshly cooked 3
 - Cooled 12
 - Cooled/reheated 8

Implications of resistant starch

Metabolic effects

Improved glucose tolerance?

Lowering of blood lipids?

Blood pressure lowering??

Gastrointestinal effects

Colonic fermentation

Lower pH in colon

↑↑ Free fatty acids

Increased faecal bulk

↑↑ Bifidobacteria

↓↓ Risk of colon cancer?

Conclusions

- **New findings about starch:**
 - **Digested at different rates in different foods**
 - **Some of it completely resistant to digestion**
- **High GI of modern starchy foods has important implications for health and disease**
- **Resistant starch is quantitatively as important as fibre for colonic health**

How is the GI measured?

- Feed 50 g CHO portion of the food to 10 subjects
eg 200g spaghetti
- Measure blood sugar at regular intervals
0, 15, 30, 45, 60, 90 and 120 mins
- Calculate 'area under the curve'
- Compare with area after reference food
This is tested at another time - express as %
- Calculate the **average value** for all 10 individuals

Sugary foods have a moderate GI

Glucose = 100

- Sucrose solution 65
- Fanta™ 68
- Muesli bars 61
- Life Savers™ 70
- Chocolate milk (low fat) 34
- Yogurt (sweetened) 33
- Icecream (low fat) 50

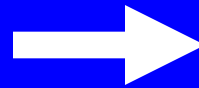
Median (range, 39 foods) = 58 (33 - 80)

Breakfast cereals

High fiber is not necessarily low GI



GI = 73



GI = 42

GI of starchy foods

Difficult to guess from composition

GI is likely to be lower if there is:

- less processing
- **high amylose-amylopectin ratio**
- high amount of viscous fibre
- **intact fibrous cell walls eg legumes**
- low degree of gelatinisation of the starch
 - eg raw cereals, some biscuits
- **large amount of fat and protein**
- **More fructose, fructose equivalents²**

What are the potential benefits?

Low GI diets for everyone

- lower day-long glucose and insulin levels
- improved insulin sensitivity
- improved blood lipid levels, higher HDL
- lower risk of heart disease
- lower risk of weight gain
- delay of ageing processes
- reduced tooth decay
- prolonged physical endurance

New classification of starches

Rapidly digested	Slowly digested	Resistant starch
<p>All glucose released in 20 mins</p> <ul style="list-style-type: none">• Bread• Potatoes (warm)• Flours• Amylopectin (cooked)	<p>Glucose released within 20 to 100 min</p> <ul style="list-style-type: none">• Raw cereals• Pasta• Legumes• High amylose starches (cooked)	<p>Starch not hydrolysed after 120 min</p> <ul style="list-style-type: none">• Cooled potato• Raw banana• Amylose (ungelatinised)