Diet and Cardiovascular Disease

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All roads lead to Rome

most common cardiovascular diseases
and their complications result from a wrong diet

most are mediated via, and interact, with

obesity
and one or more of the components of the
metabolic syndrome

1 Introduction

common diet-related cardiovascular diseases and their complications

hypertension, atherosclerosis, arteriolar necrosis, and endothelial dysfunction

manifesting as

• brain	arterial thrombosis, embolism, haemorrhage, encephalopathy, cognitive impairment, dementia
• heart	heart failure, coronary artery disease
• kidney	hypertensive and atherosclerotic nephropathy
• retina	hypertensive and atherosclerotic retinopathy
• large arteries	carotid artery disease, aortic aneurysms, peripheral arterial disease

obesity

two distinct types: central and subcutaneous/intra-muscular

now usually occurring together in the same person

definition and measurement – look and see +

central obesity

- apple shaped – fat in peritoneal cavity
- waist: female > 88 cm; male > 102 cm*
- waist/height ratio or ICO* ≥ 0.5

subcutaneous & intra-muscular obesity

- pear shaped – fat in arms, thighs, buttock
- overweight – BMI* 25 – 29 kg/m2
- obese – BMI 30 - 39; morbidly obese > 40*

etiology and pathology

central obesity

high fructose and AGE-rich food intake, tobacco, steroids, statins, neuroleptics, xeno-oestrogens,* **white fat** – cells active → oxidative cell damage, inflammation, defective apoptosis, angiogenesis

subcutaneous & intra-muscular obesity

genetics,* ↑ calorie intake, energy imbalance; **brown fat** – cells act as storage; XS mass → mechanical stress on joints and heart, poor self-image, ↓ physical activity; back to start

prevalence of central obesity increasing globally since 1980s

* arbitrary reference values; waist and height in cm → ICO = index of central obesity; BMI = body-mass index = mass kg/(height m)2;
xeno-oestrogens: therapeutic and phyto-oestrogens, DDT, PCBs, PBBs, phthalates, BPA, parabens; genetics includes epi-genetics

metabolic syndrome

an evolving amalgam of several definitions based on its most common components

- central obesity – also called visceral obesity or belly fat
- hypertension
- hyper-insulinaemia, insulin resistance, glucose intolerance
- non-insulin dependent diabetes mellitus – type 2 diabetes
- dyslipidaemia – ↑ triglycerides, ↑ LDL, ↓ HDL cholesterol
- micro-albuminuria
- inflammation
- hyper-coagulability, neo-vascularisation
- risk of cardio-vascular disease ↑

history of the metabolic syndrome

suspected from the 1950s

known before as CHAD and syndrome X inter alia

initially HT, DM, DLP, central obesity complicated by IHD

now metabolic syndrome expanded to include more conditions

history of the metabolic syndrome is a history of its components and complications

"Nowadays [1979] … IHD is by far the leading cause of death in most Western countries. Yet it seems almost unbelievable that, actually within the life-time of some of us, it was as rare for patients with IHD to be admitted to London hospitals as it was for Black patients with IHD to be admitted to Baragwanath hospital in 1960 - 1970, when there were only 1 - 2 deaths annually."

IHD UK early 20th century: "very uncommon" in public wards; ~ 12/year in private wards

IHD England and Wales 1974: 37% of male deaths; 18% of female deaths

IHD Tel Aviv 1974 and New York city 1976: 37% of all deaths

IHD Soweto 1976: 40 deaths (total population ~ 1 million)

1968 -1971: IHD deaths/20,000 people aged 55 - 64 years:

Soweto 9; Sweden101; UK141; USA 180; West Scotland 192; Finland 200; Jhb Jews 352

2000: age-standardised IHD deaths/100,000 in SA:

Blacks 151, Bruin mense 372, Whites 510, Indians 843

CHAD = community syndrome of HT, atherosclerosis and DM, HT = hypertension, DM = diabetes mellitus – only type 2 in all references, DLP = dyslipidaemia, IHD = ischaemic heart disease ; Baragwanath hospital in Johannesburg admitted only non-Whites: Bruin mense: people of mixed race also called "Coloureds"; ARP Walker. The epidemiology of IHD in the different ethnic populations in Johannesburg. SAMJ. P 748. 3 May1980. .

risk factors for the metabolic syndrome

a wrong diet

in addition to, and inter-acting with

- tobacco use
- physical inactivity
- alcohol abuse
- endocrine disruptors
- socio-economic and personal stress

what is a wrong diet?

too many or too few calories

too little food and too much foodstuffs*

– artificial concoctions flush with additives

+ ultra food processing and wrong food preparation

+ inappropriate meal distribution

+ gorging instead of nibbling

nutrient imbalance

essential nutrient deficiency

high energy-dense junk intake

• foodstuffs as used by Michael Pollan in *An Omnivore's Dilemma* to refer to artificial, synthetic, compounded mixes posing as food.

interactions within and between the metabolic syndrome and non-dietary risk factors

risk factors\disease	target organ damage	obesity	hypertension	dyslipidaemia	DM & insulin resistance	blood & vessel abnormalities	physical inactivity	tobacco use	alcohol abuse	stress
obesity	X		X	X	X		X	X	X	X
hypertension	X					X				X
dyslipidaemia	X		X			X				X
diabetes & insulin resistance	X	X	X	X		X				X
blood & vessel abnormalities	X		X							
physical inactivity	X	X	X	X	X			X	X	X
tobacco use	X		X	X		X	X		X	X
alcohol abuse	X	X	X	X	X		X	X		X
psycho-social stress		X	X		X			X	X	

other diet-related conditions

many linked to obesity and the metabolic syndrome

- acne
- allergies*
- Alzeimer’s disease
- cancers*
- Crohn’s disease
- constipation
- deficiency diseases
- dental caries
- dyspepsia & GERD
- gall-bladder disease
- gout
- haemorrhoids
- immune deficiency
- NASH
- obstructive sleep apneoa
- osteo-arthritis & osteoporosis
- PCOS
- sexual dysfunction*
- varicose veins, VTE
- vision impairment*

* allergies: skin, gastro-intestinal tract; cancer: breast, colon, rectum, gall-bladder, kidney, pancreas, oesophagus, prostate;
GERD = gastro-oesophageal reflux disease; NASH = non-alcoholic steatophilic hepatitis; PCOS = polycystic ovary syndrome;
sexual dysfunction: infertility, impotence, macrosomia; VTE = venous thrombo-embolism; vision impairment: cataracts, macular degeneration

2 definitions/meaning of food as used here

food, nutrients, calories, diet

food = a liquid or solid substance composed of a blend of nutrients

nutrient = a substance that provides the nourishment and energy essential for the maintenance of life, normal function, growth, and replacement

calorie = unit of energy-producing potential equal to the amount of heat released when food is oxidised

diet = food usually eaten by a person or by people

Is the sum of the parts (nutrients) equal to the whole (food)?

Is something that does not provide calories a food?

Is something that provides only calories a food?

Are there good and bad calories?

Can a nutrient be bad?

food additives

Food additives are compounds extracted or modified from food by chemical means or synthesised de novo – almost always a single chemical compound

They are added to food as a preservative, to enhance flavour, texture, and appearance and to supplement nutrient concentration – food fortification

They disrupt the nutrient balance derived from whole food
They may provide a lot of calories – or like free sugars <u>only</u> calories
They can have a deleterious effect on health – even if derived from food

examples of food additives – most are pure

- fibres extracted and modified from food like dextrins, sorbitol, glucans, modified starch, pectin, agar, guar gum, inulin, gelatin, condroitin, and a mixture like bran
- other food extracts like cocoa butter, fruit juice, sugars, syrups, vinegar, wine; olive, palm, vegetable, and fish oils; and animal fats like butter, cream, lard, and schmaltz
- synthetic items like salt (NaCl), other minerals, vitamins, colourants, and sweeteners
- modified extracts like high fructose corn syrup (HFCS) and hydrogenated fats

Some are assigned regulatory numbers* or listed as GRAS;* many are unregulated
Use of identified and listed items is subject to country-specific regulation and approval

- regulatory numbers prefixed with E in Europe; In USA items are listed as GRAS (generally recognized as safe) by the FDA; items listed as GRAS are less regulated than food additives

natural, organic, health, and real food

natural food = food containing no food additives including supplements, and not altered by extraction (except of water), substitutions, or chemical means

organic food = food processed* without chemicals from plants grown from seeds that are not genetically modified, irrigated by uncontaminated water in fields and soil not polluted by industrial and other waste, without synthetic and inorganic fertilisers and pesticides; from free-range animals and fish not fed grains, soya, or animal protein, or fodder laced with hormones, antibiotics, or other chemicals; + bio-diversity, fair-trade, localisation, the minimal use of fossil fuels in production and transport, home-cooking, slow-food, …

health food = a trade gimmick encompassing an arbitrary selection of items like exotic and ancient grains, often whole and raw; honey, seeds, nuts, herbs, teas, pro-biotics, …

real food = a new feel-good term embracing natural and organic food or simply a term to distinguish these from the rest, now defiled and debased, called food

no international definitions and standards
some countries have statutory definitions for natural food –
definition of organic food is regulated only within (some) national borders

- physical processing as opposed to chemical processing: cleaning, straining, winnowing, fermenting, extrusion, freezing, drying, heating, cutting, cooking and processed grains = coated, cracked, flaked, polished, pre-digested, shredded;

whole food and refined food

semantic aberrations* usually applied to grains (see also slide 82)

whole food is intact food in its original shape and size

grains are the seeds or kernels of cereal and pseudo-cereal plants

so-called *whole* grains* are not intact grains but a commercial construct

The Whole Grains Council* defined "whole grains or foods made from them [as something that] contain all the essential parts and … nutrients of the entire grain. If the grain has been processed … the food product should deliver <u>approximately</u> the same … balance of nutrients that are found in the original grain seed. This definition means that 100% of the original kernel must be present to qualify as a whole grain."

extraction and reconstitution change structure and properties

refined	= free from impurities or pure, fine, not coarse (not the issue here)
refined starch	= no such thing – starch is a chemical molecule and cannot be refined
refined grains	= that which remains after variable proportions of bran* is removed

examples: 30 % bran removed = white wheat flour; 15% bran removed = brown wheat flour

Starch is an essential life-sustaining nutrient providing energy
Grains and root vegetables high in starch are universal healthy staples
No need to demonise high starch food – even if not quite as healthy as intact or whole grains

- aberration = deviation from truth or moral rectitude; "whole" italicised to indicate incorrect use – here and subsequently; "approximately" removed from later versions of definition; bran = outer coverings of grains + germ.

processed food and foodstuff

Processed food is food transformed to enable digestion and to enhance taste, shelve-life, appearance, texture, and in our consumerist society, also sale.

Processing raw plants into edible digestible formats was critical in transforming hunter-gatherers into settled farmers and later into urban dwellers. Food processing evolved in parallel with changes in technology. In its turn the type of processing determined how people lived and worked.

all nice, slow, customised to need – a non-threatening evolution

then BIG FOOD saw an opportunity, the pace accelerated,
and the profit motive took over

Now we have shop shelves bulging with huge arrays of mass-produced, chemically-processed, food blends stuffed with sugars, salt, fats,* artificial flavours, colourants, and other additives, with seductive textures, packaged in endocrine-disrupting and/or environment-polluting containers for shelve-life, easy transportation, and financial gain.

Some of this is junk food;* some fast-food. Together with the rest,
the stuff can be termed foodstuffs* – useful when differentiating it from food.

- fats are solid at room temperature while oils are liquid – otherwise they are the same, used interchangeably here and everywhere; junk food = something of little nutritional value often high in sugars, salt, fats, and calories; foodstuff as used by Michael Pollan in *In Defence of Food*

supplementation and substitution

a hypothesis: supplementing food with additives and/or substituting additives for food, whether the additives are individually nutritious or not, results in malnutrition* and food-related diseases:

retarded growth and development, micro-nutrient deficiency syndromes, obesity, the metabolic syndrome, cancers, …

the hypothesis will be supported if:

- supplementation and substitution precede malnutrition and disease
- the relationship between supplementation and substitution and malnutrition and disease is biologically feasible

supplementation and substitution
are presumed to be severally and jointly implicated

* malnutrition = wrong, bad, poor nutrition

3 calories

slide no.	slide title
20	the right amount of calories
21	too few calories
22	too many calories
23	daily energy requirement
24	discretionary and restricted calories

just the right amount of calories

to meet daily energy requirements
not too few nor too many
customised to an individual's

- age
- body build
- physical activity
- physiological state eg adolescence, pregnancy, ...

while maintaining calorie and nutrient balance

too few calories

thrifty gene effect:

maternal under-nutrition before and during pregnancy → cardiovascular disease and obesity in off-spring

other effects:

- low birth weight
- low weight/height
- stunting
- wasting
- marasmus
- kwashiokor
- starvation
- death
- cephalo-pelvic disproportion
- depression
- hormone imbalance
- high infection rate
- immune deficiency
- rapid progression HIV → AIDS
- physical and sexual impotence
- infertility, …

too many calories

imbalance between calorie intake and energy output
when calorie intake is more than energy output

high intake more important than low output

energy density of what is eaten more important than the amount of what is eaten

overweight: BMI 25-29, obesity: BMI 30-39, morbid obesity: BMI > 40
imbalance between calorie and nutrient intake
when calorie intake is high and nutrient intake is low

as with a high intake of energy-dense, nutrient-deficient stuff like sugars*

malnutrition paradox: obesity co-existing with nutrient deficiency

50 calories/day XS →1 kg weight gain/year
2½ teaspoons sugar → 50 calories and NIL nutrients

* sugars are said to supply empty calories because sugars contain no nutrients – only calories

daily energy requirement

according to body build and physical activity
in a non-pregnant, non-convalescent adult < 60 years of age

body build	level of physical activity*				
	4	3	2	1	0
obese	30	25	20	17.5	15
overweight	35	30	25	20	17.5
normal weight	40	35	30	25	20
thin	45	40	35	30	25

calories/kg weight

* level of activity ranging from 4 = heavy manual labour daily to 0 = totally inactive;
obese: BMI > 30, overweight: BMI = 25 – 30, normal weight: BMI = 18.5 – 25; thin: BMI < 18.5

discretionary calories and calorie-restriction

discretionary calories – USDA concept

recommended daily allowance (RDA) minus calories from essential nutrients

market foil to avoid specifying limits on sugar, fat, and alcohol

discretionary calories add up quickly:

340 ml soft drink or beer	~ 150 discretionary calories
1 cup low-fat (2 %) milk	~ 32 discretionary calories

total = more than is good for most people

calorie restriction (20-30% below RDA) = better option

calorie restriction delays biological aging

↑ life expectancy and QALYs

↓ risk of stroke, CHD, diabetes type 2, IGT, HT

↓ weight, BP, CRP, Tg, total cholesterol, LDL; ↑ HDL

calorie restriction must be paired with adequate nutrient intake

USDA = US Department of Agriculture, QALY = quality of life year, CHD = coronary heart disease, IGT = impaired glucose tolerance, BP = blood pressure, CRP = C-reactive protein, Tg = triglycerides, LDL/HDL = low/high density lipoproteins

4 food groups and plates

slide no.	slide title	
26	people eat food not nutrients	
27	food groups	– USDA 2005 pyramid
28	food groups	– USDA 2010 plate
29	food plates	– as actually eaten
30	out-dated groups	– rationalised
31	groups according to chemical structure	

people eat food
not nutrients boxed into groups

concept of nutrients and food groups is influenced by

- a reductionist perspective
- scientific arrogance
- denigration of traditional cuisines
- male chauvinism – mother does not know best
- the food industry – health and nutrition claims

Grouping nutrients and food into boxes is euro-centric, pseudo-scientific, irrational, arbitrary, flawed, and outdated. The group boundaries are variable and unsound and cause confusion and misunderstanding in scientific, medical, and lay communities.

food groups according to the USDA food guide pyramid 2005

not logical, rational, or conducive to health

groups and recommended % of calories

1.	grains – preferably “whole”	44
2.	vegetables – including juices, tubers, legumes	20
3.	fruit – including juices	15
4.	milk – including yoghurt and cheese	10
5.	meat, fish, and beans (legumes)	12
6.	fats, oils, and sweets*	amount not specified*

* sweets categorised elsewhere by USDA as “discretionary” – amount not specified because the farmers’ lobby prevented recommendations on upper limits.

USDA 2010 food groups
no longer a pyramid, but a “plate”

not more logical or rational than the 2005 version

groups – in approximate order of magnitude (no figures given)

1. grains: whole and refined*
2. vegetables: dark green, red, orange, beans, peas, starchy, other
3. fruit: including 100% pure fruit juices
4. protein [sic]: meats, poultry, sea-food, beans, peas, seeds*, nuts, eggs
5. dairy products: milk, cheese, yoghurt, milk-based desserts, soymilk*
6. empty calories: items that “provide” solid fats and added sugars*

- the wording of these items is copied verbatim from an USDA internet publication; whole grains not distinguished from intact grains and used as defined by the WGC; Note: sunflower seeds listed as a protein and soymilk listed as dairy, lentils and candies/sweets not listed

food "plates" – as actually eaten

traditionally and before "coca-colanisation"*

staple – grains or high starch root vegetable ± legume

side dish – legumes, other vegetables, fermented milk/cheese

special/festive occasions – above + meat and fish + honey

in the consumerist, convenience-food era

main dish – meat, fish, eggs, cheese, fruit, vegetable salad (+ dressing)

side dish – potato, pasta, rice, bread, vegetable, cheese, SSBs*

dessert – fruit, pudding, ice-cream, sweetened yoghurt, cake, …

special/festive occasions – much more main dish and desert

traditional cuisines are healthy and preferred as is slow food, locally sourced, home-cooked with little or no food additives

- coca-colanisation = period from ~ 1945 when cheap, high density, ultra-processed, convenience food became easily accessible; SSBs = sugar sweetened beverages.

out-dated groups – rationalised

- new terms have been placed in the context of the old
- note overlap – some foods like legumes even belong in all groups

food containing carbohydrates –

sugar: items to which sugars are added, fruit; starch: grains, root vegetables, legumes; fibre: grains, root vegetables, legumes, other vegetables, fruit*

food containing fat –

dairy products (unless fat-free or low fat), eggs, meat, oily fish, legumes, grains, nuts, seeds (sunflower, pea-nuts, olives, oil palm fruit, coconuts, cocoa beans

food containing protein and purines** –

dairy products, eggs, meat** (especially organ meats**), fish,** legumes

Pre-packaged foodstuffs put together from bits and pieces including additives cannot be classified. The ingredients are not quantified but ranked in descending order of magnitude. Deliberately vague and obscuring?

* fruit placed last because fibre content is relatively low; ** food marked with 2 asterisks contain purines

groups according to chemical structure

macro-nutrients = carbohydrates, fats, proteins and purines

micro-nutrients = vitamins, minerals, fibre and anti-oxidants

suggested groups but problematic as over-lapping

mono-saccharides and di-saccharides	sugars
polyols	sugar alcohols
oligo-saccharides	most are fibres
poly-saccharides – unqualified	starch and fibre
poly-saccharides – non-starch	fibre
glyco-conjugates	most are fibres
fats – fatty acids/triglycerides	saturated, trans, and unsaturated
sterols	plant and animal
phospholipids	
other lipid conjugates	glycero-lipids, lipo-proteins, …
amino acids	protein
nucleic acids	purines
vitamins, minerals, phenols, terpenes	some are anti-oxidants, fibres, …

5 carbohydrates

essential to divide carbohydrates into its components

carbohydrates are molecules containing C, H, and O atoms
the number and arrangement of these atoms determines their

- physical properties
- physiological effects

on the basis of their properties and effects
carbohydrates can be divided into 3 big groups

sugars, starches, fibres

each of these groups can be further sub-divided chemically into smaller groups

food however straddles chemical boundaries
in natural and man-made combinations

C = carbon, H = hydrogen, O = oxygen

carbohydrates

chemistry and its effect on digestion, absorption, and metabolism

- carbohydrate: compound consisting of 1 or more saccharide molecules or monomers
- saccharide: ring or chain molecule with H, OH, and O attached to 3 - 8 usually 6 Cs
- in chain form one C atom is unbound; when joined to O it is called a carbonyl radical (C=O)
- in ring form OH and H asymmetrically replace O in C=O → α or β anomers with OH at C1 and CH_2OH at C5 on opposite sides or same side of the plane (trans and cis forms)
- structural isomers have the same molecular formula but differ in the way their atoms are joined; eg glucose, fructose and galactose which are 6 C isomers called hexoses
- D and L monosaccharide enantiomers are non-superimposable isomeric mirror images
- a glycosidic bond formed from the condensation of 2 saccharides at the anomeric C1 is designated either as α or β followed by the ordinals (1 to 6) of the two Cs involved eg α1:4

structure, digestion, absorption, and metabolism

- enzymes in the upper intestinal tract can act only at the α1:4 glycosidic bond to break down di-saccharides, oligo-saccharides and poly-saccharides into mono-saccharides
- only D mono-saccharides are absorbed from the small intestine
- glucose is metabolised in all cells in the presence of insulin → energy, H_2O, and CO_2
- XS glucose is preferentially converted into glycogen in the liver and muscles
- fructose is transported to the liver → glycogen; XS fructose → triglycerides and fatty acids
- glycogen → glucose for energy reserve, in XS → triglycerides and fatty acids for storage

carbohydrates – more definitions

- simple carbohydrate: a carbohydrate of 1or 2 monomers (monosaccharide or disaccharide)
- sugar: another word for a simple carbohydrate, colloquially used to denote table sugar
- sucrose: a di-saccharide of equal amounts of glucose and fructose chemically bonded; table sugar
- sugar alcohol: a hydrogenated derivative of a sugar; also called a polyol
- high fructose corn syrup (HFCS): a synthetic unbound mixture of fructose and glucose
- complex carbohydrate: a carbohydrate of > 2 saccharides as opposed to a simple carbohydrate
- oligosaccharide: a carbohydrate of 3 - 10 saccharides; non-digestible if β linked, a prebiotic
- polysaccharide: a carbohydrate of > 10 saccharides or monomers; often 1000s
- starch: polysaccharide of > 200 D glucose monomers α1:4 linked in tightly-coiled chains (amylose) + > 1000 glucose monomers of α1:4 chains linked by α1:6 bonds to form branches (amylopectin)
- rapidly and slowly digested starch: starch that is rapidly or slowly digested in the small intestine
- resistant starch (RS): starch that resisted digestion in the upper intestinal tract
- non-starch polysaccharide (NSP): as the name implies; not digestible in the upper intestinal tract
- fibre: naturally occurring polyols, oligosaccharides, resistant starch, and NSPs which may or may not be chemically bound to other molecules* - not digestible/digested in the upper intestinal tract
- roughage: another name for fibre; also called indigestible food residue

* other molecules = phenols, lipids, amino acids, protein, ...

where are carbohydrates found

1. whole food – intact, no extraction
   - sugars – honey, fruit, root vegetables, other vegetables, milk, ...
   - starch – grains, legumes, root vegetables
   - fibre – legumes, grains, root vegetables, other vegetables, sea weeds, animal offal, fruit, ...
2. portions remaining after extraction
   - sugars – fruit and vegetable juice, molasses, de-fatted milk
   - starch – flour/meal from grains, root vegetables, legumes
3. extracted portions and synthetic artificial compounds

   table sugar, HFCS, sugar alcohols, bran, modified starch, pectin, guar, …

people eat food containing carbohydrates (carbs)

people do NOT eat carbs

bad carbs and good carbs

sugars are BAD carbs

- sugars provide no nutrients, only calories – empty calories
- fructose does not satisfy hunger and hence provokes over-eating
- fructose when ingested with glucose as in sucrose and HFCS is associated with central obesity and other components of the metabolic syndrome

and now for the really VERY BAD news

- sugars contain reactive carbonyl radicals (C = O) – fructose > glucose
- reactive carbonyl radicals form AGES with proteins, nucleic acids, and lipids
- AGEs release oxidants (oxidative stress) and form carcinogenic acrylamide

"Maternal blood and food-derived AGEs prematurely raise sAGEs in children to adult norms, preconditioning them to abnormally high oxidant stress and inflammation and thus possibly to early onset of diseases such as diabetes. … Infants' sAGEs are significantly increased with the initiation of processed infant food intake, raising daily AGEs consumption by ∼7.5-fold."*

starch and fibre (the other carbohydrates) are GOOD carbs – essential for a healthy life

* Maternally Transmitted and Food-Derived Glycotoxins... Veronica Mericq et al. Diabetes Care October 2010 vol. 33: no. 10 . p 2232-2237

free radicals

chemically highly reactive atoms, molecules, or ions with unpaired electrons

reactive carbonyl groups (C=O) – exogenous and endogenous

fructose and galactose	> glucose
fructose, galactose, and glucose	> sucrose
mono-saccharides	> disaccharides
chain and furanose forms	> cyclic and pyranose forms

carbonation* as in fizzy, sparkling drinks
increases the number of C=O groups > 5 times

carbonyl radicals combine to form AGEs that are associated in vivo with oxidative stress, inflammation, cancers, metabolic syndrome and its complications, neurodegenerative disorders, ...

reactive oxygen species (R = O) – endogenous

good effects	intra-cellular killing of bacteria and cell signalling
bad effects	when production > consumption → oxidative stress and inflammation

oxidative stress produces reactive carbonyl groups, destroys enzyme function, and contributes to cancers, metabolic syndrome, premature aging, dementia, ...

reactive carbonyl groups →← oxidative stress

* yeast-fermentation of sugars → ethanol + CO_2; CO_2 + H_2O → carbonic acid (H_2CO_3); CO_2 + H_2CO_3 = carbonation

advanced glycation end products (AGEs)

produced by spontaneous non-enzyme mediated glycation

between a carbonyl radical (C=O) and an amino group (NH_2)

endogenous serum advanced glycation end products sAGEs

re-arranged glycation products from circulating non-metabolised sugars + circulating and tissue NH_2 groups from proteins, nucleic acids, and lipids in the process releasing amyloid and free O_2 radicals

sAGEs are formed at a constant slow rate in normal persons starting in the foetus and slowly excreted → variable accumulation in the body

low circulating sugars	→ reversal of glycation reaction
high circulating sugars*	→ glycation reaction
glycation products + dehydration	→ AGEs formation

exogenous AGEs – derived from food by cooking a sugar with a protein or a fat without water at ≥120º C as in frying, roasting, grilling, and baking after marinating in sugar

10 - 30% of ingested AGEs are absorbed

direct correlation between AGEs intake and circulating sAGEs level

* as in diabetes, insulin resistance, and high fructose intake

items containing AGEs

- dried and condensed milk
- sweets, desserts, and milk chocolates – milk and sugar
- roast and grilled meat, crispy* French fries, toast
- baked food – bread crust, bagels, biscuits, cakes, cookies, donuts, pastries, pies, tarts, quiches
- processed infant food and infant formula
- dark-coloured cold drinks, dark beer, and other dark-coloured foodstuff
- dark-coloured flavourants and colourants

food may be ≥ 200 times more immuno-reactive after cooking – especially after grilling, frying, baking, and broiling

Since the 1950s AGEs have been the basis of the food flavouring and browning industry

100s of different flavour and odour compounds have been created

they break down to form more new AGES compounds

* crispy from sugar-coating

6 sugars

sugars – definitions and examples

- table sugar: crystallised concentrated extract from sugar cane or sugar beet juice
- natural sugar: as found in plants and mammals (lactose in milk)
- added sugar: sugar added by a manufacturer, cook, or consumer
- free sugar: added sugar, sugars in honey, syrups, fruit juice concentrates, …
- unbound sugar: monosaccharide not chemically bound to another saccharide
- synthetic sugar: as the name implies – manufactured, not found in nature

mono-saccharides:	glucose/dextrose, fructose, galactose, mannose	
di-saccharides:	sucrose	= glucose bound to fructose (table sugar)
	lactose	= glucose bound to galactose (milk sugar
	maltose	= glucose bound to glucose
sugar alcohols:	sorbitol, mannitol, xylitol, maltilol, erythritol, …	
synthetic sugar:	HFCS (mixture of unbound glucose and fructose)*	

sugar alcohols provide about 2 calories/g energy*

other sugars provide 4 calories/g energy

sweet taste: fructose > sucrose > glucose (173:100:74)

- HFCS = high fructose corn syrup; labelling it synthetic was contested by its manufacturers, users and distributors – USA 2008; erythritol provides NIL calories

glucose, fructose, and sucrose

- glucose and fructose are hexoses – in ring (no double bonds) or chain (open) form
- open chain hexoses have C=O radicals; > soluble and unstable; rare: fructose > glucose
- glucose is an aldose;* 99% in a stable pyranose ring;* configured in α or β forms
- fructose is a ketone* isomer of glucose; in solution only 70% in the pyranose* form
- furanose ring has 5 members; unstable; glucofuranose rare; 22% fructose fructofuranose
- hexoses exist free or chemically bonded with other saccharides ± amino-acids, lipids, …
- sucrose is a chemically stable non-reducing (no C=O) disaccharide consisting of equal amounts of glucose and fructose covalently bonded at their reducing ends
- high fructose corn syrup is a mixture of free, unbonded fructose and glucose
- β-linked glucose and fructose molecules are not digested in the upper intestinal tract and are found in lactose, oligosaccharides, non-starch polysaccharides, and other fibres

fruit and vegetables contain sucrose, glucose, and fructose
vegetables contain ~1/3 less sugars than fruit
sucrose, HFCS, and fructose are often added to beverages and food
glucose is seldom added to beverages and food

- aldoses have the carbonyl group C=O at the end of the C chain at C1; ketones at C2 and bonded to 2 other Cs: C-(C=O)-C;
  pyranose = 6 member ring consisting of 5 Cs + 1 O linked at C1; the ring form and greater number of ring members confer thermodynamic stability

how the body handles glucose, fructose, and sucrose

Glucose is absorbed from the upper intestinal tract, stimulates the production and secretion of insulin and leptin → energy, CO_2, and H_2O for use where needed, or → glycogen for storage in the liver and in muscles.

Fructose is absorbed from the upper intestinal tract, does NOT stimulate the production and secretion of insulin and leptin and does NOT → energy, CO_2, and H_2O. It is transported directly to the liver → glycogen. When the glycogen stores are full, fructose → fatty acids which stay in the liver or → central white fat depots.

Sucrose is broken down into glucose and fructose in the upper intestinal tract including the mouth by the action of sucrase produced and secreted locally.

Glycogen → glucose when energy is needed. When glycogen stores are full, XS → fatty acids → subcutaneous and muscle brown fat depots.

XS circulating glucose and fructose → AGEs
fructose > glucose

digestion and absorption of fructose in small intestine

free (unbound) – digested and absorbed

natural – fruit, vegetables, honey
fruit juice concentrate, cane syrup, treacle, molasses

man-made – HFCS, crystalline fructose, commercial agave syrup*

bound in sucrose and polyols – digested and absorbed*

natural – fruit, vegetables, maple syrup

man-made – sugar (all colours, forms, and grades)

bound in fibre – not digested and not absorbed*

(fructo-oligosaccharides*, fructans*, other non-starch polysaccharides)

natural – root and green leafy vegetables, traditional agave syrup*

man-made – extracts from root vegetables, eg chicory root

* fructo-oligosaccharides and fructans (3-10 and >10 β-linked fructose molecules resp); exogenous conversion: fructans → fructo-oligosaccharides → man-made fructose as in commercial agave syrup; fructose in α configuration is absorbed but not in β configuration

sugar alcohols or polyols

found in fruit, vegetables, and grains

also manufactured by the food industry by the hydrogenation of sugars

used as bulking agents and sweeteners – food additives

- partially hydrolysed in the upper intestinal tract
  to fructose + an indigestible fraction
- fructose absorbed → liver then → glycogen, fatty acids, AGEs
- therefore not sugar-free or zero-calorie
- indigestible fraction = fibre → SCFAs and gases, potentially causing large bowel distention, abdominal discomfort, and diarrheoa

in comparison with parent sugars

sugar alcohols taste less sweet and provide less energy

permitted in USA in products advertised as “sugar-free”

must be identified as a sugar on food labels in SA

comparative data on sugar alcohols

sugar alcohol	% sweetness	% absorbed	cal/g
xylitol	90	25	2.6
maltilol	75	< 40	2.4
starch hydrolysates	75	> 65	3.4
sorbitol	70	~ 50	2.6
erithritol	65	0	0.0
isomalt	60	< 20	2.4
mannitol	50	~ 25	2.8

% sweetness compared to sucrose at 100

energy = 60 minus 85% as much as glucose at 4Kcal/g*
derived from the metabolism of their breakdown products
(fructose hydrolysate and short-chain fatty acids)

EU Directive for calculating energy content: 1g yields 2.4 kcal* (90/496/EEC)

* except erythritol which is not absorbed so has zero energy yield

7 the sweet taste of food

slide no.	slide title
49	source of the sweet taste
50	sugar – pure, white, and deadly*
51	table sugar and its by-products
52	other sweeteners derived from plants
53	high intensity sweeteners
54	sweeteners in sachets
55	sugars in fruit and vegetables
56	other natural sweeteners

* The title of John Yudkin's book. 1972 – was out of print for many years!

source of sweet taste

from plants as eaten – natural:

sugars (glucose, fructose, sucrose) in fruit, some vegetables (including sugar cane and sugar beet), honey and maple tree sap

fibres (polyols, fructans, oligofructose, conjugated glycosides) in the fruit (agave, monk fruit, pumpkin), roots (agave, onion), and leaves of vegetables and other plants (agave and stevia)

extracted from plants and/or synthesised from plant compounds – artificial:

table sugar, treacle, and other sugar by-products, fructose, corn syrup, HFCS, glucose syrup, agave nectar, concentrated fruit juice, inulin, oligo-fructose, sugar alcohols (sorbitol, xylitol, erythritol), glycosides (rebaudioside, mogroside, glycyrrhizin)

discovered by chance or developed in laboratories – high intensity sweeteners:

acesulphame, aspartame and its derivatives neotame and alitame, cyclamate, saccharine, sucralose

USA 2005 - 2009: 75% formulated foodstuff contained sweeteners; mostly calorific*
global food and beverage industry 2008: 70.4 million tonnes sweeteners used*

* USA data from J Academy Nutrition and Dietetics; Global data from Euromonitor

sugar – pure, white, and deadly

a sweet-tasting food additive

provides no nutrients only energy – empty calories

sucrose extracted from sugar cane a grass or from sugar beet a tuber

sugar cane

- grown in tropical and sub-tropical regions
- stems chopped and taken to processing
- juice extracted with water or diffusion
- carbonatated* and heated to clarify juice
- water evaporated under a vacuum
- seeded with sugar crystals → crystals
- crystals separated, dried → sticky brown
- carbonatated, bleached → semi-refined
- refined by dissolving, boiling, filtering, ...

sugar beet

- grown in temperate regions
- tubers cleared of leaves on-site
- washed and sliced in processing plant
- juice extracted by diffusion
- carbonatated and filtered to purify juice
- pH adjusted with Na_2CO_3 and sulphur
- water evaporated by boiling under vacuum
- cooled and seeded with sugar crystals
- crystals separated in centrifuge and dried

brown sugar = dirty white sugar

or crystals coated in molasses or dyed to produce the brown colour

- carbonatation = $Ca(OH)_2 + CO_2 \rightarrow Ca\ CO_3$ and high pH; this + heat→ protein coagulation, absorption of colourants, and glucose and fructose hydrolysis

table sugar and its by-products

- white cane sugar: 100% sucrose – purified and/or bleached brown sugar crystals
- sugar from sugar beet: 100% sucrose – carbonatated, sulphated, filtered, evaporated – juice
- brown sugar: sucrose crystals from 3rd boiling + 3.5 - 10% molasses added or not removed; dyes and other chemicals may be added for a darker colour, to improve flow, …
- natural brown sugar: sucrose crystals from 1st boiling of sugar juice + vitamins and minerals also called raw sugar, whole cane sugar, turbinado, dimerara and muscovado sugar
- molasses: < sucrose than treacle + water, vitamins, minerals – after 3rd boiling; black, thick
- treacle: < sucrose than first syrup + water, vitamins, minerals – after 2nd boiling; dark colour
- first syrup: glucose, fructose, sucrose + water, vitamins, minerals = left-overs after 1st boiling off of sucrose crystals from sugar beet or sugar cane juice; pale or golden colour; also called cane syrup, golden syrup, or pale treacle

sucrose hydrolysed in food preparation and in the body
→ unbound 50% glucose + 50% fructose

other sweeteners derived from plants sold in the shops for people to buy

- agave nectar: fructose + vitamins, minerals, water from hydrolysed inulin from agave plant
- fruit-juice concentrate: glucose, fructose, sucrose extracted from fruit, filtered, pasteurised, concentrated, chemicals and “natural fruit by-products” added or removed, packaged
- glucose/dextrose syrup*: glucose, maltose, gluco-oligosaccharides from hydrolysed starch
- high fructose corn syrup (HFCS): corn starch → glucose syrup + GM* enzyme → 90% fructose syrup + glucose syrup → 42, 55, and 65% fructose/glucose HFCS mix
- invert sugar: 47.5% glucose, 47.5% fructose, 5% sucrose from splitting sucrose
- monk fruit extract – HI* (mogroside) sold as *Nectress* (+ erythritol, sugar, and molasses), …
- stevia extract – HI (rebaudioside) sold as *PureVia* (+ dextrose) and *Truvia* (+ erythritol)

fructose content: honey < HFCS 42 < invert sugar < sugar < HFCS 55/65 < agave nectar*

HFCS has a longer shelf life and retains moisture better than sugar

HFCS is cheaper than sugar and easier to transport and use

* dextrose = glucose; glucose/dextrose syrup also called corn syrup if made from corn; also made from wheat, tapioca, and potato starch; GM = genetically modified; HI = high intensity sweetener; agave nectar 70-85% fructose

high intensity sweeteners

mired in controversy, collusion, and conflict

associated with toxicity claims and commercial rivalry

~ 20 – 300 times sweeter than sugar

but no body/bulk, no viscosity, and may/often leave a bitter after-taste

therefore sugars (dextrose, glucose, lactose, dextrin, malto-dextrin), polyols (sorbitol, erythritol), starch, silicon, ... and flavour enhancers added for a natural taste sensation and mouth feel, to provide bulk, and as fillers

sugar is not replaced – only reduced

not calorie-free in sachets and in formulated food that need bulk

if < 5 calories/amount usually consumed can be labelled zero-calories in USA and SA (?)

global food and beverage industry 2008:

77.2 thousand tonnes high intensity sweeteners used

700.6 thousand tonnes non-sugar bulk sweeteners used

no data on how the bitter taste of artificial sweeteners is camouflaged in beverages

not all are permitted in all countries

sweeteners in sachets

sweetener	intensity	trade name/s as marketed in South Africa
sucralose	600	splenda
saccharin	300-500	canderel,* equal, hermesetas
rebaudioside*	200-300	canderel, purevia, truvia
acesulphame	200	canderel, equal
aspartame	160-200	canderel, nutrasweet
cyclamate	30	sucaryl, sweet 'n low

(intensity refers to the strength of the sweet taste in comparison with table sugar)

Small amounts of sweetener are sufficient to impart a sweet taste.
By using several different sweeteners in combination the bitter after taste and the actual/suspected toxic and other side effects may be reduced.

Aspartame has been shown to be addictive and to be linked to a sweet tooth, dental caries, osteoporosis, central obesity, DM, ↑Tg, and liver, kidney, and CNS* damage

- canderel is a brand name for several colour coded sweeteners; intensity of rebaudioside refers to the powder extract;
  CNS = central nervous system; aspartame is used in 90% of artificially-sweetened beverages in USA and in SA in all Pepsi and Coca Cola products

sugars in fruit and vegetables

fruits and vegetables	total	glucose	fructose	sucrose
banana	14.00	2.67	2.67	7.00
grape	13.60	6.56	6.53	0.52
apple	9.86	1.82	5.93	2.11
plum	8.61	2.21	1.20	5.20
orange	8.23	2.44	2.56	3.23
peach	6.71	0.98	1.12	4.61
onion raw	5.61	1.85	1.59	2.14
pumpkin and marrow	4.42	1.69	1.43	1.30
tomato raw	2.85	1.21	1.50	0.14
bean green cooked	2.73	1.00	1.34	0.43
lettuce	1.13	0.44	0.55	0.13
spinach cooked	0.52	0.15	0.14	0.23

g sugar per 100g item in descending order of total sugar*

bound fructose in polyols and fructans contributes to a sweet taste

* Data from Scientific Tables Ciba Geigy Ltd.1970

other natural sweeteners

- honey: 31% glucose, 38% fructose, 9% melezitose + maltose, 1% sucrose, trace of vitamins, minerals, phenols, and other antioxidant-like substances, 7% water; made by bees from the nectar of different flowers → distinct flavours
- maple syrup: sucrose + vitamins, minerals, water; evaporated Maple bark sap
- agave nectar: inulin* from roots and leaves; boiled sap = dark sweet syrup
- stevia: rebaudioside (diterpene glycoside) from fresh, dried, and crushed leaves
- monk fruit or luohan guo: mogroside (triterpene glycoside), glucose, and fructose + vitamin C; from fruit rind and dried and fermented fruit pulp
- licorice: glycyrrhizin (triterpene glycoside) from raw or dried roots

* inulin is a fructan

8 sugar stories

history of sugar - sucrose

- sugar cane first domesticated in New Guinea: ~ 8000 BC
- sugar used in rice and barley dishes and in fermented beverages in India: 400 - 350 BC
- cane grown and sugar produced in India's west coast and Persian gulf delta: 400 – 800
- Arab conquerors introduce Islam and sugar cane cultivation, sugar making, and taste for sugar into North Africa, Spain, and South-East Europe: ~711 - 759
- Eastern Mediterranean supplies sugar to Middle East, North Africa, and Europe: 800 +
- Crusaders take over production, spread knowledge of sugar to Europe: 1096 +
- warfare, plague, and poor administration of sugar industry → decline in Europe
- indentured and slave labour on plantations in Spanish and Portuguese Atlantic island colonies supply sugar to Europe; refined in port cities along West African coast : 1400s
- Columbus carries sugar cane from Canary Islands to Caribbean: 1493
- African slaves and skilled sugar masters imported to "new world" sugar plantations: 1510 +
- France and Britain replace Spain as sugar growers/producers in slave-manned Caribbean plantation colonies → ↑ sugar consumption, ↑ slave trade, and ↑ profits: 1600s
- sugar in Europe now a common food and an important trading commodity
- Napoleonic wars → loss of Saint-Dominique in the Caribbean → sugar from beet in Europe
- steady ↑ consumption: 1850 +; ↑ production 500 - 800%: 1900 – 1970
- sugar-soaked diets colonise world:1945 +; 9% world calories from sugar: 1970
- sugar and HFCS = 50% of dietary carbohydrate in people > 2 years old in USA: 1994 – 1998
- sugar and HFCS consumption peak in USA > 40kg per person per year: early 2000s

Major source: *Sweetness and Power – the place of sugar in modern history*. Sidney W Mintz. 1985. Penguin Books.

history of high fructose corn syrup

Japan	research enabled commercialised production of HFCS: early 1970s
USA	HFCS rapidly introduced into processed food and beverages: 1975 - 1985
USA	HFCS inexpensive relative to sucrose because of corn subsidy to farmers, sucrose import quotas and tariffs, and confiscation of USA cane assets in post-revolution Cuba + USA boycott of Cuba: 1982
USA	HFCS replaces sucrose in Coca Cola and Pepsi Cola drinks: 1984
USA	HFCS replaces sucrose as major sweetener in all food-stuffs: 2003
USA	HCFS = sole caloric sweetener in all soft drinks: 2003 - 2008
USA	% fructose of total energy intake: 8% in1977 - 1978; 10.2% in 1988 - 1994
Japan	HCFS = 25% of sweetener consumption: 2002
EU	HFCS = 2 - 3% of all sugar produced because of quotas: 1977 +
USA	HFCS intake increased 1000% in parallel with increase in obesity, metabolic syndrome, NASH: 1970 - 2000
USA	public awareness of presumed link between fructose and disease → consumer resistance → ↓ HFCS in beverages and processed food: 2008
USA	sucrose replaces HFCS in beverages, name change for HFCS proposed: 2011
Globally	market calories from sucrose + HFCS ↑ from 218 to 280/person/day: 1960 - 2013

food containing added sugars

- soft drinks (sodas), chocolate, “tonic” drinks
- mixed and pure fruit juices, speciality mixed drinks
- instant mixed coffee, shop magewu*
- sweetened condensed milk and yoghurts
- other sweetened milk products
- jam, sweets (candies), chocolates, “snacks”
- puddings, jellies, sorbets, ice-creams, custards
- sweetened stewed and glazed fruit
- bread, cakes, biscuits, cookies, buns, scones
- ready-to-eat breakfast “cereals” and “dinners”, ...
- pre-packed mixed spices, sauces, spreads, stock, soups
- tinned vegetables, fish and meat products, legumes

* magewu = traditional soured sorghum and maize drink

added sugars in USA diet

SOURCE OF ADDED SUGAR	%
non-diet soft drinks	33.3
sugars and candy/sweets	16.1
sweetened grains, such as cakes, cookies, pies	12.9
fruit drinks, such as fruitades and fruit punch	9.7
breakfast cereals and other grains such as breakfast bars	9.6
dairy desserts & milk products such as ice cream, sweetened yogurt & milk	8.6
other grains, such as cinnamon toast and honey-nut waffles	5.8
other	4.0

- 1994 – 1996: added sugars (excluding polyols) →16% of total energy, 31.5% of energy from carbohydrates, and 50% of carbohydrates for 20% of population
- 1999: annual HFCS per-capita consumption peaked at 29 kg
- 2007: consumption HFCS down to 25.5kg and cane sugar at 28.2kg
- 2008: sucrose and fructose = 150g (600 calories) of total daily intake/person

data including text in table verbatim from USDA Dietary Guidelines, 2005

fructose in USA diet

intake

1977 – 1978: everybody:	3.7 g/day	8.0% of total energy intake
1988 – 1994: everybody:	54.7 g/day	10.2% of total energy intake
adolescents:	72.8 g/day	12.1% of total energy intake

commonest source

sugar-sweetened beverages – mostly HFCS 55 and 65*	30%
grain-based products – mostly breakfast cereals – HFCS 42 and 55	22%
fruit and fruit juice – no added HFCS	19%

HFCS – high fructose corn syrup

1994 - 1998 people > 2 years: 6.7% of daily calories
11.0% of daily calories in top 20% consumers
20.0% of all carbohydrates consumed

2005: 52% of sugars (excluding sugar alcohols) in all processed food

* HFCS 55 generally regarded as safe by FDA (GRAS) for use in beverages
but HFCS 65 found in most popular soft drinks in 2010

history of stevia

fresh and dried whole leaves of stevia* plants and extracts

India: used in Ayurvedic practice > 1500 years

Paraguay and Brazil: used medicinally, as sweet treats, and in teas – 100s of years

many other regions in South America and the Far East: used traditionally – centuries

extracted and purified stevia glycosides (glucose + steviol)

commercially available products in 2013

stevia glycosides + filler (erythritol or “dextrose”)* + flavourants

Japan	stevia glycosides commercially available: 1971
WHO	no evidence of carcinogenic activity, rather possible benefits to health: 2006
Europe	stevia glycoside use permitted – Codex Alimentarius Commission: 2011
USA	stevia leaves use prohibited: 1991; permitted as GRAS supplement: 1995
USA	pure rebaudioside glycoside approved as a food additive: 2007
USA	most popular sweetener on the market: 2013

rebaudiosides → stevioside ~ 250 - 300 times sweeter than sucrose

fresh leaves ~ 30 - 45 times sweeter than sucrose

* ~ 240 varieties, some genetically modified; filler used by Coca Cola/Cargill and Pepsi respectively

9 sugars – summary

* SSB = sugar sweetened beverages

the case against sugars

sugars provide no nutrients – only calories and contribute towards:

- reduction in satiety → poor appetite control
- relative ↑ energy intake and ↓ nutrient intake
- overweight, obesity, diabetes, dyslipidaemia, other components and complications of the metabolic syndrome
- ↑ purines* → ↑ blood uric acid → gout and hypertension
- ↑ reactive carbonyls → AGEs and oxidative cell damage
- premature aging and dental caries*

reverting to a diet low in sugars is associated with weight loss, a reversal of unhealthy trends, and general well-being

* fructose affects purine synthesis and degradation; all fermentable carbohydrates cause caries - but sugars more than starch

the case against sugar-sweetened beverages and fruit juices

- high calorie and sugars content + no or few nutrients
- easy to ingest excessive amounts in liquid form
- rapid intake and absorption of sugars
- glucose binge effect: ↑ insulin → ↓ blood glucose, ↑ adrenalin
- low satiety effect of liquids compared to solids
- intake not compensated by reduced solid food intake

in addition:

- fibre and micro-nutrients in fruit juice < than in whole fruit
- sugar concentration in fruit juice > than equivalent volume whole fruit
- ↑ beverage intake associated with > intake of sugar-soaked solids
- SSBs like “energy drinks” may contain unbalanced micro-nutrient cocktail

direct relationship between SSB intake and metabolic syndrome

what the expert reports said about sugars

WHO 2003:

It is recognized that higher intakes of free sugars threaten the nutrient quality of diets by providing significant energy without specific nutrients. (Restricting) free sugars was … likely to contribute to reducing the risk of unhealthy weight gain …

USA Dietary Guidelines Advisory Committee 2004:

Compared with individuals who consume small amounts of foods and beverages that are high in added sugars, those who consume large amounts tend to consume more calories but smaller amounts of micronutrients. …Studies suggest a positive association between consumption of sugar-sweetened beverages and weight gain.

AHA 2013:

SSBs may be linked to ~180,000 deaths in the world each year
SSBs may be associated with ~ 25,000 deaths in the USA each year

opinion on sugars updated – 2013

Robert Lustig: “Sugar in all its forms is a key contributor to many of our diet-related diseases, including obesity, DM, heart disease, high blood pressure, and cancer.”

The Telegraph UK: “Sugar undeniably acts like [a poison] by damaging organs, interfering with brain signals, and promoting damaging addictive behaviour.”

New York Times: “Sugar is indeed toxic. It may not be the only problem with the Standard American Diet, but it’s fast becoming clear that it’s the major one.”

George Bray: SSBs whether sweetened with sucrose or high fructose corn syrup “are a significant factor in the obesity epidemic in the United States.”

EPIC study: “Drinking one 12-ounce of SSB/day can increase risk of DM by 22%.”

BMJ: The food industry "continues to adopt strategies to deny sugar's role as a major causative factor in what now represents the greatest threat to our health worldwide: diet related disease”. ... Industry's involvement with nutrition bodies and sport "allows the major food corporations to peddle pathology with impunity.”

The UK Academy of Medical Royal Colleges: Ban TV “advertising of foods high in saturated fat, sugar, and salt before 21:00 hours and further tax sugary drinks.”

recommendations on sugars

upper limits as recommended by institutions who were subjected to commercial pressures

USDA 2000	added sugars 25% of daily calorie intake
WHO 2003	free sugars 10% of daily calorie intake*
USDA 2005	no upper limit specified – only advice to limit intake of added sugar*

These values were much too high

NOT prudent nor in accordance with independent scientific analyses

AHA 2013 added sugar <100/150 calories/day for women/men (± 5%)

current evidence suggests very little if any added sugars + a low fruit intake

* 2003 limit challenged by industry with demotions in senior WHO personnel; 2005 industry-driven wording

10 starch

starch misnomers*

starch is a chemical which cannot be refined – only defined

Refined starch is a misnomer. Starch extracted from plants can be called pure – meaning only starch, nothing else – but NOT refined

In the pure form starch is an industrial compound and NOT a food
White wheat flour is not pure starch – 70% of the original grain is present

food that contains a lot of starch always contains other nutrients also

- grains – whole, ground, milled, polished, flaked, pearled, …
- pseudo-cereals – whole, ground, milled, …
- root vegetables – whole, ground, mashed, …
- legumes/pulses – dried whole, ground, pureed, …
- other (fruit eg unripe banana, pith of tree trunk) – whole, ground, …

* misnomer = misapplied or inappropriate name

structure of starch – as starch and fibre

starch is a mixture according to mass of

amylose	20 - 30%
amylopectin	70 - 80%

amylose is a small, compact, coiled, insoluble, linear molecule consisting of 300 - 3000 glucose molecules linked by α1:4 glycosidic bonds

amylopectin is a large water-soluble branched molecule of >10,000 glucose molecules made up of short α1:4 bound chains of ~ 20 - 40 molecules linked as branches by α1:6 glycosidic bonds

number of molecules: small amylose > large amylopectin

starch as starch has the same structure as starch as fibre

difference depends on whether or not it is digested in the upper intestinal tract

- α1:6 glycosidic links of amylopectin are not digested in the upper intestinal tract
- the tightly-packed structure of amylose → reduced digestion in upper intestine
- starch retrogradation (crystalline → gelatinised → crystalline) ↑ resistance to digestion

what is starch retrogradation

- starch is stored in plants as crystalline granules
- crystalline granules are insoluble in cold water
- crystalline granules are not edible

on boiling

- the granules swell, are disrupted, and become soluble in water
- the granules are now no longer crystalline but gelatinised
- gelatinised starch can be digested in the upper intestinal tract

on cooling

- the gelatinised starch granules re-crystallise or retrograde
- retrograded granules are not digested in the upper intestine

retrograded starch is resistant starch
resistant starch is a fibre

how the body handles starch

if digestible

- broken-down into glucose molecules in the upper intestinal tract
- glucose molecules absorbed from the small intestine
    - rapidly higher up in the small intestine
    - slowly along the rest of the small intestine

if not digestible = resistant

- not broken down in or absorbed from the upper intestinal tract
- passes undigested into the lower intestinal tract
- broken down by bacteria into short-chain fatty acids (SCFAs)
- SCFAs absorbed and/or acting and metabolised locally

resistant starch looks and acts like a fibre – so it is a fibre

food high in starch = food high in fibre

whole, milled, ground, sifted, refined, flaked, pearled, ...

- cereals: barley, maize, millet, oats, rice, sorghum, rye, wheat
- pseudo-cereals: amaranth, buck-wheat, quinoa
- root vegetables: cassava (tapioca, manioc), chufa, mashua, oca, potato, sweet potato, tannia (cocoyam), taro, ulluco, yam
- other: fruit (plantain), tree trunk (sago)

and then there are dried legumes/pulses

black beans, black-eye beans, broad beans, butter beans, haricot beans, kidney beans,
lima beans, mung beans, red beans, soya beans, and sugar beans;
chick peas (garbanzo beans, chana), whole (mushi) and split peas; lentils

much more than *whole* grains (even intact grains)
the Eurocentric, USDA, and WHO mantra

root vegetables
underground plant food stores

good source of food for man and beast
storage nutrients: starch, inulin, polyols, and sugars
also protein, vitamins, minerals, anti-oxidants

known in botany as rhizomes, tubers, bulbs, corms, roots, …

- rhizome – horizontal underground main stem: arrowroot, turmeric, ginseng, ginger
- stem tuber – part of an enlarged rhizome or stolon: potato, tiger-nut (chufa), oca
- root tuber – enlarged lateral root: sweet potato, cassava, yam, earth apple
- bulb – short stem with fleshy leaves in which food is stored: onion, garlic
- corm – short, vertical, enlarged underground stem with protective leaves: taro, konjac
- taproot – enlarged taproot: parsnip, turnip, carrot, radish, beet
- stolon – horizontal underground off-shoot from the main rhizome stem

in praise of the homely potato

- a good source of starch and fibre
- protein quantity low but quality high (due to digestibility and amino acid composition – all 4 essential amino acids present + high lysine)
- high in biological* and satiety value
- high in resistant starch, K, Mg, vitamins (C, B6, folate), and phenolics*
- low in fat and sodium – unless added in preparation and processing*
- no gluten or phytates
- the only complete food, relatively affordable, common to all food cultures
- unfairly, irrationally, and wrongly demonised

RA McCance* a renowned nutrition scientist lived an intellectually productive, physically active, and healthy life on a diet almost exclusively of potatoes.

- biological value (proportion of absorbed protein incorporated into the body's proteins): 90-100, soybeans 84, legumes as a group 73 cf egg at 100; phenolics like flavonoids and phenolic acid provide 25% of USA vegetable phenolic /anti-oxidant /phytochemical intake; preparation and processing also enhance nutritional profile: oven baking, cooling, and vacuum frying increase resistant starch content; Prof McCance died aged 94

traditional staples* and regional preferences

Africa

- South, Central, and East: maize, millet, potato, rice, sweet potato, sorghum, wheat
- West: cassava, chufa, maize, millet, plantain, sorghum, taro, tannia, yam, rice
- North: barley, couscous, rice, wheat

America

- South and Central: amaranth, arrow-root, barley, cassava, maize, mashua, oca, plantain, potato, quinoa, rice, sorghum, sweet potato, taro, tannia, ulluco, yam
- North: amaranth, barley, maize, oats, potato, rice, wheat

Asia

- South and East: amaranth, arrow-root, barley, buck-wheat, cassava, millet, plantain, rice, sorghum, sweet potato, wheat, yam
- Middle East: barley, couscous, rice, wheat
- Pacific: oca, sago, taro, yam

Europe

- South: buck-wheat, maize, potato, rice, wheat
- West, Central, and North: barley, bulgar, millet, oats, potato, rice, rye, wheat
- East: barley, buck-wheat, maize, millet, oats, potato, rye, wheat

Australia – resembles Pacific Islands and North Europe

* staple = a food eaten routinely and in such quantities that it constitutes a dominant portion of a standard diet in a given population – all starches

staples in our diet

“nutritive anchor of an entire culture”

“People subsist on some principal complex carbohydrate usually a grain or root crop around which their lives are built. It provides the raw materials out of which much of the meaning in life is given voice. Its character, names, distinctive tastes and textures, the difficulties associated with its cultivation, its history, mythical or not, are projected on the human affairs of a people who consider what they eat to be the basic food, to be the definition of food.

People brought up in starch-centred cultures may feel that they have not really eaten unless they have had [their starch] but they will also feel that [this] is not enough unless it is accompanied by [a side-dish like a relish, sauce, or stew]. … These supplements are not ordinarily consumed in large quantities – hardly ever in quantities equal to those of the starches.

[W]hole societies have apparently now begun to stand such patterns on end. … The radical dietary changes of the last 300 years have largely been achieved by revolutionary pressures in food processing and consumption and by adding new foods, rather than simply cutting back on older ones.”

Extract from: *Sweetness and Power – the place of sugar in modern history*. Sidney W Mintz. 1985. Penguin Books.

11 cereals and pseudo-cereals

cereals and grains – definitions

- cereals: plants from the grass family such as barley, maize, oats, rice, wheat
- pseudo-cereals: broad-leaf plants like amaranth, buckwheat, quinoa
- grains: edible seeds or kernels of cereals and pseudo-cereals, usually dehusked
- hull: scaly, coarse, dry, protective covering of a grain; also called husk or chaff*
- pericarp: outer layer of a grain composed mostly of non-starch polysaccharides
- aleurone layer: thin protein layer under the pericarp surrounding the endosperm
- endosperm: starchy inner core of a grain; also contains some protein and fats
- germ: embryo + protein, fats, sugars, starch, minerals, vitamins, anti-oxidants
- whole-grain: not intact but reconstituted from ground, cracked, or flaked with husk, pericarp, aleurone, germ, and endosperm in the same proportion as in the intact grain*
- bran: pericarp, aleurone, germ, a little endosperm ± husk: a by-product of processing
- refined grains: mostly endosperm – remainder after bran has been removed
- extraction ratio: % intact grain left after some bran removed; eg *whole* wheat flour: 100% - 0% removed, brown flour: 85% -15% removed, white flour: 70% - 30% removed
- white colour: white wheat flour is bleached and white rice is polished with talc

* whole-grain as an adjective not a noun as defined by the WGC and the FDA; the husk when removed from the grain is called chaff;

the semantics and politics of grains

whole grains are not intact grains

By international agreement* grains or foods made from them can be called whole grain if after separation of its parts and subsequent recombination they contain all the “essential” parts of the grain in “approximately the same” ratio as found in the original grain. (see also slide 16)

for grains used in commercially processed food

definition qualified with standards for stamps and claims:

- Whole Grain Council: ≥ 8g and ≥ 16g whole grain/serving = basic and 100% stamp
- Australia: no official position but claims can be made if ≥ 10% whole grain or ≥ 4.8g/serving
- Canada: wheat flour can be called "whole wheat" only if ≤ 5% of the original kernel is missing
- Germany: ≥ 90% wheat and rye bread; 100% pasta
- Netherlands: 100% bread; ≥ 50% other foods
- Scandinavia: 100% flour, grains; ≥ 25% bread; ≥ 50% porridge, pasta; ≥ 15% pizzas, pies
- USA - FDA: ≥ 51% of total weight whole grain; allows 5% bran to be removed from wheat flour

but the sum of the parts is not the same as the whole

(note that fat in bran is removed to reduce rancidity and increase shelf life)

* Whole Grain Council definition May 2004; the FDA’s definition is similar; standards last updated 2009

processing some cereals

Roller milling strips out the parts of the wheat kernel. The finest particles of the endosperm are sieved out. Coarser particles with bran attached are then ground, and the bran including the germ is separated from the flour. In traditional whole grain stone grinding the germ is ground into the endosperm and is not part of the removable bran.

The outer husk is removed with a rice huller to produce brown rice. White rice is produced when the rest of the husk and bran are removed. If rice is parboiled before milling, vitamins from the bran like thiamine (B_1) migrate into the endosperm and the starch is gelatinised. Rice flour is ground white rice.

Centripetal acceleration separates the husk of the oat grain from the groat. The husks are ground into insoluble oat fibre. The groats are roasted to prevent the enzyme activated by dehusking from breaking down fat. The roasted groats are processed into flaked or rolled oats, ground into oat flour, or separated into de-branned flour and bran.

The pericarp of the maize grain is fused with the husk. The grain is wet-processed or pre-soaked with or without an alkali (nixtamalised*) or dry-milled to produce corn flour, grits, hominy, mealie meal, and polenta or partially gelatinized into “flaked” corn. Grading depends on the extent of winnowing and sifting to remove coarse particles.

* nixtamalised = pre-soaked in Ca $(OH)_2$ to soften; makes niacin, lysine and tryptophane accessible – traditional in Asia and South America

refining cereals

partially removes nutrients and modifies relative composition of protein, fat, non-starch polysaccharides, vitamins, minerals, anti-oxidants, phyto-oestrogens, phytic acid, …

nutrient composition of maize meal*

	protein	fat	fibre	Na	K	Mg	Ca
		g/100g			mg/100g		
no.1 straight-run	9.2	4.3	11.0	11	346	123	10
unsifted white	9.1	3.7	6.0	9	337	100	5
sifted white	9.0	3.5	5.0	7	295	90	4
special white	8.9	2.5	3.0	7	251	75	4
super white	8.8	1.2	3.0	5	151	32	3

nutrient composition of wheat bran and wheat flour*

	protein	fat	fibre	Na	K	Mg	Ca
		g/100g			mg/100g		
crude bran	15.6	4.3	42.4	2	1182	611	73
whole wheat flour	13.7	1.9	12.6	5	405	138	34
brown bread flour	12.6	1.8	7.0	4	250	80	20
cake flour	8.2	0.9	2.7	2	105	85	14

* source: MRC Food Composition Tables – 3rd edition (1991) South Africa; fibre in tables = NSPs as in old definition which excludes resistant starch

wheat – triticum spp

varieties widely used today:

- durum wheat* – high in proteins, relatively low in gluten → pasta, semolina
- bread wheat* – selectively cultivated, high in gluten → bread

old varieties not in general use; some coming back as gourmet foods:

- khorasan wheat – contains gluten but less allergenic
- einkorn – high in protein, eaten in parts of Europe
- emmer wheat – farro in Italy, a relic crop still eaten in Ethiopia
- spelt – a hybrid of emmer, high in protein but moderate gluten content

and then there are the recent* cross-bred varieties of bread wheat:

- white wheat from red wheat: anthocyanins and tannins removed
- soft wheat from hard wheat: protein including gluten content reduced
- soft and hard white wheat: mixed and matched

hypothesis: white wheats and wheat intolerance – coincidence or related?

* durum wheat is very hard; bread wheat = triticum aestivum vulgare; recent = USA 1970s and more widely marketed since 1990s spreading to Asia; Australia earlier

whole wheat and white bread

A quote from *Davidson and Passmore - Human Nutrition and Dietetics* edited by R Passmore and MA Eastwood; 8th edition (1986) page 184

> "There are many records of healthy communities who get up to 70% of their dietary energy intake from wheat. In an experiment which is now a classic Widdowson and McCance* showed that children in orphanages in Germany were healthy and grew well on diets in which 75% of the energy was provided by wheat, about 20% by vegetables and only about 5% by foods of animal origin.
>
> Furthermore there was no difference between groups of children whose bread was made from flour of 100, 85, and 70% extraction.
>
> This experiment confirmed common observation that bread made from flour was a nutritious food, even if the extraction rate was as low as 70% as in most white bread."

* Widdowson EM, McCance RA 1954 Studies on the nutritive value of bread and on the effect of variations in the extraction rate of flour on the growth of undernourished children. Spec Rep Ser Med Res Coun Lond no 287 (Special Report Series Medical Research Council London).

rice – an almost universal staple

eaten by over half the world's population

- ancient origin – domesticated ~ 10 000 years ago
- used whole – brown, white, polished, par-boiled; as porridge ± fermentation; ground – flour, rice wine, rice milk, alcohol; puffed
- short, medium, or long-grain according to amylopectin content
- nutrient quality depends on variety, soil, processing, preparation
- brown and de-branned white rice differ in insoluble fibre, vitamin A and vitamin B_1 content; neither provides high quality protein
- not a complete food whether brown or white, unless fortified
- may contain arsenic – especially in USA ← past pesticide use

almost always eaten with a side-dish of legumes, vegetables, meat, and fish

Beri-beri historically linked to eating white rice is a multi-factorial deficiency disease that is not due only to a deficiency of vitamin B_1. It is found in people subsisting on an unvaried diet of white rice that is not parboiled and <u>without</u> a side-dish.

maize – food for people

a universal nutritious staple

traditionally eaten with a nutritionally complementary side-dish of legumes, peanuts, oil, vegetables, meat, fish, fresh milk, sour milk, cream, …

- finely ground and prepared as a soft, sour, stiff, crumbly porridge or bread and called phutu, pap, mushwe, impuphu, phaletshe, magewu, sadza, nshima, oshifima, ubwali, ugali, buhobe, angu, banku, akamu, ogi, fufu, kuon, hupfu, tortilla, cou-cou, funche, mayi moulin pura, cou-cou, polenta, kuožganci, puliszka, kačamak, mamalika, corn bread, …
- coarsely ground and prepared as a porridge – grits and hominy (nixtamalised), braai-pap, ...
- whole – fresh (corn on the cob, sweet corn), dried (samp, pop-corn)
- crushed – as a rice (mealie rice)

also used and abused to make

- fuel – kernels and cobs
- industrial plastics, fabrics, adhesives – endosperm
- animal fodder, dog food – kernels
- breakfast cereals, HFCS, food additives, edible oil – mostly endosperm
- alcoholic drinks (isitshwala, chicha, Boubon whiskey, beer) – kernel
- silage – leaves and stalks

grits – the traditional southern USA staple

The state of Georgia declared grits its official prepared food in 2002.

"Whereas, throughout its history, the South has relished its grits, making them a symbol of its diet, its customs, its humour, and its hospitality, … and whereas, grits has been a part of the life of every South Carolinian of whatever race, background, gender, and income; and whereas, grits could very well play a vital role in the future of not only this State, but also the world … ”

Charleston's The Post and Courier proclaimed in 1952:

"An inexpensive, simple, and thoroughly digestible food, (grits) should be made popular throughout the world. Given enough of it, the inhabitants of planet Earth would have nothing to fight about. A man full of (grits) is a man of peace."

and in Zambia

“Forget money, forget healthcare, forget a functioning education system, if there is one thing Zambians really cannot live without, it's nshima*.”

* quote from Sweetness and Power – the place of sugar in modern history. Sidney W Mintz. 1985. Penguin Books; nshima = maize meal porridge;

pseudo-cereals

- not grasses like cereals but broad-leaved plants
- seeds can only be eaten cooked – whole, cracked, crushed, ground, ...
- protein quantity and quality high, gluten not present
- resistant starch and other fibres high
- popular and widely used in ancient times and traditionally especially in the Far East and South America
- recently increasingly available in “health food” and niche markets

- amaranth: cultivation banned by conquistadores, now not much used
- buckwheat: biological value > 90%, contains rutin (phenolic glycoside) an anti-oxidant, popular in Russia and Far East, groats → kasha, common usage replaced by wheat when nitrogen fertiliser introduced early 1900s
- quinoa: biological value 100%, locally cheap (South America) but very expensive in USA and EU niche markets → ethical and market challenges

12 fibre – definitions and structure

dietary fibre/roughage

both names are misleading because what they refer to is usually not fibrous or rough, but viscous and gelatinous

a comprehensive definition of a misnomer - 2011

fibre is a naturally occurring carbohydrate that

- is consumed as food
- is not rapidly or fully digested in, or absorbed from, the upper intestinal tract
- has unique physical properties
- exerts unique physiological effects on intestinal tract function and structure

fibre is only found in nature – in plants and animals

an extracted or synthetic compound is not a fibre even if it has similar chemical and physical properties and physiological effects

other definitions of fibre

no consensus – so there are many

2009: European Union definition - Codex Alimentarius

"carbohydrate polymers with =/> 10 monomeric units, which are not hydrolysed by … enzymes in the small intestine … and belong to the following categories:

- edible carbohydrate polymers naturally occurring in food as consumed
- carbohydrate polymers, obtained from raw material in food by physical, enzymatic, or chemical means and … synthetic carbohydrate polymers [both of] which have been shown to have physiological effects of benefit to health by generally accepted scientific evidence to [sic] competent authorities."

older definitions

Research Institute for Nutritional Diseases. South African Medical Research Institute (1991): "Fibre is ... the sum of cellulose, soluble and insoluble non-cellulosic polysaccharides, and lignin".

Geigy Scientific Tables (1981): Crude fibre is "that part of food insoluble in water, ethanol, ether, sulphuric acid and sodium hydroxide."

why no consensus on definition

historical	increasing knowledge of structure, properties, and effects
complex structures	many chemical formulations within many sub-groups – some still not fully characterised, others not unique
interactions	extrinsic factors alter in vivo properties and effects

difficulty with defining fibre is compounded by

- paucity of reliable, unbiased, accurate, detailed data
- reductionist division of food into separate groups and sub-groups
- in vitro and in vivo properties and effects differ
- effects cannot be isolated from that of other nutrients
- lack of sensitivity to probable deleterious consequences from eating un-natural, extracted, modified, and synthetic compounds
- embedded conflicts of interest among decision makers
- deliberate misinformation to accommodate the food industry

what is included in the "2011" definition

- resistant and slowly-digested starch
- non-starch polysaccharides
- non-digestible oligosaccharides
- sugar alcohols
- glyco-conjugates – non-digestible saccharides chemically bound to non-carbohydrate compounds

Fibre is always an integral part of food.
Fibre never occurs in grand isolation on its own.
Extracted compounds with properties and effects that resemble fibre are food additives – neither fibre nor food.

chemical structure determines digestibility and absorption

(fibre is a carbohydrate; carbohydrate =/> 1 saccharide molecule)

because	only D mono-saccharides can be absorbed
and	enzymes in the upper intestinal tract can only digest (break down) other carbohydrates if their saccharide molecules are linked by α1:4 bonds
therefore	not all carbohydrates are digested in the upper intestinal tract into mono-saccharides that can be absorbed from the upper intestinal tract
and	undigested carbohydrates (by definition fibre) pass into the lower intestinal tract

Only glucose, fructose, sucrose and the α1:4 bonded chains in starch are digested in the upper intestinal tract. All other saccharides pass undigested into the lower bowel

two exceptions – different reasons

- lactose (milk sugar) – β1:4 galactose-glucose
- resistant starch – not endogenously digested

under certain conditions lactose is not a fibre and starch is a fibre – as defined by their “new” physiological effects

Lactase, an enzyme that breaks down lactose into galactose and glucose, is only found in the small intestine of small children and some adults. When lactase is absent as in most adults, lactose is not digested in the small intestine and passes into the large intestine as fibre. Fermented milk products like yoghurt are absorbed because fermentation like lactase breaks lactose down into monosaccharides.

The rate and extent of starch digestion in the upper intestinal tract depends on the intrinsic physical properties of the starch granule, on how the food containing starch is cooked and eaten, and on the accessibility of the starch molecule to the absorptive surfaces of the small intestine. Starch may thus be slowly-digested in the small intestine or pass undigested into the large intestine where it is called resistant starch. The α1:6 linked monomers of the amylopectin fraction of starch are also not digested.

physical properties of fibre

fibre is usually either soluble or insoluble in water
but ß-glucans and hemi-celluloses are both

- soluble fibre becomes viscous and forms gels when moist
- soluble and insoluble fibre holds water
- insoluble fibre binds to organic molecules

Solubility depends on the hydrophilic-hydrophobic balance, the extent and duration of exposure of the hydrophilic surface area and on the size and physical structure of the fibre molecule

- physical patterning and the number of pores in the fibre matrix
- type and regularity of intra-molecular branching

soluble fibres are more hydrophilic, behave like colloids, and are viscous;
insoluble fibres are larger, more rigid, have more branches, and are fibrous

resistant and slowly-digested starch

RS1 – physically encapsulated starch granules inaccessible to enzymes*
RS2 – native crystalline B-type starch granules and intrinsic structure
RS3 – cooked and cooled retrograded starch granules
RS4 – starch granules chemically modified to resist digestion*

heat processing → 20-30% of starch to become RS3 resistant

amount of RS3 resistant starch in large bowel

↑ by the amylose content of the food and quantity ingested
↓ by chewing and the amount of water used in cooking
↓ by concomitant ingestion of fat, glucose, sodium nitrate, emulsifiers
↓ by slow transit through small intestine → more slowly-digested starch

% resistant starch in selected food – in descending order

legumes - white beans autoclaved	11.20
legumes - yellow peas boiled	9.5
potato - cold salad	5.9
rice - parboiled long grain boiled	3.7
pasta - spaghetti boiled 9 minutes	2.9
potato - boiled hot	2.0
wheat - puffed breakfast cereal	1.2
rice - sticky porridge	1.2
oats - uncooked flakes	0.3

* RS1 starch is found in intact cereals and pseudo-cereals; RS4 starch is unnatural and therefore NOT a fibre but an additive;
The molecules in amylose are tightly bound in a spiral thus resisting digestion; the molecules in amylopectin are loosely aligned

13 fibre – effect and measurement

effect on intestinal tract

soluble fibres tend to form gels and to hold water
insoluble fibres tend to form a mesh of inter-twined fibrils and increase water holding capacity; less gel-forming

viscosity and gel formation

- retards passage of food
- delays gastric emptying
- slows diffusion of nutrients to absorptive surfaces of gut
- delays absorption of glucose and lipids from small intestine
- lines mucosal surfaces: prevents contact with toxic organic molecules and bile acids, interferes with their absorption, inhibits pathogenic bacterial invasion

water holding capacity

- slows diffusion of nutrients to absorptive surfaces of gut
- increases stool bulk and reduces stool density in large intestine
- lowers large bowel transit times
- limits exposure of mucosa to toxic organic molecules
- binds with organic molecules
- binds with bile salts, 2ndary bile acids, & other organic molecules in small and large bowel → ↓ absorption, ↑ excretion

effect on intestinal function

Interactive and interdependent extrinsic factors and processes related to the eater and to the food that is eaten (what, how prepared, and how chewed, ...) and the alimentary tract itself interact with the intrinsic fibre properties to determine the bioavailability and in vivo effect of ingested fibre

factors:

- general well-being of the eater
- timing and duration of meals, conviviality
- rate and extent of chewing, digestion, absorption
- concomitant use of water, alcohol, tobacco, food additives
- other* nutrients and moisture in food ingested now and before
- temperature of food, relative and absolute amount of fibre present

effects:

- ↑ viscosity and water-holding capacity of intestinal contents
- ↑ binding of organic and toxic molecules in large intestine
- ↑ faecal weight
- intestinal transit time: ↓ in small bowel, ↑ in large bowel
- beneficiation of colon bacterial population and fermentation

* other = not fibre

effect on colon bacteria – microbiome

food source/substrate for bacterial fermentation/digestion = soluble fibre

end products of fermentation: SCFAs: butyric, propionic, acetic acid
gases: CO_2, hydrogen, methane

rate and extent of fermentation depend on:

- degree of solubility, source, and chemical structure of the fibre
- concomitant availability of more readily fermentable fibres
- type and volume of colonic micro-flora
- intestinal transit time

SCFAs act locally and systemically

local action	systemic action
colonocyte nutrition improved	provide 2cal/kg energy
cancer cell growth ↓	immune protection ↑
pH ↓ → polyps and inflammation ↓	pH ↓ → mineral absorption ↑
→ 2ndary bile acids production ↓	Insulin release
→ 2ndary bile acid excretion ↑	liver glyconeogenesis
→ immune protection ↑	cholesterol synthesis
bacterial volume ↑ and	↓ from propionic acid
bacterial profile beneficially altered*	↑ from acetic acid

* beneficial bacteria (lactobacilli, bifidobacteria) ↑, pathogenic bacteria (clostridium perfringens) ↓

summary of effects: locally, systemically, and epidemiologically

locally on gastro-intestinal tract:

- satiety increased with reduction in appetite
- bowel action/stool evacuation improved
- local cellular health and immunity improved
- flatulence and abdominal discomfort

systemically:

- water, sodium, and mineral absorption increased
- calorie intake per unit of ingested carbohydrate reduced
- post-prandial insulin, leptin, and ghrelin responses reduced
- blood glucose level modulated
- post-prandial blood glucose response flat
- serum cholesterol lower
- lipid profile altered from differential acetate and propionate absorption
- immunity enhanced

epidemiologically:

- weight loss and reduced weight gain from iso-caloric intakes
- total and LDL blood cholesterol levels lower
- serum triglyceride levels lower
- risk of hypertension, diabetes, coronary heart disease, and stroke lower
- risk of colon and rectal cancers lower

none of the effects are unique to fibre

measurement of fibre - I

position post 1980 – when resistant starch was “discovered”

“There are basic differences in studying purified [fibre] polymers, highly concentrated but not purified fibres, and diets high in high-fibre whole foods.”*

identification and measurement of nutrients is based on:

- chemical structure
- physical properties
- physiological effects – questionable

measurement not possible, practical, or meaningful because:

- there is no agreed definition of fibre
- of differences in source material and methods of measurement
- chemical structure is complex and in some cases not known
- chemical structure of resistant starch is not exclusive
- physical properties affected by variable extrinsic factors
- physiological effects cannot be uniquely ascribed to fibre

* Spiller GA. Beyond dietary fiber. American Journal of Clinical Nutrition. 1991; 54(4): 615-617

measurement of fibre - II

examples of problems and discrepancies pre and post 1980

fibre content of selected foods from three credible sources*

	indigestible	insoluble	unspecified	
	residue	fibre		
	USDA 2005		Ciba-Geigy	SA MRC
cabbage - whole	21.5	17.5	1.5	2.2
bread - rye	21.0	1.6	0.4	5.8
bread - whole wheat	15.5	2.0	1.5	6.6
legumes - kidney beans	15.0	2.8	4.0	7.2
onions	10.5	10.0	0.6	1.6
carrots	9.9	9.0	1.0	3.2
potatoes	9.9	2.8	0.5	1.9
legumes - soya beans	5.1	2.4	4.9	5.1
bread - white	4.0	0.8	0.2	3.1

g/100g of dry matter or whole food*

some values still in use in food labels and in “scientific” discourse

* columns 1 & 2: dry matter; columns 3 & 4: whole food; column 1 in descending order
USDA Dietary Guidelines. 2005; Scientific Tables Ciba Geigy,1970; MRC (South Africa) Food Composition Tables – 3rd edition .1991;

measurement of fibre – III what the fundis say

“[There are] two systematic biases inherent in comparing the fibre intake of different populations … differences in methods of estimating food intake and in the methods for estimating dietary fibre content of foods”

compounded by the variable, interactive, and constantly changing effect of extrinsic factors on the amount of starch that resists endogenous digestion

impossible to isolate effect of fibre

“[The] basic unresolved dilemma in the study of the physiological effects of dietary fibre … is the difficulty of separating the responses due to fibre from those due to other materials found in fibre-rich foods.”

“[P]resent knowledge indicates that fibre cannot be isolated as a single factor affecting [metabolism] but must be evaluated in the context of the total dietary pattern.”

14 recommendations – with details

eat food high in fibre

because it is not possible to measure the fibre content of food, Adequate Intake (AI) or Recommended Daily Allowance (RDA) levels cannot be set <u>so just eat food high in fibre</u>

grains	wheat, maize, rice, barley, sorghum, quinoa, … whole or ground, refined, flaked, pearled, or par-boiled, …
root vegetables	potato, yam, cassava, parsnips, turnips, … boiled, baked, or fried, whole or mashed, hot or cold, …
legumes	beans, peas, lentils: whole, split or ground, mashed, …
other vegetables	pulp, skin, and pips: raw, boiled, baked, grilled, fried, but NOT the pure extracted juice
algae and fungi	dried sea-weed, mushrooms, yeast
offal	brain, cornea, lungs, skin, cartilage, bones, exoskeleton
fruit	pulp, skin, and pips: raw, stewed, or baked, whole or mashed, but NOT the pure extracted juice

ignore the values printed on food labels – they are wrong

where is fibre found

- resistant and slowly-digested starch

grains:	endosperm of wheat, maize, barley, quinoa – white or yellow, intact or ground, refined, flaked, pearled, polished, par-boiled, …
legumes:	seeds of beans, peas, lentils – whole, split, mashed …
root vegetables:	potato, yam, cassava – whole or ground, mashed, …

- non-starch polysaccharides

grains:	wheat, maize, rice, rye, barley, oats – intact or ground
root vegetables:	onion, parsnip, turnip, sweet potato, earth apple, …
legumes:	beans, peas, lentils – whole, split, mashed, …
other vegetables & fruit:	pulp, skin, pips (pomace)* but NOT the juice
other:	algae and fungi, sea-weed, mushrooms, yeast

- other non-digestible carbohydrates

oligo-saccharides	legumes, green leafy vegetables, fungi
sugar alcohols:	sweet potato, sweet corn, carrots, beet-root, berries
glycoconjugates:	spinach, legumes, cartilage, brain, and similar offal

* the pulpy residue from oranges and apples or similar fruit after crushing and pressing

examples: non-starch polysaccharides

type	sub-type	where found
glucans	β-glucans	cereal bran, baker's yeast, mushrooms, algae
	cellulose	firm green plants – cell walls, hemp, algae
hemi-celluloses	arabinoxylans	cereals – bran and endosperm
	xyloglucans	of soft green plants – cell walls
	glucomannan	konjac – corm
β fructans	inulins	onions, sweet potato, parsnips, green beans
	levans	barley, wheat, rye, triticale – young grains
	graminans	grasses used as animal fodder
galactans	agar	red algae
	carrageenans	red algae
	pectin	fruit and vegetables – pulp and skin not juice
mannans	alginate	brown algae
galacto-mannans	fenugreek	fenugreek – endosperm of seed
	guar	guar – endosperm of seed
	tara	Peruvian mountain shrub – endosperm of seed
	carob bean	carob tree – seeds and pods
xylan		cereals – bran and husk, algae; with glucans

examples: oligosaccharides

type	where found
fructo-oligosaccharide	barley, rye, green beans, same as inulin: agave flower, leaf, stalk and sap, asparagus, burdock, chicory, dandelion, earth apple (Jerusalem artichoke), garlic, leeks, onions, parsnips, sweet potato, taro, tiger-nuts, turnips, wild yams
galacto-oligosaccharide	soy-beans
raffinose-oligosaccharide	grains, green beans, cabbage, asparagus, Brussel's sprouts, broccoli, other vegetables, fungi
stachylose	legumes, green beans, other vegetables
verbascose	legumes

examples: sugar alcohols – polyols

polyols are mono and disaccharides
whose carbonyl group has been reduced to a hydroxyl group

hydrogenated monosaccharide hydrolysates:
sorbitol, mannitol, xylitol, and erythritol

hydrogenated disaccharide hydrolysates:
isomalt, lactitol, and maltitol

polyols are found in:

fruit:	berries, plums, pineapple, …
vegetables:	asparagus, olives, beet-root, carrots, oats, sweet potatoes, maize (kernel and cob), mushrooms, algae, …

examples: non-digestible glycoconjugates

type	name	where found
amino acid -	chitin	fungi, crustaceans and insects – exoskeleton
glucosaminoglycans	chitosan	crustaceans – exoskeleton
	hyaluronan	animal skin and joints
protein	psyllium	plantago plant – not consumed as food
glycoproteins	prolamine*	cereals – wheat, barley, rye, maize, oats
	heparan	animal offal – applies to all glycoproteins
	dermatan	especially skin, lungs, blood vessels, tendons
	chondroitin	especially cartilage, brain matrix
	keratan	especially cornea, cartilage, bone
terpenes	saponins	agave, grains, fennel, fenugreek, ginseng roots, legumes, onions (red), paprika, sea cucumber, spinach, starfish, yam (red, wild)
phenols	lignin	plants – leaves and stems of all plants

* assuming that the prolamine component (gliadin, hordein, secalin, zein, avenin) of the gluten in cereal respectively is a glyco-aminoglycan

15 glycaemic index, satiety, …

glycaemic index (GI)

The GI of a food is defined as the incremental area under the 2 hour blood glucose response curve following ingestion of 50g of available carbohydrates (without fibre), expressed as a percentage of the corresponding area after ingesting an equivalent amount of carbohydrate from a standard reference product (glucose or white bread)

GI affected by GIT motility, digestion, absorption, and by:

- amount, consistency, and composition of carbohydrate in test material – especially fructose content (nil response) and resistant starch (blunted response)
- presence of non-carbohydrate test material components and food additives
- differences in cultivation, cultivars, storage, preparation, … of test material
- previous meal or lente effect, blood glucose level, insulin resistance

validity of GI measurement as formally listed challenged by:

- differences in test methodology, sample size, type, and mass of reference product
- non-equivalence of available and other carbohydrate in test material and reference product
- data on fibre (for subtraction) obtained from non-accredited sources usually manufacturers
- quantitative data on fibre anyway meaningless because fibre cannot be measured
- similar branded manufactured items vary widely in available carbohydrate content
- “GI values measured in vivo can be significantly different for the same foods measured in vivo”

References: DJA Jenkins et al. Am J Clin Nutr 2002. 266-273S; 2. Kaye Foster-Powell et al. Am J Clin Nutr 2002;76:5–56;
FAO/WHO (1998) Carbohydrates in Human Nutrition (Paper No. 66).

GI reflects fibre content

when it does not reflect fructose content

The relative amounts of rapidly available glucose (RAG) and slowly available glucose (SAG) are the main determinants of glycaemic index (GI) for grain products. “A high SAG content identifies low-GI foods for which health benefits have been proposed.” Englyst KN et al Br J Nutr. (2003);**89**:329-339

... and so for all food containing carbohydrates

except fructose which has no effect on blood glucose

RAG = free glucose especially in liquid form; SAG = glucose from starch digestion

resistant starch and other fibres further reduce the rate and amount of glucose absorbed

the beneficial effects of a low GI parallel the effects of fibre

low GI causes:

↓ oxidative damage
↓ gut hormones and insulin secretion
↓ counter-regulatory responses
slow sustained insulin release

low GI results in:

↓ serum lipids in hyperlipidemics
↑ HDL cholesterol
↓ risk of DM, CVD, Ca colon and breast
improved glycaemic control

GI, fructose, and a layman's guide

confusions and challenges

Because fructose does not increase blood glucose levels

food and foodstuff containing fructose → lower GI.

so if a low GI is healthy, then is fructose healthy?

NO fructose is unhealthy, a poison – especially in XS

because a high GI food → glucose and glucose is allegedly unhealthy
but the body needs glucose – it is the body's most important source of energy
glucose should be slowly absorbed
and the intake of SAG should be just enough – not too much

energy should not be supplied by fructose, fat, and protein

therefore GI is not useful as a guide to healthy eating

GI howlers* and questions

gems gleaned from the definitive published list*

- white table sugar has a lower GI than a baked potato
- the GI of rice ranges from 38 – 94 (due to variable amylose content)
- some carrots have a GI of 92 while other carrots have a GI of 32

summary: the GI is unpredictable, invalid, unreliable, inaccurate, misleading

So why is the term GI still in use? Is it because the data has not been integrated into mainstream scientific and popular discourse so that starch can still be demonised?

Is the lack of an effect of fructose on blood glucose/GI ignored so that fructose and food and drink containing fructose can be marketed as good, low GI "food"?

The question is, is this deliberate? And if deliberate, quo bono?

recommendation on GI: consign it to the proverbial dust-bin of history

an alternate simple and realistic recommendation is:

eat a diet low in sugars and high in starch and other forms of fibre

- howler = a mistake, especially an embarrassing one that evokes laughter;
  K Foster-Powell , SHA Holt, JC Brand-Miller. Am J Clin Nutr 2002;76:5–56, - GI list data generated "often as a result of contract research by industry"

the related matter of satiety and appetite

<u>factors increasing satiety</u>

- ↑ insulin and leptin secretion
- ↑ brain glucose and leptin levels
- ↑ water, fibre, and protein meal content
- bulky low-fat food eaten <u>slowly</u>
- enough sleep – at least 6 hours/night

<u>factors increasing appetite</u>

- ↓ brain glucose and leptin levels
- ↑ fructose-laden drinks and foodstuffs
- low ambient temperature
- sensation of stomach emptiness
- not enough sleep (↑ ghrelin secretion)

factors influencing how much is eaten

- habit, palatability, pleasure, social convention
- adaptation to scarcity over millennia – thrifty gene
- working and living arrangements and conditions
- food production and distribution practices

With skewed seductive and provocative abundance and the aggressive and ubiquitous promotion of cheap, “convenient”, energy-dense, sugar and fat laden, ready-to-eat food and drinks, the urge to gorge and binge can be irresistible and social and physiological controls, if any, easily over-ridden.

satiety index = SI

SI = index of short-term satiety compared with white bread at 100
subjectively rated 2 hours after eating 240-calorie set portions of food
in ≤10 minutes and confirmed by measuring post study ad lib consumption

food or foodstuff	SI
cake	65
Mars bar	70
bread - white	100
potato chips	116
bananas	118
cornflakes	118
cookies	120
lentils	133

food or foodstuff	SI
cheese	146
popcorn	154
bread - whole wheat	157
baked beans	168
beef steak	176
oranges	202
porridge	209
potatoes - boiled	323

interesting perhaps but not useful as a scientific analytic tool
or even as a sale's pitch despite the hope that:

"If the differences we report between the satiating properties of foods are reproducible and correlate with weight changes then high satiety food choice tables could be devised. Based on this new knowledge, the food industry could formulate products designed specifically to enhance satiety" – or preferably to reduce satiety and increase sales?

Holt SHA, Brand Miller J.C, et al. A Satiety Index of Common Foods. European Journal of Clinical Nutrition, 1995, p675. Study supported by Kellogg's inter alia

lessons from GI and SI

- eat bulky soft or raw food rather than dry food*
- eat food low in sugars and high in starch and fibre
- avoid all foodstuff containing added fructose
- nibble and don’t gorge – small, frequent meals/snacks
- eat slowly and relish each morsel
- use small portions in small plates; then you can stop eating when you feel full and still leave a clean plate
- drink something safe with each meal/snack

ignore low GI adverts – rather check labels for ingredients

cultivate healthy habits
your body will adapt and be the better for it

* It’s the water content that matters: soft, raw, and boiled food have a high water content; fried, roasted, and dried food contain less water;

recommendations on carbohydrates

eat very little if any free sugars

use and enjoy food high in starch and fibre as our forebears did and traditional societies still do

- starch should provide ≥ 70% of total daily energy
- intact grains are healthier than food made from *whole* grains which are slightly healthier than food made from refined grains
- root vegetables and legumes contain lots of starch and fibre
- eat plenty vegetables (fibre ↑) and little fruit (sugars ↑)

and don't forget to add a healthy side dish as customarily eaten with every high-starch main dish