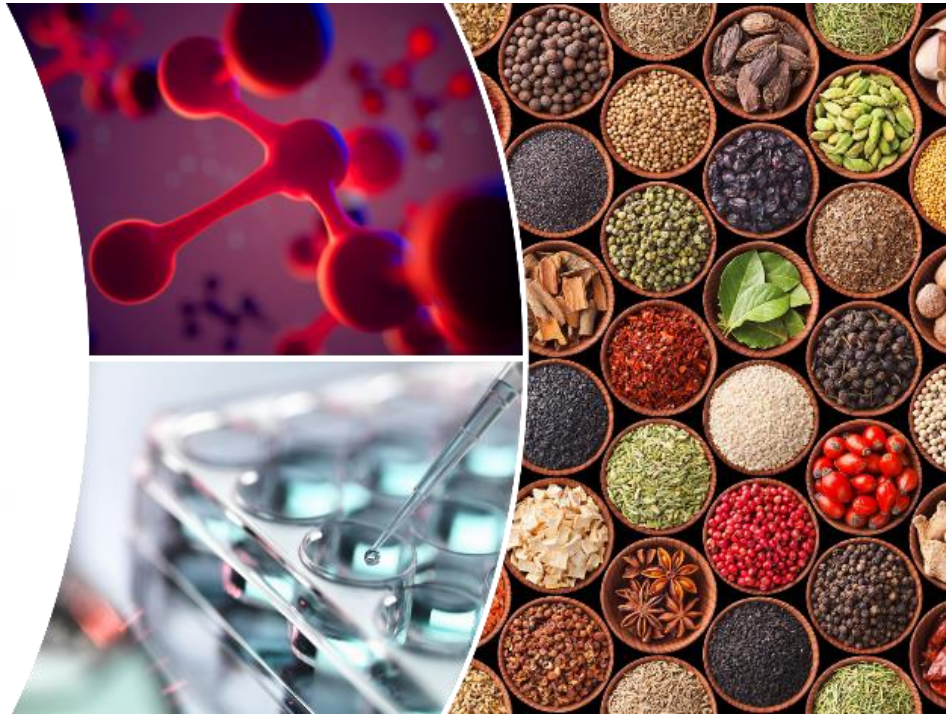


Entrepreneurship in Food & Nutrition Science

Course 3

Nutrition building blocks: Macro- and micronutrients

Macro- and micronutrients – Learning objectives

By the end of this lecture, you should be able to :

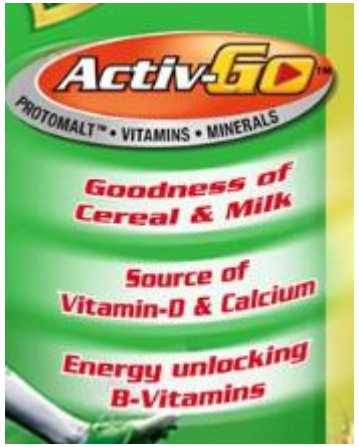
- Describe how to measure the quality of the 3 key macronutrients (carbohydrates, proteins, lipids)

- Understand how to optimize the quality of these macronutrient for a new product development

- Understand how presence of specific micronutrients can be leveraged to boost the concept of a product

- Understand the principles of Nutrient Profiling and what are the key parameters that can impact a Front-of-Pack labelling / Rating

Nutrition communicated on packs



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A balanced diet requires the right quantity but also quality of macronutrients

Carbohydrates
(50-55% daily energy)

Proteins
(10-15% daily energy)

Fats
(20-35% daily energy)

Sugars, refined carbs — Fibres

Lower in essential amino acids — High in essential amino acids

Saturated fatty acids (SFA) — Mono- & poly-unsaturated fatty acids (MUFA, PUFA)

EPFL

Carbohydrates

Carbohydrates
(50-55% daily energy)

Sugars, refined carbs — Fibres

Definition and Classification of Carbohydrates

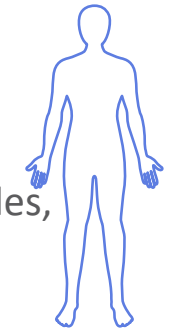
Carbohydrates are formed of 1 or more monosaccharides

Sugars = mono and disaccharides

Starch and maltodextrins = digestible* polymers of glucose with ∝1-4 and ∝1-6 bonds

Functions in the body:

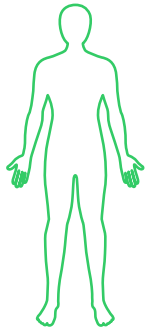
- Energy production
- Energy storage
- Building macromolecules (nucleic acids, mucopolysaccharides, etc.)



Dietary fibers = undigestible* polymers of monosaccharides

Functions in the body:

- Prebiotics
- Gut health
- Energy production (2 kcal/g as SCFA)



*by human digestive enzymes: SCFA, short-chain fatty acids

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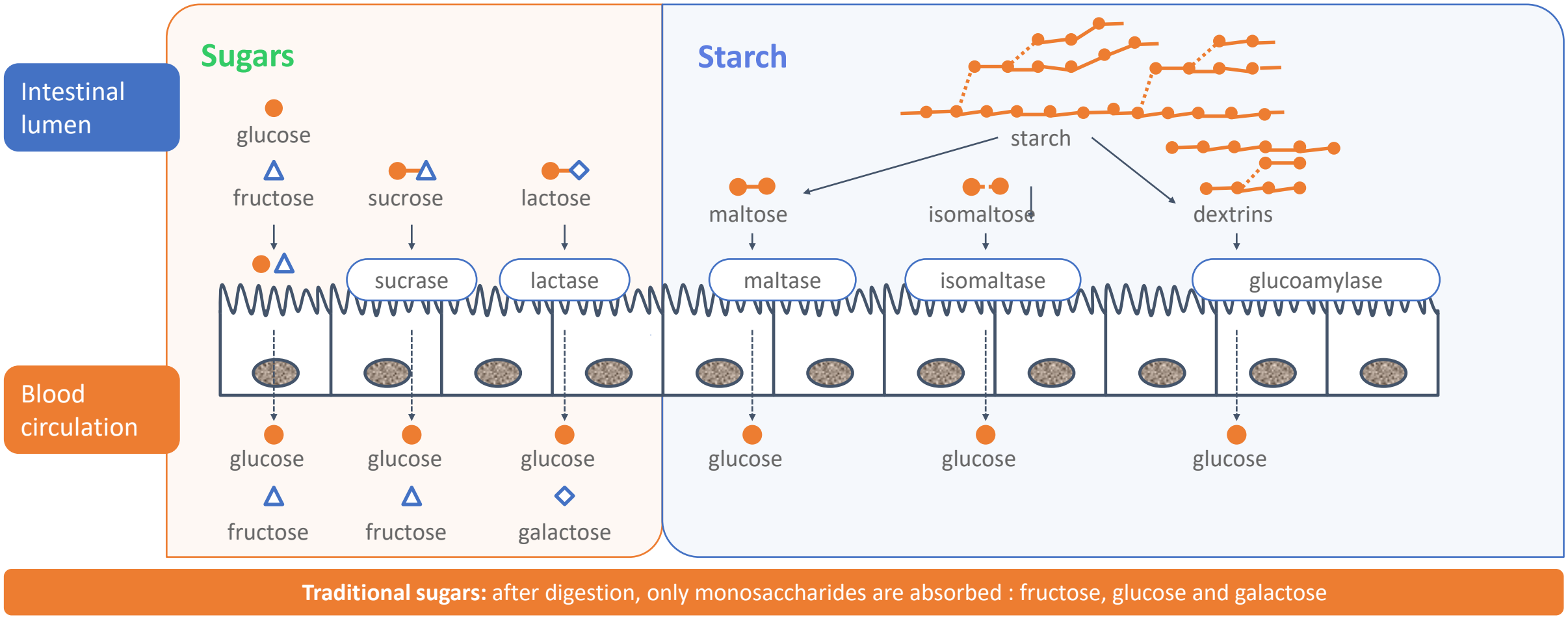
Sugar digestion & absorption



Traditional sugars: after digestion, only monosaccharides are absorbed : fructose, glucose and galactose

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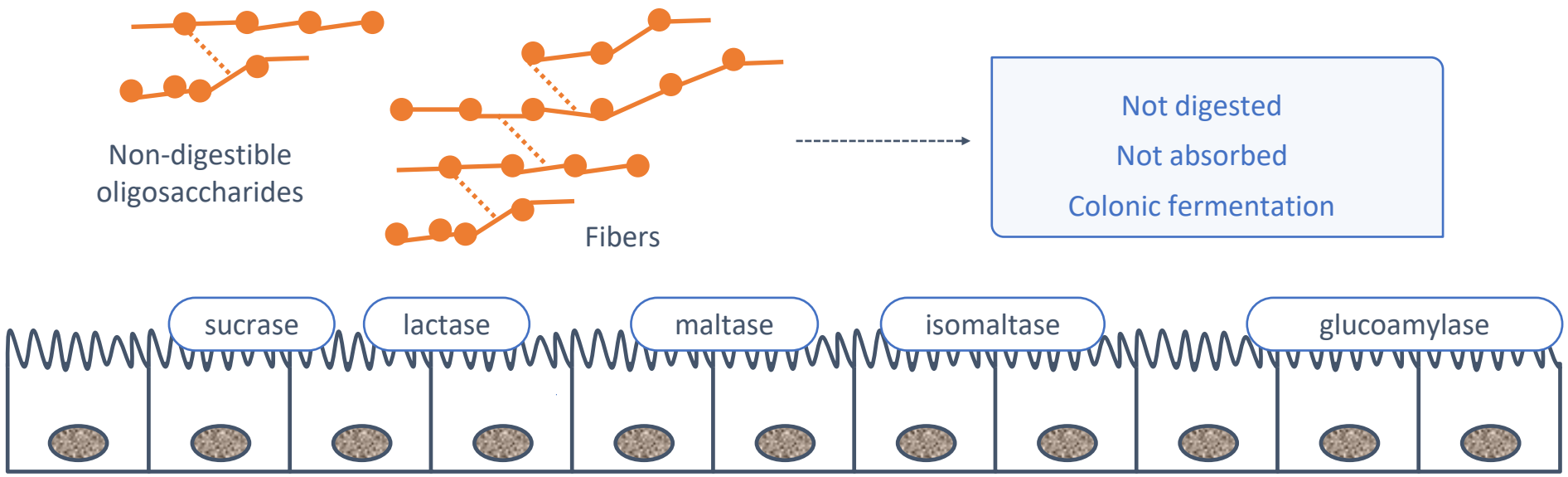
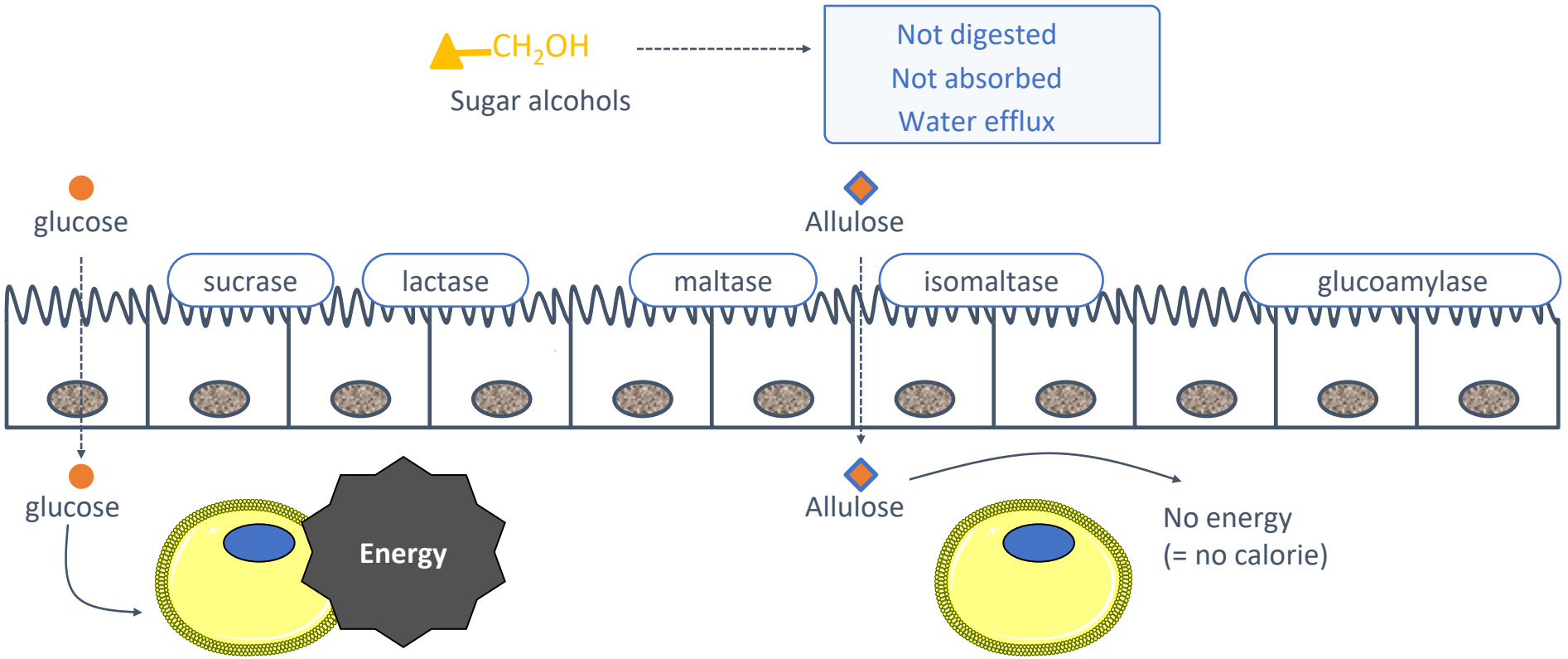
Fibres and non-digestible oligosaccharides



Fibers and non-digestible carboydrates are neither digested nor absorbed; they can be fermented in the colon

Sugar alcohols & non-metabolizable sugars



Sugar alcohols are not asborbed and not digested. Due to their additional alcohol group, they can trigger water efflux in the colon (-> diarrhea)

Non-metabolizable sugars are absorbed, but they cannot be used to provide energy

Summary of common sugars and health impact

Caries

Obesity risk

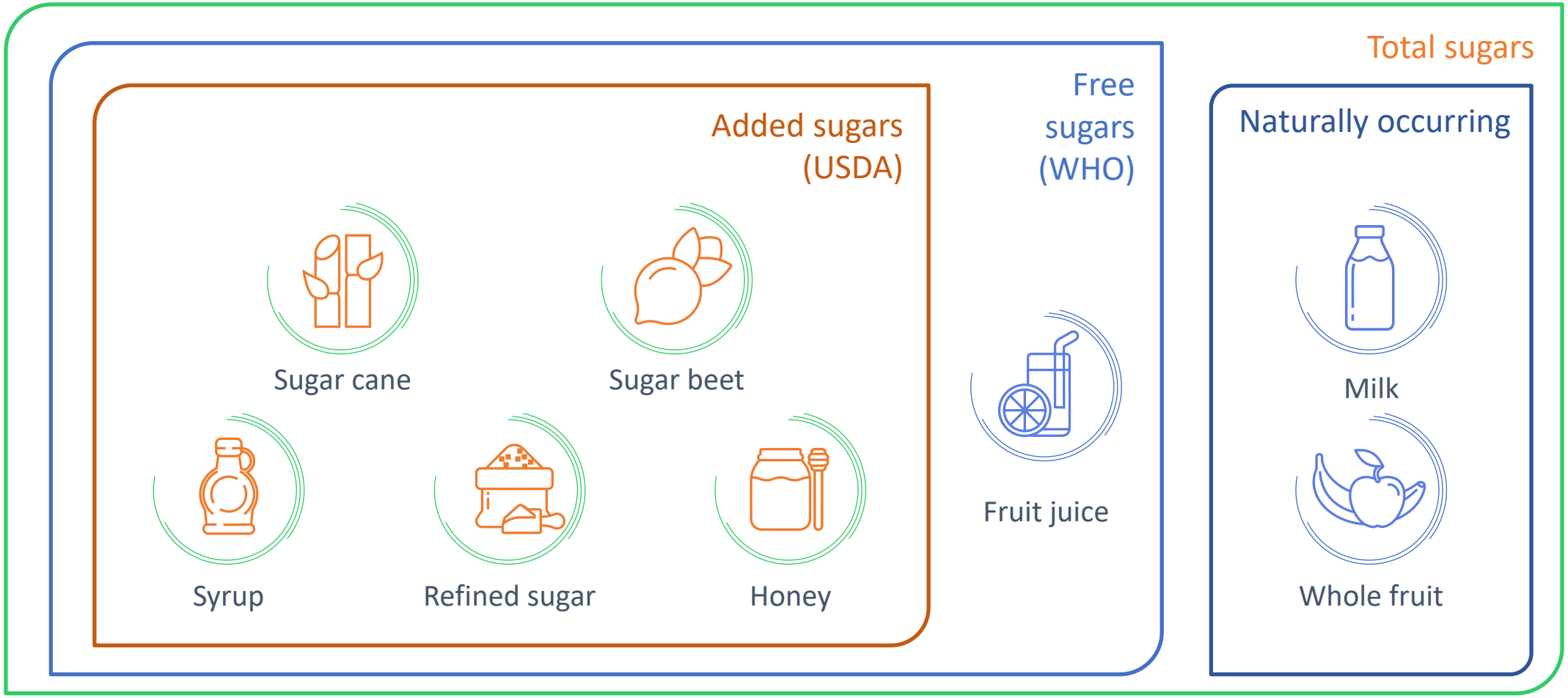
Type-2 diabetes risk

Cardiovascular risk

	Cariogenicity	Energy (kcal/g)	Sweetness	Glycemic Index (GI)	Blood lipids
Fructose	+	4	1.4	19	++
Glucose	++	4	0.75	100	+
Sucrose	++	4	1	68	++
Lactose	-	4	0.16	46	- (?)
Starch	-	4	<0.1	105	-
Fibres	-	2	<0.05	<5	-

Tolerable upper intake level for dietary sugars | EFSA

Sugars classification: added vs naturally occurring



1. U.S. Department of Agriculture. 2015-2020 Dietary Guidelines for Americans. https://www.dietaryguidelines.gov/current-dietary-guidelines/2015-2020-dietary-guidelines. Published 2016. Accessed April 20, 2020; Fidler Mis N et al. J Pediatr Gastroenterol Nutr. 2017;65(6):681-696. US Department of Agriculture (USDA). ChooseMyPlate. Added sugars. https://www.choosemyplate.gov/eathealthy/added-sugars. Accessed November 16,2020.

Proteins

Proteins
(10-15% daily energy)

Lower in essential amino acids

High in essential amino acids

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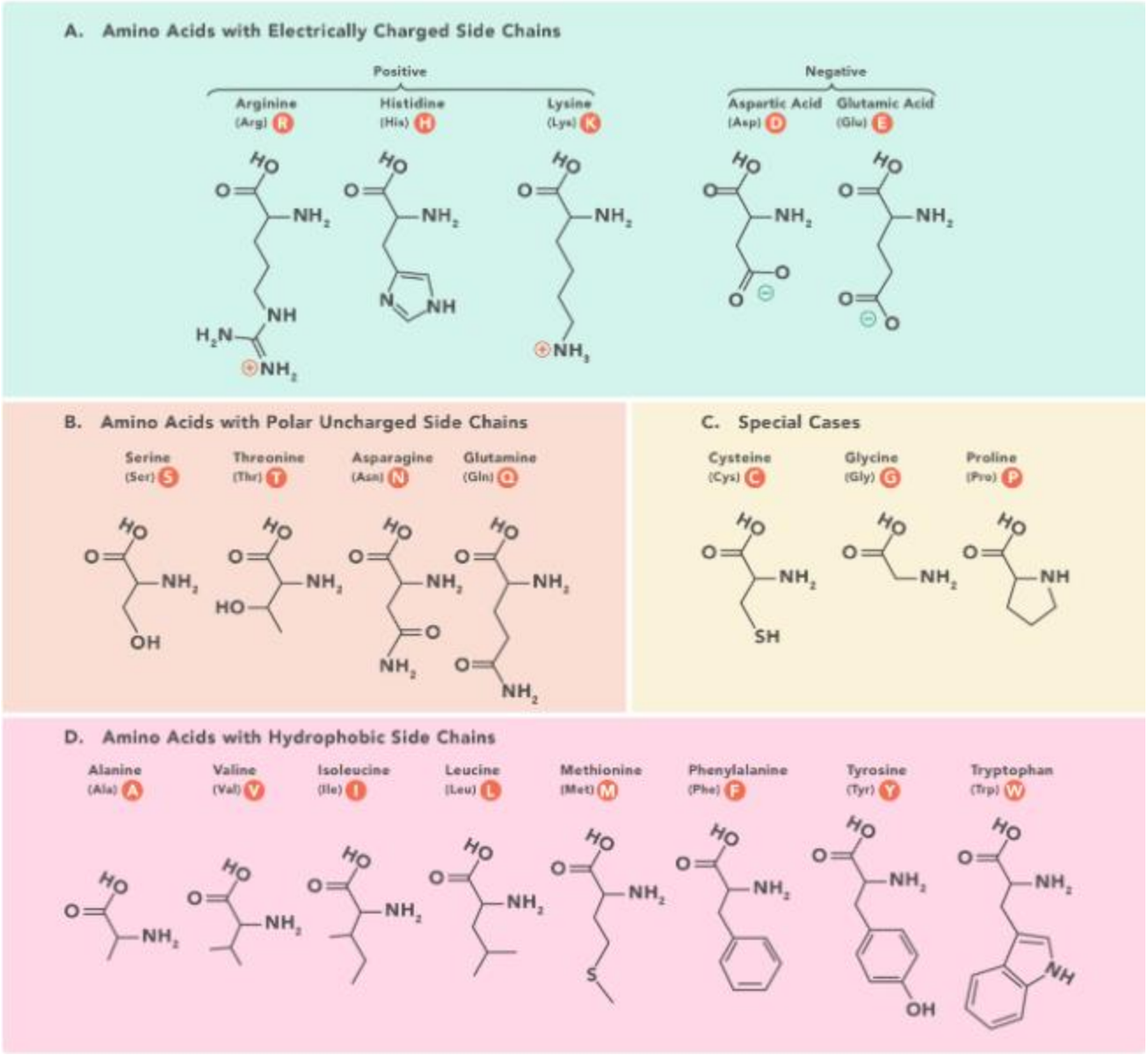
Protein structure



Nitrogenous organic compounds present in all living organisms

- Consist of one or more chains of amino acids
- 4 kcal/g
- 20 amino acids

Essential

Ile	Phe	His
Leu	Thr	
Lys	Trp	
Met	Val	

Non-Essential

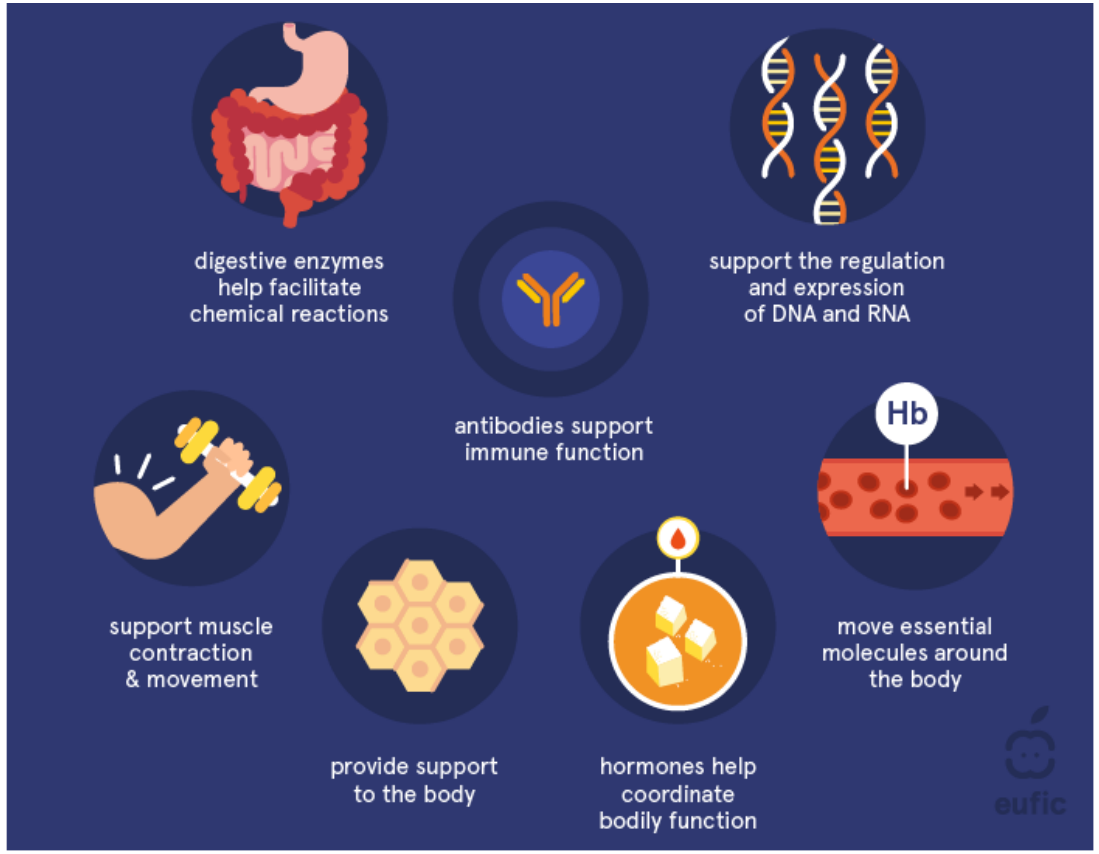
Ala	Cys	Pro
Arg	Glu	Ser
Asp	Gln	Tyr
Asn	Gly	

CANNOT BE SYNTHESIZED BY THE BODY AND MUST BE ACQUIRED THROUGH DIET

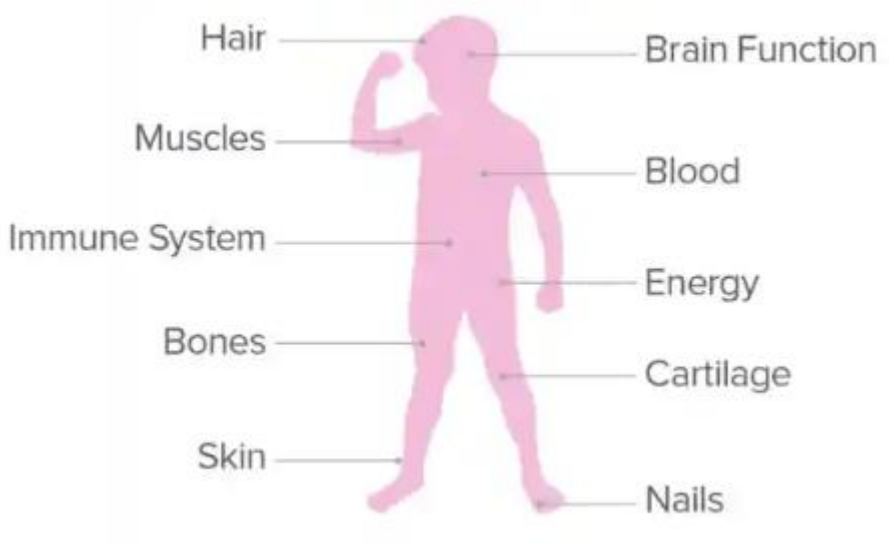
Essential Amino Acids: Chart, Abbreviations and Structure | Technology Networks

Essential functions of proteins for normal body function & growth

PROTEINS SUPPORT MANY ESSENTIAL FUNCTIONS



IN CHILDREN PROTEIN SUPPORTS THE DEVELOPMENT OF:



Sources: EUFIC; The Benefits of Protein in Childhood Nutrition - Ed Miniat

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How much protein do we need to eat?

Protein dietary requirement - the amount of protein or/and its constituent amino acids that must be supplied in order to:

1. satisfy the metabolic demand
2. maintain appropriate body composition and growth rates

Protein requirement (g/kg body weight per day)					Protein requirement (g/day)	
Age (years)	Maintenance	Growth	Average requirement	Safe level of protein intake	Average weight (kg)	Average safe level of protein intake
0.5	0.66	0.46	1.12	1.31	7.5	10.2
1-2	0.66	0.20	0.86	1.05	11	11.4
3-10	0.66	0.07	0.73	0.90	14.1 - 28.5	12.7-26.2
11-14	0.66	0.07	0.73	0.90	45.6	40.8
15-18	0.66	0.04	0.70	0.87	56.4 - 66.5	39.5 - 46.5
>18	0.66	0	0.66	0.83	50 - 75	47.4 – 57.9

Adapted from Protein and Amino Acid Requirements in Human Nutrition
Report of a Joint WHO/FAO/UNU Expert Consultation, 2007

Amino acid score

- Recommended amino acid scoring patterns for infants, children and older children, adolescents and adults (*Dietary protein quality evaluation in human nutrition, FAO, 2013*).

AA requirements mg/ g protein	ILE	LEU	LYS	MET+ CYS	PHE+ TYR	THR	TRP	VAL	HIS
Infants (<0.5 yr)*	55	96	69	33	94	44	17	55	21
Children (0.5-3 yr)	32	66	57	27	52	31	8.5	43	20
Older child, adolescent, adult	31	61	48	24	41	25	6.6	40	16

* requirements of infants (birth to 6 months) correspond to the pattern of a breast milk

- Amino acid profile of selected protein sources

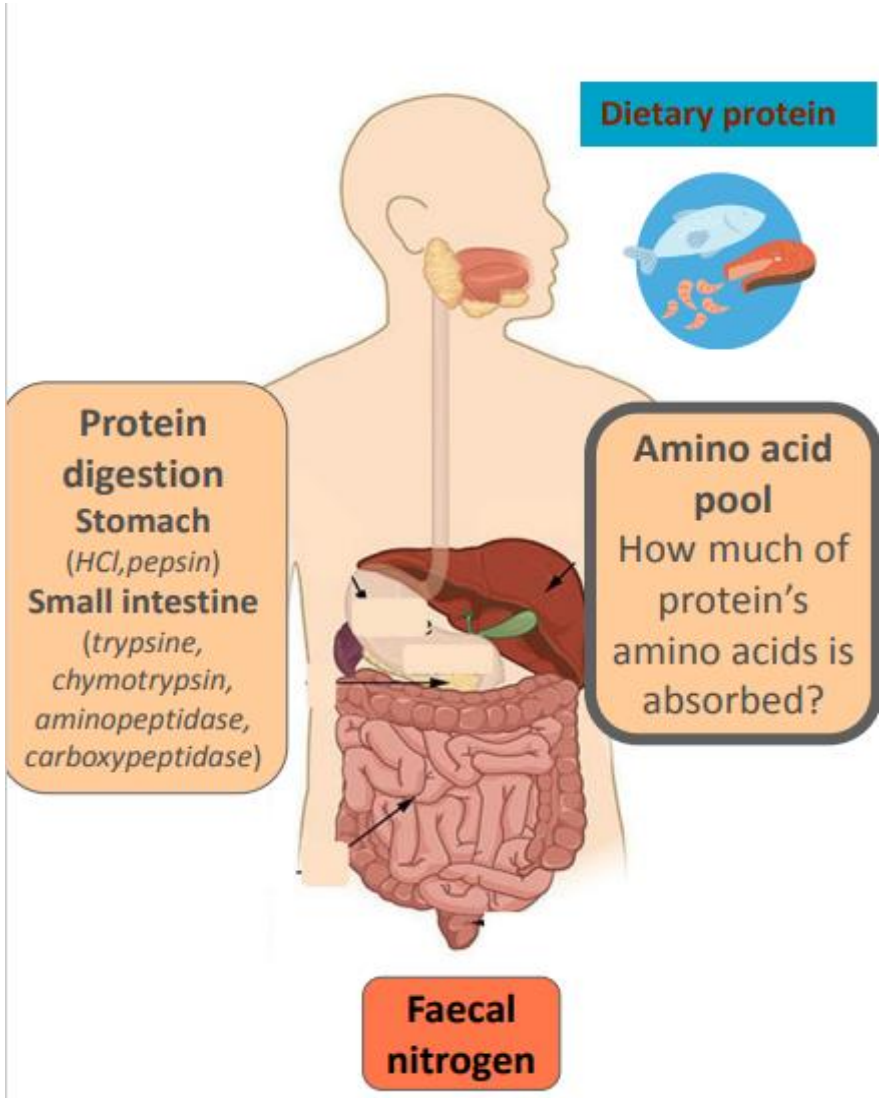
mg AA/g protein	Source	ILE	LEU	LYS	MET+ CYS	PHE+ TYR	THR	TRP	VAL	HIS
Soy protein isolate	Supplier	47	74	70	26	88	37	13	42	26
Brown rice protein isolate	Supplier	58	91	51	47	85	48	16	60	22
Canola protein isolate	Supplier	39	72	63	52	68	43	14	47	32
Potato protein isolate	Supplier	41	104	71	35	118	70	10.5	47	19
Milk Powder	U.S. Dairy Export Council, 2005	64	104	84	39	102	48	15	71	29
Gelatin	USDA	14	29	40	7	24	17	0	24	8

AAS = mg of amino acid in 1 g test protein/mg of amino acid in requirement pattern

→ **the lowest ratio**

Ref: Food and Agriculture Organization 2013; Hertzler et al. 2020

Protein quality is defined by PDCAAS



Adapted from OpenStax College, http://cnx.org/content/col11496/1.6
And Dietary protein quality evaluation in human nutrition. (2013). FAO

PDCAAS

=

Essential Amino Acid score

x

Digestibility

- Protein Digestibility Corrected Amino Acid Score

- Effectiveness with which a protein can meet the essential **amino acids requirement** of a specific age group
- Ratio between **amino acid composition** and recommended amino acid **reference patterns** (FAO / WHO)

- Susceptibility of food proteins to be **hydrolyzed** by digestive enzymes in the gastrointestinal tract
- Fraction of protein that is **available for absorption**

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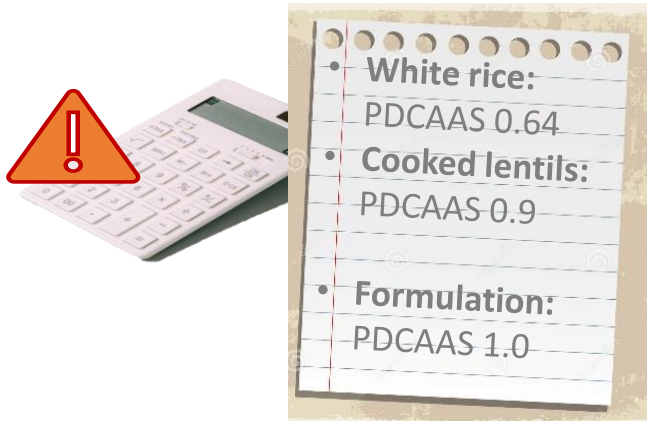
Protein quality is defined by PDCAAS

Protein source	Requirement pattern	AAS	True Digestibility	PDCAAS
Soy protein isolate	Infants (<0.5 yr)	0.76	95% [1]	0.72
	Children (0.5-3 yr)	0.96		0.91
	Older child, adolescent, adult	1.05		1.00
Brown rice protein isolate	Infants (<0.5 yr)	0.74	99% [2]	0.73
	Children (0.5-3 yr)	0.90		0.89
	Older child, adolescent, adult	1.07		1.00
Canola protein isolate	Infants (<0.5 yr)	0.71	93.3% [3]	0.66
	Children (0.5-3 yr)	1.09		1.00
	Older child, adolescent, adult	1.18		1.00
Potato protein isolate	Infants (<0.5 yr)	0.62	94% [4]	0.58
	Children (0.5-3 yr)	1.09		1.00
	Older child, adolescent, adult	1.18		1.00
Milk Powder	Infants (<0.5 yr)	0.88	95% [5]	0.84
	Children (0.5-3 yr)	1.44		1.00
	Older child, adolescent, adult	1.62		1.00
Gelatin	Infants (<0.5 yr)	0.00	98.4% [6]	0.00
	Children (0.5-3 yr)	0.00		0.00
	Older child, adolescent, adult	0.00		0.00

1 Protein and Amino Acid Requirements in Human Nutrition *Report of a Joint WHO/FAO/UNU Expert Consultation, 2007*
2 Supplier
3 Fleddermann et al., *2013, Clinical Nutrition*
4 Knorr, D., 1978, Lebensmittel Wissenchaft und Technologie
5 Dietary protein quality evaluation in human nutrition. (2013). FAO
6. Keith and Bell, 1988. The journal of Nutrition.

Lower in essential amino acids
→ Low PDCAAS

High in essential amino acids
→ High PDCAAS



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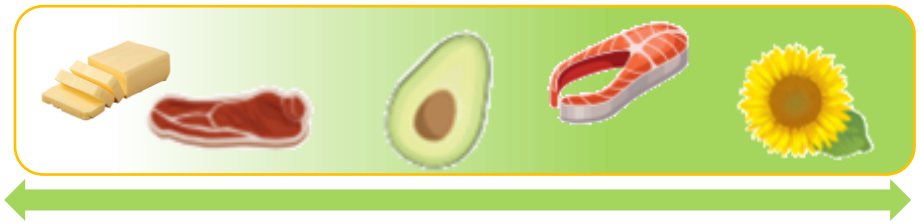
Lipids

Fats
(20-35% daily energy)



Saturated fatty acids (SFA)

Mono- & poly-unsaturated fatty acids (MUFA, PUFA)

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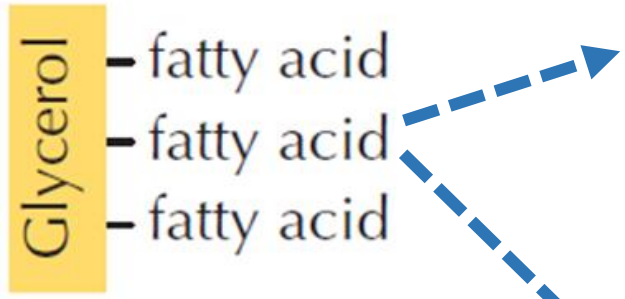
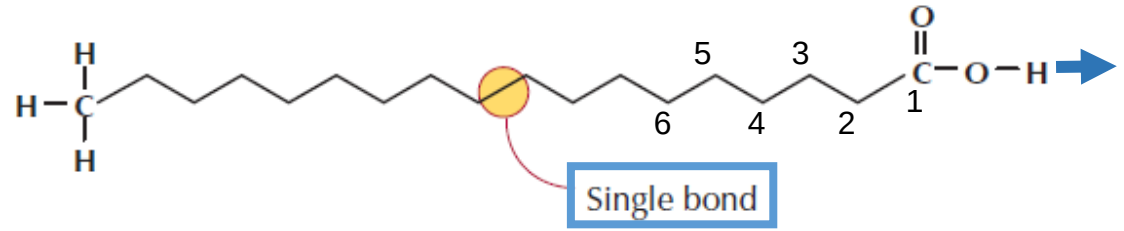
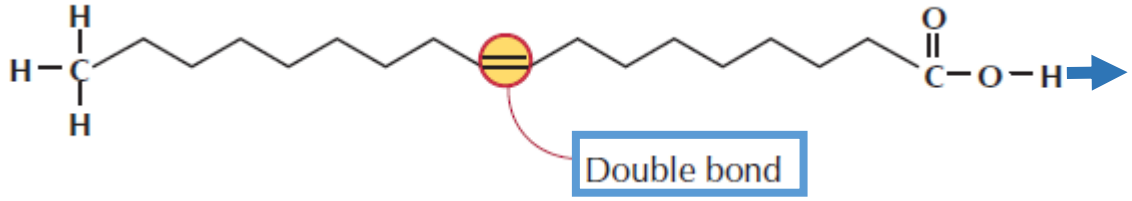
Lipid biochemistry

- Fats include lipids (triglycerides, phospholipids & sterols), oils & fat-like substances.
- Triglycerides are the primary form of lipids in the diet & make up nearly 90% of all fat calories ingested.
- A Triglyceride is composed of a glycerol backbone & 3 fatty acid chains
- Fatty acids can be saturated or unsaturated



Structure of a triglyceride





Saturated fatty acid
(no double bond in the structure)

Monounsaturated fatty acids (MUFA), found in high amounts in olive oil, have only one double bond

Unsaturated fatty acid
(1 or more double bond in the structure)

Polyunsaturated fatty acids (PUFA), found in nuts & seeds, have two or more double bonds

- Triglycerides are also categorized as:

Long chain
LCTs, 12–24 carbons

Medium chain
MCTs, 6–12 carbons
(C8 and C10 are the most common ones)

Short chain
SCTs < 6 carbons

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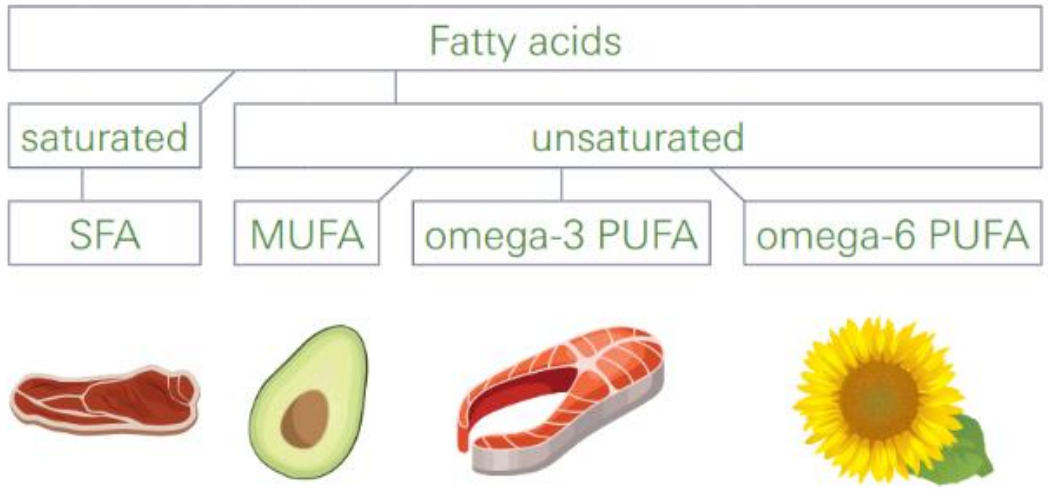
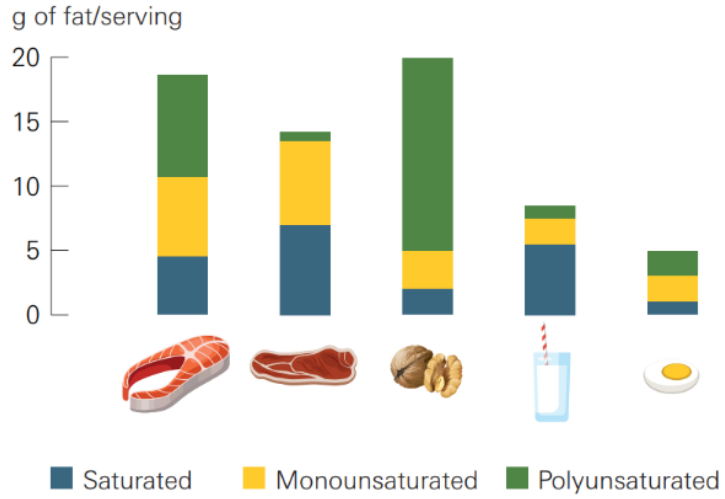
Lipid’s biological role

- Fundamental components of cellular & subcellular membranes
- Precursors of bioactive molecules (*e.g*. hormones)
- Store and supply of chemical energy (1g fat = 9 kcal)
- Stored in adipose tissue in unlimited amounts
- Serves as assistant in the absorption of vitamins A, D, E and K into the bloodstream

Dietary sources of lipids

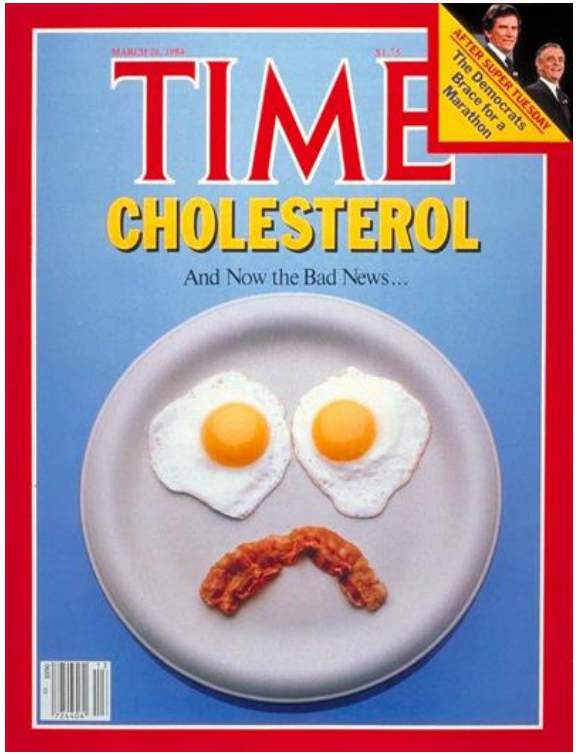




Recommendations:

- Total fat: 20-35% of total energy intake
- SFA: <10% of total energy intake
- Omega 6, omega 3 PUFAs: 2.5-9%, 0.5-2% of total energy intake

Evolution of scientific recommendations on fat



1961 *1984* *2014*

Cholesterol & *trans* fats: 2 cases for revision of recommendations

Cholesterol

- The body can synthesize cholesterol, so it is not required in the diet
- Cholesterol's role: cell membranes; precursor of some hormones and vitamin D
- Most dietary cholesterol comes from foods which are also significant sources of dietary SFA e.g., dairy and meat products.
- **Many health authorities have withdrawn their recommendations to limit dietary cholesterol and instead recommend limiting SFA intake (less than 10% total daily energy intake)**

trans fats

- Because of their chemical configuration, *trans* fats behave more like saturated fats and are solid at room temperature
- **Partially hydrogenated vegetable oils (PHO) were popular food ingredients because of their high content of *trans* fats which provided the structure of solid fats without the SFA**
- Trans fats increase the levels of LDL-C ("bad" cholesterol), decrease the levels of HDL ("good cholesterol") and increase CVD risk
- In 2015 the US Food and Drug Agency withdrawed the GRAS status for PHO for any **use in human food considering not safe for consumption**. As a result, most food manufacturers have eliminated them from products
- Trans fatty acids are also formed in the rumen of ruminants and are naturally found in milk, beef or lamb, in small amounts.

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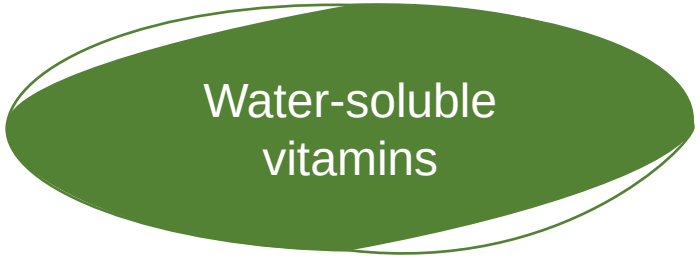
Micronutrients

Vitamins & Minerals

- Micronutrients, often referred to as vitamins and minerals
- Consumed in mg or µg/day
- They are vital to healthy development, disease prevention, and wellbeing
- Except for vitamin D, micronutrients are not produced in the body and must be derived from the diet

Vitamins

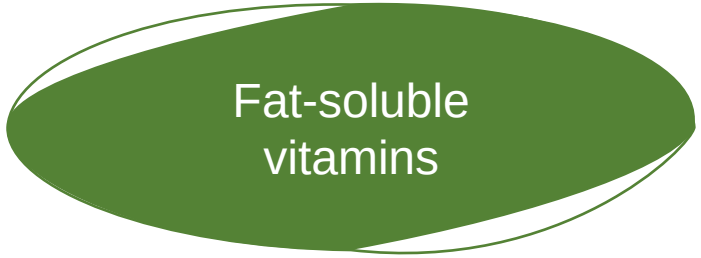
- Vitamins are needed in small amounts by the body, yet they are essential for good health.
- They serve as cofactors for metabolic reactions & energy utilization. However, vitamins do not provide energy.
- *Vitamins are classified into 2 groups:* water-soluble *&* fat-soluble.



Include the B vitamins complex family and vitamin C

- B complex family includes mainly:

  Thiamine (vitamin B1), riboflavin (vitamin B2), niacin, vitamin B6, vitamin B12, folic acid, biotin & pantothenic acid.
- The excess of water-soluble vitamins is excreted in the urine



- Excess intake of fat-soluble vitamins is potentially more toxic than water-soluble vitamins since they are stored in the body.

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Minerals & trace elements

- Minerals (mg quantities) and trace elements (in µg quantities) are essential and fulfill various functions in the body as electrolytes, enzyme constituent, building material. They do not provide any energy

- Minerals and Trace Elements are naturally found in the body as ions but not as pure elements
- Most vitamins and mineral have approved health claims

Minerals	Minerals	Trace elements
Calcium (Ca)	Sodium (Na)	Copper (Cu)
Chlorine (Cl)	Fluoride (F)	Chromium (Cr)
Magnesium (Mg)	Iron (Fe)	Iodine (I)
Phosphorous (P)	Manganese (Mn)	Selenium (Se)
Potassium (K)	Molybdenum (Mo)	Zinc (Zn)

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Examples of authorized health claims in Europe

Carbohydrates

Carbohydrates contribute to the recovery of normal muscle function (contraction) after highly intensive and/or long-lasting physical exercise leading to muscle fatigue and the depletion of glycogen stores in skeletal muscle

Non-digestible carbohydrates

Consumption of foods/drinks containing <name of all used non-digestible carbohydrates> instead of sugars induces a lower blood glucose rise after their consumption compared to sugar-containing foods/drinks.

Food and Feed Information Portal Database | FIP (europa.eu)

Monounsaturated and/or polyunsaturated fatty acids

Replacing saturated fats with unsaturated fats in the diet contributes to the maintenance of normal blood cholesterol levels [MUFA and PUFA are unsaturated fats]

Protein

Protein is needed for normal growth and development of bone in children.
Protein contributes to a growth in muscle mass
Protein contributes to the maintenance of muscle mass
Protein contributes to the maintenance of normal bones

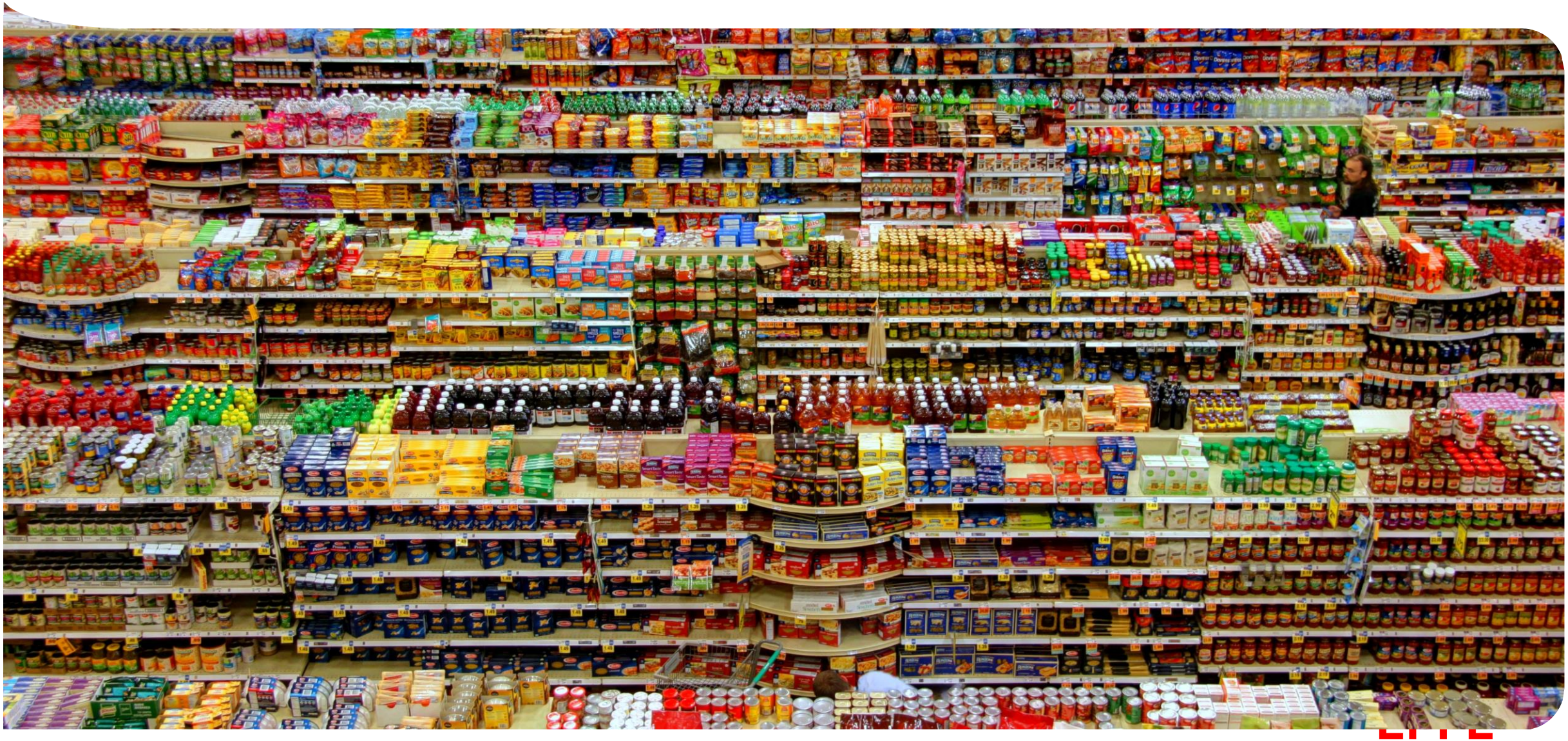
Calcium and vitamin D

Calcium and vitamin D are needed for normal growth and development of bone in children

Riboflavin (Vitamin B2)

Riboflavin contributes to normal energy-yielding metabolism

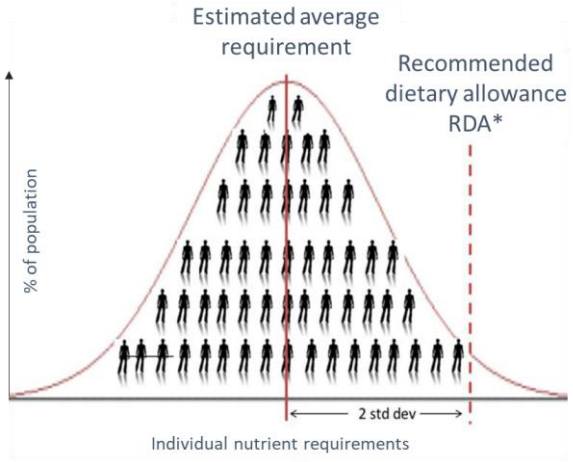
Nutrient profiling systems to classify food products

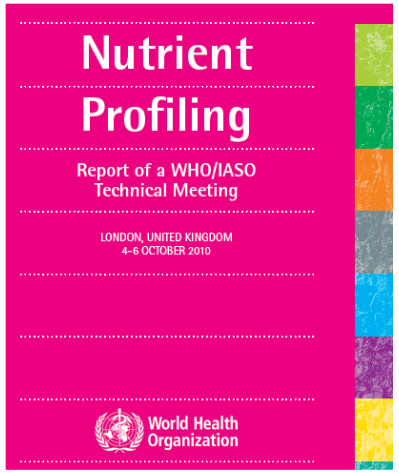


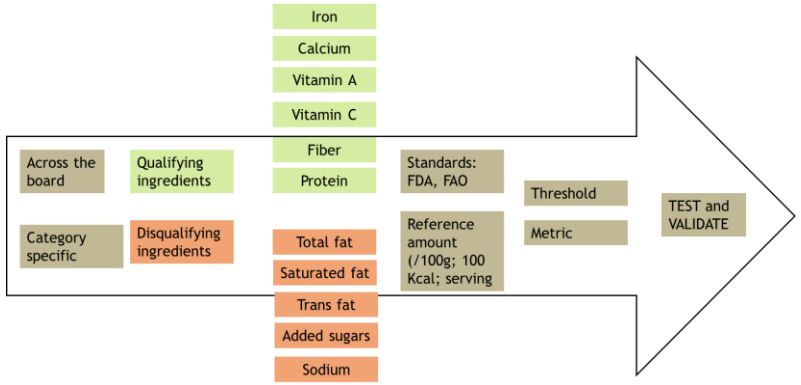
What is Nutrient Profiling?

"The science of **classifying or ranking foods** according to their **nutritional composition** for reasons related to **preventing disease and promoting health**"

WHO, 2010







Dietary Recommendations **for a healthy diet** → **Translation** → **Tangible food and beverage criteria** used for various applications

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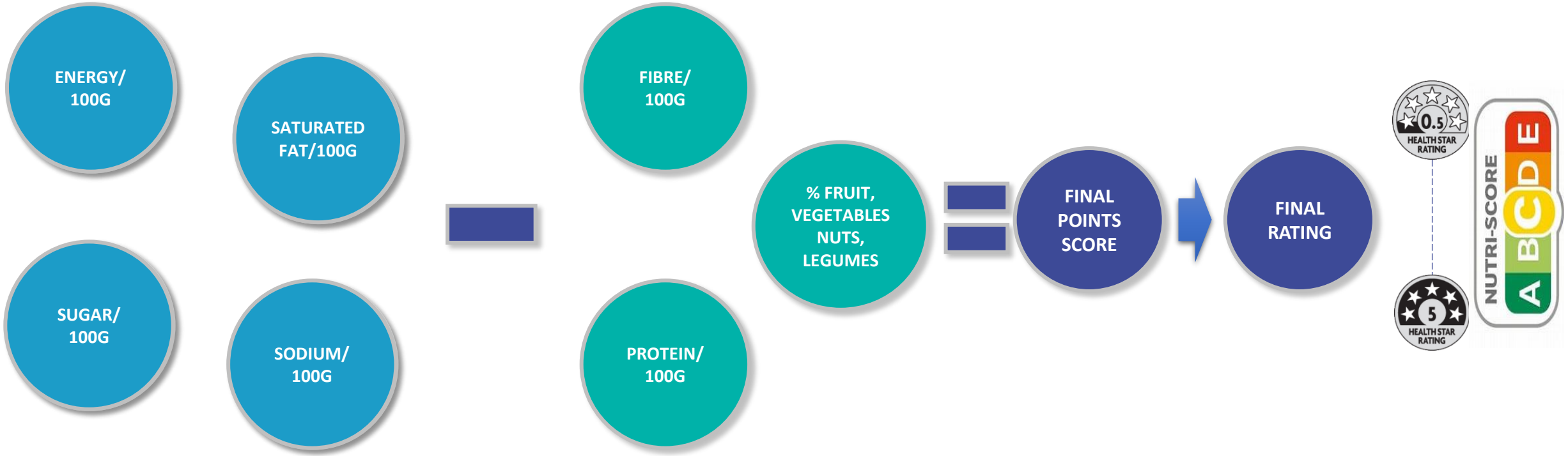
General principles

Negative nutrients allocated points, based on the level per 100g

Positive nutrients/components allocated points, based on the level per 100g



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Food categories or across the board

ACROSS THE BOARD

Foods are compared against one set of criteria

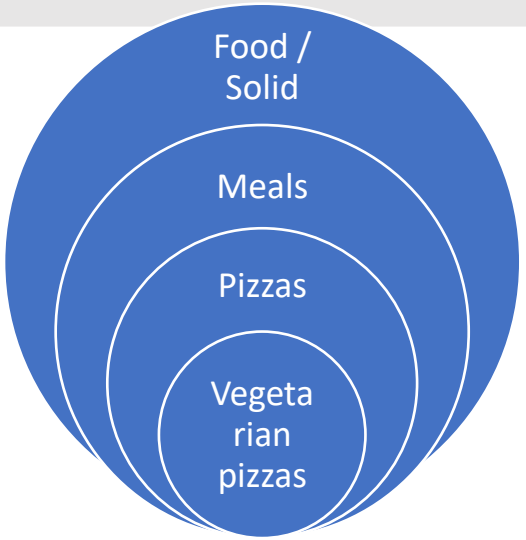
✓ Encourages the consumer to switch to a **better food category**

FOOD CATEGORY

Nutritional quality is compared within a food category

✓ Encourages the consumption of more healthful product **within** a food category

- The number of categories depends on the aim



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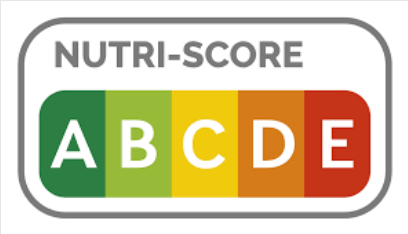
Define output - thresholds or scoring

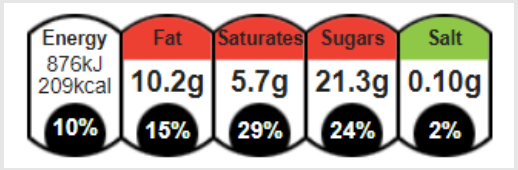
SCORE

- Numerical value
- Single algorithm or combination of thresholds

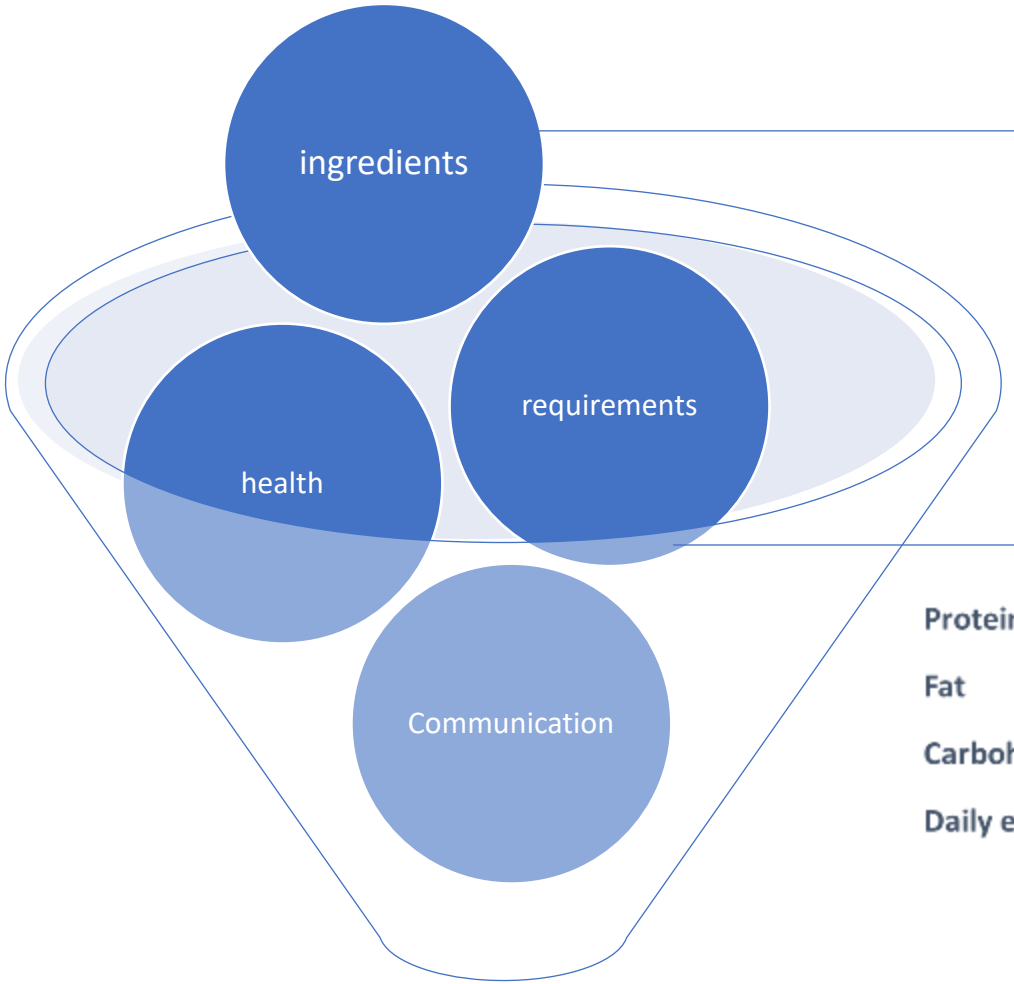


THRESHOLD

- A single value for each nutrient that must not be exceeded (upper limit) or that must be reached (lower limit) in a food



Conclusion: several factors to consider in order to make a recipe



Final recipe

Carbohydrates: cereals (corn, wheat, oat, …), pulses (soy, beans, …)
Proteins: meat (poultry, beef, …), pulses, isolates
Lipids: oils (vegetable, fish), animal fat…
Other bioactives?

	Adult human (% Daily energy)	Adult dog (% Daily energy)	Adult cat (% Daily energy)
Protein	10-35%	25%	34%
Fat	20-35%	30%	35%
Carbohydrates	45-65%	45%	31%
Daily energy	2000 kcal	960 kcal	220 kcal

Key take-home messages

- Nutrient quality is as important as quantity, and can impact health in a positive or negative way
- Optimizing nutrient quality can allow some differentiated communication
- Recommended macro- and micronutrient amount are adapted to age stages & population (e.g. disease versus healthy)
- Nutrient profiling can allow to further optimize a product nutritional composition for health & communication

Suggested further readings

- Carbohydrates

Importance of Carbohydrate Quality: What Does It Mean and How to Measure It? - PMC (nih.gov)

- Proteins

Perspective: The Public Health Case for Modernizing the Definition of Protein Quality - PMC (nih.gov)

- Lipids

A healthy approach to dietary fats: understanding the science and taking action to reduce consumer confusion - PMC (nih.gov)

- Micronutrients

"General function" health claims under Article 13 | EFSA (europa.eu)

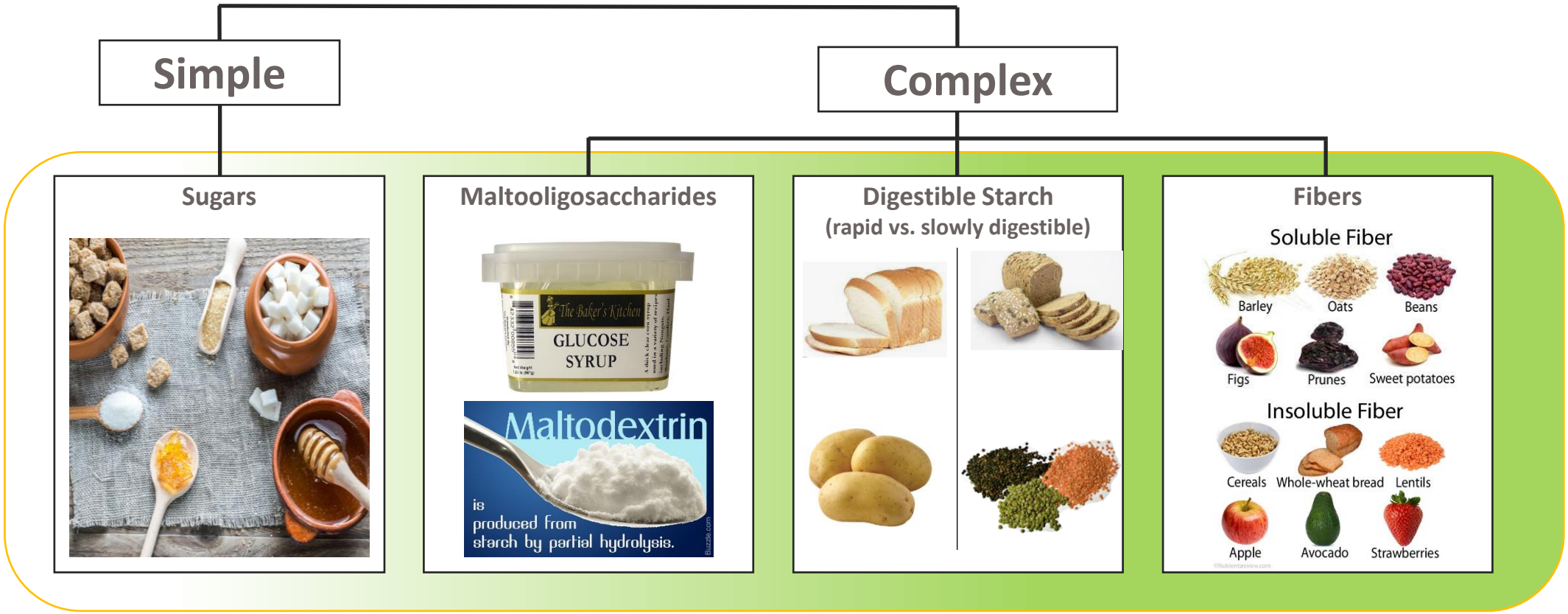
- Nutrient profiling

Perspective: How to Develop Nutrient Profiling Models Intended for Global Use: A Manual | Advances in Nutrition | Oxford Academic (oup.com)

EPFL

BACK UP

Dietary sources of carbohydrates



Lamothe LM, Lê KA, Samra RA, Roger O, Green H, Macé K. The scientific basis for healthful carbohydrate profile. *Crit Rev Food Sci Nutr*. 2019;59(7):1058–1070

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