5. Carbohydrates, Proteins, and Fats – Structure, sources, and functions

Carbohydrates · Proteins · Fats

Structure — Dietary Sources — Physiological Functions

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1 · Carbohydrates

1.1 Chemical Architecture

- **Monosaccharides** – single 6-carbon units (glucose, fructose) absorbed by SGLT-1 & GLUT-5.
- **Disaccharides** – two monosaccharides linked by α/β-glycosidic bonds; hydrolysed by brush-border enzymes (e.g., lactase).
- **Oligosaccharides** – 3-10 units; α-galactosides in legumes escape digestion, act as prebiotics.
- **Digestible polysaccharides** – starch (20 % amylose, 80 % amylopectin) plus animal glycogen.
- **Non-digestible polysaccharides** – insoluble cellulose & hemicellulose; soluble pectin, β-glucan; resistant starch.

1.2 Dietary Sources & Quality – Explore the interactive sheet **“Carbohydrate Classification & Key Features.”** Note how whole-grain cereals and millets supply complex starch + fibre, whereas fruits add fructose plus polyphenols.

1.3 Key Functions

1. **Energy** – 4 kcal · g^{-1}, sparing amino acids from catabolism.
2. **Protein sparing** – adequate glucose prevents gluconeogenesis from muscle.
3. **GI Health** – fermentable fibres → SCFA production; insoluble fibre expedites transit.
4. **Biosynthesis** – pentose phosphate pathway yields NADPH & ribose for nucleotides.

Carbohydrate Classification & Key Features:

Category	Representative Units	Common Food Sources	Key Physiological Features
Monosaccharides	Glucose, Fructose, Galactose	Honey, ripe fruits	Rapid ATP supply
Disaccharides	Sucrose, Lactose, Maltose	Table sugar, milk, malted drinks	Quick energy + aids calcium absorption (lactose)
Oligosaccharides	Raffinose, Stachyose	Legumes, whole grains	Prebiotic; gas production
Digestible Polysaccharides	Starch (Amylose & Amylopectin), Glycogen	Rice, wheat, maize, potatoes	Primary caloric source worldwide
Non-digestible Polysaccharides (Fibre)	Cellulose, β-glucan, Pectin, Inulin	Whole grains, vegetables, fruits	Gut motility, cholesterol lowering

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2 · Proteins

2.1 Structural Levels (see **“Protein Structural Hierarchy”** table)

- **Primary** – peptide-bonded AA sequence; mutations alter function (e.g., sickle cell Hb).
- **Secondary** – α-helices/β-sheets via H-bonds; disrupted by heat, pH.
- **Tertiary** – 3-D folding creates active sites; stabilised by hydrophobic interactions, disulfides.
- **Quaternary** – multiple polypeptides (e.g., Hb tetramer) enable cooperativity.

Protein Structural Hierarchy:

Structural Level	Bonding / Forces	Dietary Implication

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Primary	Peptide bonds	AA sequence determines quality
Secondary	Hydrogen bonds	Heat can disrupt → denature
Tertiary	Hydrophobic, ionic, disulfide bridges	Proper folding essential for enzymes
Quaternary	Hydrophobic & ionic between subunits	Subunit separation during digestion

Protein Quality & Content Of Selected Foods:

Food	Protein g/100g	PDCAAS
Egg	13.0	1.0
Milk	3.3	1.0
Chicken	27.0	0.92
Soybean	36.0	0.92
Lentils	9.0	0.75
Wheat	11.0	0.54

2.2 Amino-Acid Essentials

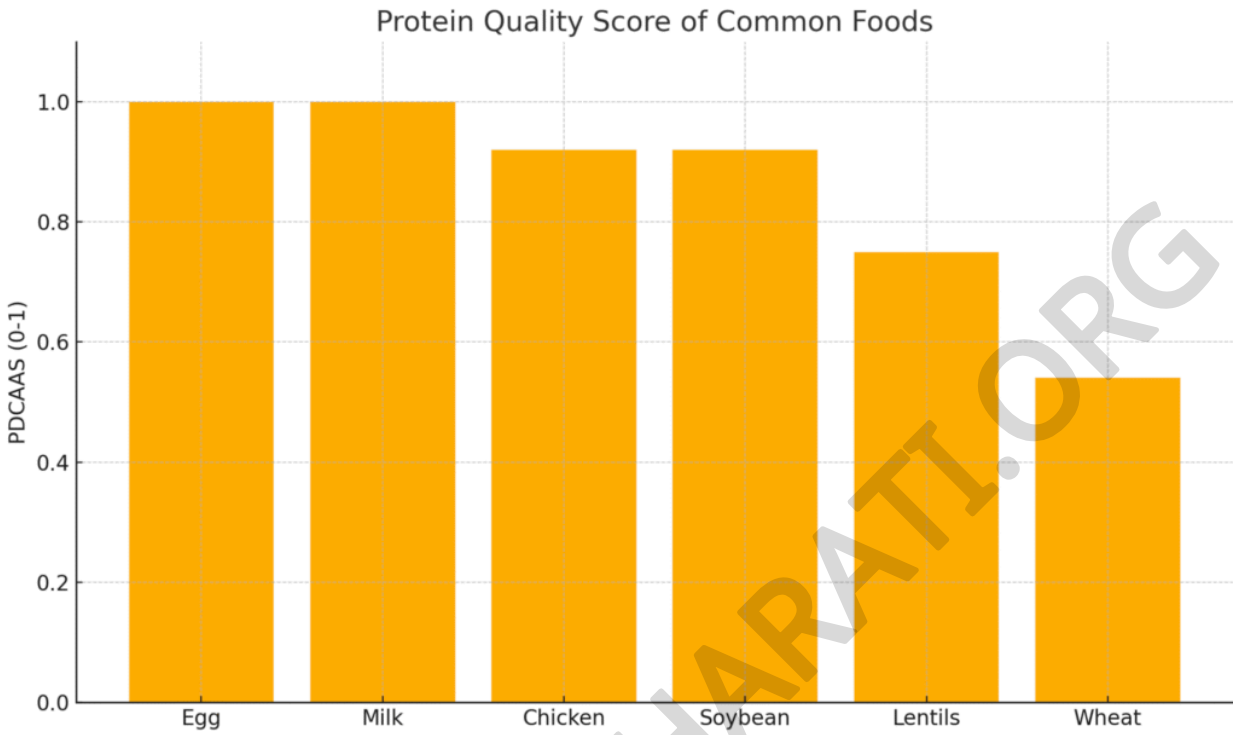
Nine indispensable AAs must be supplied exogenously; histidine is critical in rapid growth; arginine becomes conditionally essential in trauma.

2.3 Sources & Quality

Interactive datasets rank foods by grams protein and PDCAAS. The bar chart **"Protein Quality Score of Common Foods"** highlights egg and milk as reference proteins (PDCAAS = 1.0), soybean as the best plant source, and the importance of cereal-pulse complementation.

2.4 Biological Roles

- **Structural** – collagen, actin-myosin.
- **Functional** – enzymes, hormones (insulin), antibodies (IgG).
- **Transport** – haemoglobin, albumin.
- **Regulatory** – oncotic pressure, acid–base buffering (imidazole of histidine).
- **Energy (starvation)** – gluconeogenic substrate, 4 kcal · g^{-1}.



3 · Fats / Lipids

3.1 Chemical Spectrum – From simple fatty acids to complex phospholipids and sterols (see **"Types of Dietary Fat & Health Notes"**).

- **SFA** – fully hydrogenated; solid at room temp, hypercholesterolaemic in excess.
- **MUFA** – oleic acid-rich oils; improve HDL/LDL ratio.
- **PUFA** – ω-6 linoleic vs. ω-3 α-linolenic & long-chain EPA/DHA; crucial for eicosanoid synthesis and neural development.
- **Trans FA** – industrial hydrogenation by-products; pro-inflammatory.
- **Phospholipids** – amphipathic; build cell membranes, lipoproteins.
- **Cholesterol** – precursor for bile acids, vitamin D, steroid hormones.

3.2 Dietary Sources
Ghee & coconut oil for SFA; olive/ground-nut for MUFA; sunflower & flaxseed for PUFA; vanaspati for trans fats (avoid); egg yolk and liver for sterols.

3.3 Physiological Functions

1. **Energy reserve** – 9 kcal · g^{-1}; adipose cushioning and insulation.
2. **Cellular architecture** – membrane fluidity governed by FA composition.
3. **Hormone & signalling** – prostaglandins, leukotrienes, thromboxanes from PUFA.
4. **Nutrient absorption** – micellar solubilisation of vitamins A D E K.
5. **Satiety & flavour** – slow gastric emptying; carry lipid-soluble aromas.

Types Of Dietary Fat & Health Notes:

Type	Key Example	Major Sources	Health Note

SFA	Palmitic 16:0	Butter, ghee, coconut	↑ LDL if excess
MUFA	Oleic 18:1	Olive, groundnut, mustard oils	Cardio-protective
PUFA ω-6	Linoleic 18:2	Sunflower, soybean oil	Essential FA for eicosanoids
PUFA ω-3	α-Linolenic 18:3	Flaxseed, chia, fish oils	Anti-inflammatory, brain health
Trans FA	Elaidic 18:1 trans	Vanaspati, fried snacks	↑ CVD risk
Phospholipids	Lecithin	Egg yolk, soy	Membrane component
Sterols	Cholesterol	Egg yolk, liver	Hormone precursor

4 · Integrated Macronutrient Interplay

- Adequate carbohydrate ensures amino acids build tissue instead of being oxidised.
- Essential fatty acids modulate gene expression influencing lipid & glucose metabolism (PPAR activation).
- High-quality protein improves satiety, facilitating healthier fat and carbohydrate choices.

A balanced diet (Chapter 4) orchestrates these macronutrients within recommended proportions, complemented by micronutrients to optimise metabolic harmony.

Quick Review

1. **Describe** the structural difference between amylose and amylopectin and its effect on glycaemic index.
2. **Explain** why combining wheat roti with dal yields a higher biological value protein than either food alone.
3. **List** three functions of phospholipids beyond membrane structure.