

NOTESKARTS | PREMIUM STUDY NOTES

BP812ET — DIETARY SUPPLEMENTS & NUTRACEUTICALS

UNIT — II | Phytochemicals as Nutraceuticals & Functional Foods
B.Pharm 8th Semester · PCI / AKTU Syllabus · Exam-Ready + MCQs + Question Bank ·

UNIT-II | LEARNING OBJECTIVES

After studying this unit, the student will be able to:

- 1: Define phytochemicals and explain their role as nutraceuticals; classify them by chemical nature with examples.
- 2: Describe the occurrence, chemical structure, mechanism of action, and health benefits of Carotenoids — α -Carotene, β -Carotene, Lycopene, Xanthophylls, and Lutein.
- 3: Explain the occurrence, chemical nature, and medicinal significance of organosulfur compounds (Diallyl Sulfide, Allyl Trisulfide), polyphenolics (Resveratrol), and Flavonoids (Rutin, Naringin, Quercetin, Anthocyanidins, Catechins, Flavones).
- 4: Differentiate between Prebiotics and Probiotics; explain Fructo-oligosaccharides (FOS) and Lactobacillus with their health benefits.
- 5: Classify Phytoestrogens (Isoflavones, Daidzein, Genistein, Lignans) and explain their chemical nature and role in hormonal health and cancer prevention.
- 6: Describe Tocopherols (Vitamin E forms) and functional foods — Oats, Wheat bran, Rice bran, Seafoods, Coffee, and Tea — with their active compounds and health benefits.

PHYTOCHEMICALS AS NUTRACEUTICALS — INTRODUCTION

What are Phytochemicals?

Phytochemicals (from Greek '**phyto**' = plant) are **biologically active, non-nutrient compounds** produced by plants as secondary metabolites for defense against pathogens, UV radiation, and herbivores. When consumed by humans, they confer significant health benefits and are therefore classified as **nutraceuticals**.

Phytochemicals

Non-nutritive bioactive compounds in plant foods that have health-protective effects. They are NOT essential for survival (unlike vitamins/minerals) but significantly reduce risk of chronic disease.

Phytochemical Class	Sub-class	Representative Compounds
Carotenoids	Carotenes (no oxygen)	α -Carotene, β -Carotene, Lycopene
Carotenoids	Xanthophylls (with oxygen)	Lutein, Zeaxanthin, Astaxanthin
Polyphenols	Flavonoids	Quercetin, Rutin, Naringin, Catechins, Anthocyanidins
Polyphenols	Stilbenes	Resveratrol
Polyphenols	Lignans	Secoisolariciresinol (SDG)
Organosulfur	Sulfides / Thiosulfates	Allicin, Diallyl Sulfide, Allyl Trisulfide
Phytoestrogens	Isoflavones	Genistein, Daidzein, Glycitein
Phytoestrogens	Lignans	Enterolactone, Enterodiol (from SDG)
Terpenes	Tocopherols (Vitamin E)	α , β , γ , δ -Tocopherol, Tocotrienols
Prebiotics	Oligosaccharides	Fructo-oligosaccharides (FOS), Inulin

Exam Trick

Phytochemicals \neq Nutrients. They are 'non-nutrient' bioactive compounds. Examiners love this distinction. If asked 'Are carotenoids nutrients?' — the correct answer is: Carotenoids are phytochemicals; β -Carotene is a pro-vitamin (Provitamin A) and thus crosses into nutrient territory.

CAROTENOIDS

Carotenoids are **fat-soluble yellow-to-red pigments** belonging to the isoprenoid/terpenoid family. They are **C40 polyene compounds** (tetraterpenes) with a long conjugated double bond chain responsible for their characteristic colour and antioxidant activity. Over 700 carotenoids are found in nature; humans absorb ~40 from diet.

Carotenoids

Fat-soluble C40 tetraterpene pigments (yellow/orange/red) in plants and microorganisms. Classified as: (1) Carotenes — pure hydrocarbons (no oxygen), e.g., β -Carotene, Lycopene; (2) Xanthophylls — oxygenated carotenoids, e.g., Lutein, Zeaxanthin.

α -Carotene (Alpha-Carotene)

α -Carotene (Alpha-Carotene)

Source / Occurrence

Carrots (*Daucus carota*) — primary source; also pumpkin, sweet potato, kale, collard greens. Carrot has $\alpha:\beta$ ratio of ~1:2.

Chemical Nature	C ₄₀ H ₅₆ — Tetraterpene (carotene). Has ONE β-ionone ring (at one end) and ONE α-ionone ring (at other end). Hydrocarbon — NO oxygen. Yields ONE molecule of retinol on cleavage (compared to 2 from β-carotene). Solubility: fat-soluble.
Mechanism of Action	Converted to Vitamin A (retinol) by β-carotene-15,15'-dioxygenase enzyme in intestinal mucosa. Has ~50% provitamin A activity of β-carotene. Antioxidant via quenching singlet oxygen and free radicals.
Medicinal Uses / Health Benefits	Provitamin A activity (eye health, immune function); Antioxidant (cancer prevention); Cardioprotection; Anti-tumour (inhibits growth of liver, lung, and skin tumour cells).

△ Exam Trick

α-Carotene has ONE β-ionone ring → yields ONLY ONE molecule of retinol.
β-Carotene has TWO β-ionone rings → yields TWO molecules of retinol. This is the most common MCQ on carotenoids!

β-Carotene (Beta-Carotene)

β-Carotene (Beta-Carotene)

Source / Occurrence	Carrots, sweet potato, pumpkin, mango, papaya, apricot, dark leafy greens (spinach, kale). Also produced by Dunaliella salina (microalgae) — commercial source.
Chemical Nature	C ₄₀ H ₅₆ — Tetraterpene (carotene). Has TWO β-ionone rings (symmetrical molecule). Pure hydrocarbon — NO oxygen. Most potent provitamin A carotenoid — 100% provitamin A activity. Cleaved centrally by dioxygenase to yield 2 molecules of all-trans retinal → retinol.
Mechanism of Action	Central cleavage by β-carotene-15,15'-oxygenase → 2 retinal → 2 retinol (Vitamin A). Singlet oxygen quencher (antioxidant). Anti-peroxidation of membrane lipids. Upregulates connexin (gap junction communication → anticancer).
Medicinal Uses / Health Benefits	Vitamin A deficiency (night blindness prevention); Antioxidant and cancer chemopreventive; Immune enhancement (T-cell proliferation ↑); Photoprotection (skin); Cardioprotection; Macular degeneration prevention.

⊕ Clinical

Caution: HIGH-DOSE β-Carotene supplements (>30 mg/day) INCREASED lung cancer risk in smokers (ATBC and CARET trials). Pro-oxidant effect at high doses. Always mention this in exams — 'Paradox of β-Carotene'.

Lycopene

Lycopene

Source / Occurrence	Tomatoes (<i>Lycopersicon esculentum</i>) — RICHEST source (processed tomato > raw tomato due to cis-isomer release with heat). Also: watermelon, guava, pink grapefruit, papaya, red peppers, rosehip.
Chemical Nature	C ₄₀ H ₅₆ — Acyclic carotene (NO ionone rings at either end, unlike α and β). Open-chain tetraterpene. Eleven conjugated double bonds (longest conjugated chain among common carotenoids). NOT a provitamin A (no β -ionone ring = no retinol conversion). Bright red pigment. Fat-soluble.
Mechanism of Action	Most potent singlet oxygen quencher among carotenoids (2x more potent than β -carotene). Inhibits IGF-1 (Insulin-like Growth Factor 1) signaling → anticancer. Connexin upregulation. Inhibits cell cycle progression (G1 arrest). Reduces oxidative DNA damage.
Medicinal Uses / Health Benefits	Prostate cancer prevention (strongest evidence — 40% risk reduction in Harvard study); Cardiovascular protection (LDL oxidation ↓); Antioxidant; Skin photoprotection; Osteoporosis prevention; Anti-diabetic (insulin resistance ↓).

Exam Trick

Lycopene has NO provitamin A activity (no ionone ring). It is the strongest natural antioxidant carotenoid by singlet oxygen quenching. Bioavailability is HIGHER from cooked/processed tomatoes (tomato paste, ketchup) than raw tomatoes. Cooking breaks cell walls + releases cis-lycopene.

Xanthophylls (Oxygenated Carotenoids)

Xanthophylls are **carotenoids that contain oxygen** (as hydroxyl, epoxide, ketone, or aldehyde groups). The two most important xanthophylls for human health are **Lutein and Zeaxanthin**, which selectively accumulate in the macular region of the retina.

Xanthophyll	Chemical Formula	Oxygen Groups	Primary Source	Health Role
Lutein	C ₄₀ H ₅₆ O ₂	Two hydroxyl (-OH) groups	Kale, spinach, egg yolk, marigold	Macular degeneration prevention, eye health
Zeaxanthin	C ₄₀ H ₅₆ O ₂	Two hydroxyl (-OH) groups	Maize/corn, saffron, wolfberry	Retinal protection, lens clarity
Astaxanthin	C ₄₀ H ₅₂ O ₄	Two ketone + two hydroxyl	Salmon, shrimp, microalgae <i>Haematococcus</i>	Strongest antioxidant carotenoid (6000x vs Vit C)
β -Cryptoxanthin	C ₄₀ H ₅₆ O	One hydroxyl group	Papaya, citrus, pumpkin	Provitamin A, bone health
Canthaxanthin	C ₄₀ H ₅₂ O ₂	Two ketone groups	Chanterelle mushrooms, flamingo feathers	Antioxidant, colour additive (E161g)

Lutein

👁️ Lutein	
Source / Occurrence	Kale (highest concentration), spinach, Swiss chard, parsley, egg yolk, marigold flowers (<i>Tagetes erecta</i> — commercial extraction source), peas, broccoli.
Chemical Nature	C ₄₀ H ₅₆ O ₂ — Xanthophyll (oxygenated carotenoid). Two hydroxyl groups (-OH) at C-3 and C-3'. Has an ϵ -ionone ring at one end and β -ionone ring at other — distinguishes it from Zeaxanthin (which has two β -ionone rings). Isomer of Zeaxanthin. Fat-soluble. NOT a provitamin A.
Mechanism of Action	Macular Pigment Optical Density (MPOD) \uparrow — acts as a blue-light filter in the macula and lens. Quenches reactive oxygen species (ROS) in retinal tissue. Reduces photo-oxidative damage. Anti-inflammatory (NF- κ B \downarrow). Brain health: lutein concentrated in infant brain tissue.
Medicinal Uses / Health Benefits	Age-Related Macular Degeneration (AMD) prevention; Cataracts prevention; Glaucoma; Cognitive function in ageing; Atherosclerosis; Skin photoprotection; Cancer (breast, colon) — antioxidant mechanism.

★ Point

Lutein + Zeaxanthin = the TWO carotenoids found in the human MACULA (central retina). They are not made by the body — MUST come from diet. AREDS2 trial confirmed 25% reduction in AMD progression with supplementation.

Master Comparison — All Carotenoids

Carotenoid	Type	C Formula	Ionone Rings	Provitamin A	Colour	Top Source
α -Carotene	Carotene	C ₄₀ H ₅₆	1 β + 1 α ring	Yes (50%)	Orange	Carrots
β -Carotene	Carotene	C ₄₀ H ₅₆	2 β -rings	Yes (100%)	Deep orange	Carrots, pumpkin
Lycopene	Carotene	C ₄₀ H ₅₆	None (acyclic)	NO	Bright Red	Tomatoes
Lutein	Xanthophyll	C ₄₀ H ₅₆ O ₂	1 β + 1 ϵ ring	NO	Yellow	Kale, spinach
Zeaxanthin	Xanthophyll	C ₄₀ H ₅₆ O ₂	Two β -rings	NO	Yellow	Corn, saffron
Astaxanthin	Xanthophyll	C ₄₀ H ₅₂ O ₄	2 β -rings + ketones	NO	Deep Red	Salmon, shrimp

ORGANOSULFUR COMPOUNDS — SULFIDES

Organosulfur compounds are **sulfur-containing secondary metabolites** found in *Allium* species (garlic, onion, leek, chives) and Brassica vegetables. They are responsible for the characteristic pungent odour and most biological activities of these foods.

Diallyl Sulfide (DAS)

Diallyl Sulfide (DAS)	
Source / Occurrence	<i>Allium sativum</i> (Garlic) — primary source. Also present in onions, leeks, chives, scallions. Formed when Allicin (unstable) decomposes on exposure to heat or during metabolism.
Chemical Nature	Chemical formula: $(\text{CH}_2=\text{CH}-\text{CH}_2)_2\text{-S}$. Thioether — contains ONE sulfur atom bridging two allyl groups. Diallyl monosulfide. Molecular weight: 114.2 g/mol. Volatile oil component — responsible for cooked garlic aroma. Fat-soluble.
Mechanism of Action	Inhibits CYP2E1 enzyme (cytochrome P450) → reduces activation of procarcinogens. Induces Phase II detoxification enzymes (GST, NAD(P)H:quinone oxidoreductase). Inhibits <i>H. pylori</i> growth. Modulates NF- κ B, reduces TNF- α . Mild antioxidant activity.
Medicinal Uses / Health Benefits	Colon cancer prevention (strongest evidence); Liver protection (CYP2E1 inhibition reduces alcohol-induced liver damage); Antimicrobial (<i>H. pylori</i>); Cardioprotective (LDL oxidation ↓); Anti-inflammatory.

Allyl Trisulfide (Diallyl Trisulfide — DATS)

Allyl Trisulfide / Diallyl Trisulfide (DATS)	
Source / Occurrence	<i>Allium sativum</i> (Garlic) — formed from spontaneous breakdown of Allicin (diallyl thiosulfinate). Major component of distilled garlic oil. Also found in aged garlic extract.
Chemical Nature	Chemical formula: $(\text{CH}_2=\text{CH}-\text{CH}_2)_2\text{-S}_3$. Thiosulfide — contains THREE sulfur atoms bridging two allyl groups. Most biologically potent of the diallyl polysulfides. Molecular weight: 178.3 g/mol. Pungent garlic oil component. Fat-soluble.
Mechanism of Action	Most potent anticancer diallyl polysulfide: Induces apoptosis via caspase-3/-9 activation (intrinsic pathway). G2/M cell

	cycle arrest. Generates H ₂ S (vasodilatory). Strongest HMG-CoA reductase inhibition (cholesterol ↓). Potent H. pylori inhibition. Upregulates Nrf2 → antioxidant enzymes.
Medicinal Uses / Health Benefits	Cancer (prostate, lung, colon — strongest of all garlic sulfides); Cardiovascular (LDL ↓, platelet aggregation ↓, BP ↓); Antimicrobial (MRSA, H. pylori); Neuroprotective; Antifungal; Anti-diabetic (insulin secretion ↑).

Organosulfur Hierarchy — Comparison

Compound	Sulfur Atoms	Formula	Potency (anticancer)	Mechanism
Diallyl Sulfide (DAS)	1 (monosulfide)	(CH ₂ =CHCH ₂) ₂ S	Least	CYP2E1 inhibition, Phase II induction
Diallyl Disulfide (DADS)	2 (disulfide)	(CH ₂ =CHCH ₂) ₂ S ₂	Moderate	Apoptosis, GST induction, HMG-CoA inhibition
Diallyl Trisulfide (DATS)	3 (trisulfide)	(CH ₂ =CHCH ₂) ₂ S ₃	Most Potent	Apoptosis ↑↑, H ₂ S production, G2/M arrest
Allicin	Thiosulfinate	(CH ₂ =CHCH ₂)S(O)SCH ₂ CH=CH ₂	Moderate (unstable)	Antimicrobial, thiol inhibitor
S-Allyl Cysteine (SAC)	Thioether	NH ₂ CH(COOH)CH ₂ SCH ₂ CH=CH ₂	Mild (stable)	Antioxidant, neuroprotective (in AGE)

Exam Trick

Potency of garlic sulfides: DATS > DADS > DAS. More sulfur atoms = more potent anticancer activity. This is because more sulfur = more H₂S generation and more thiol-disrupting capacity in cancer cells. Easy 1-mark answer!

POLYPHENOLICS — RESVERATROL

Polyphenols are the **largest group of phytochemicals**, characterized by multiple phenol rings. They include flavonoids, stilbenes, lignans, and phenolic acids. **Resveratrol** is the most studied stilbene — famously associated with the 'French Paradox' (low CVD rates despite high-fat diet in France, attributed to red wine consumption).

Resveratrol — Detailed Profile

Resveratrol

Source / Occurrence	Red grapes skin (<i>Vitis vinifera</i>) — PRIMARY source; Red wine (80–640 µg/mL); Peanuts and peanut butter; Blueberries, mulberries, cranberries; <i>Polygonum cuspidatum</i> (Japanese knotweed) — highest commercial source; Cocoa, dark chocolate.
Chemical Nature	C ₁₄ H ₁₂ O ₃ — Trans-stilbene derivative (3,4',5-trihydroxystilbene). Contains two phenol rings connected by an ethylene bridge (-CH=CH-). Exists as cis and trans isomers — TRANS-RESVERATROL is the biologically active form. Polyphenol (stilbenoid). Molecular weight: 228.24 g/mol. UV-absorbing compound.
Mechanism of Action	SIRT1 (Sirtuin-1) activator → mimics caloric restriction → extends lifespan (anti-ageing). eNOS activation → Nitric Oxide ↑ → vasodilation → BP ↓. AMPK activation → metabolic benefits. COX-1 and COX-2 inhibition → anti-inflammatory, anti-platelet. Inhibits NF-κB → anti-cancer. Aromatase inhibition → antiestrogenic (breast cancer). Inhibits VEGF → anti-angiogenic.
Medicinal Uses / Health Benefits	Cardiovascular protection (French Paradox); Anti-ageing (SIRT1 activation); Cancer prevention (breast, prostate, colon — NF-κB ↓, apoptosis ↑); Anti-inflammatory (COX inhibition); Neuroprotection (Alzheimer's — reduces beta-amyloid aggregation); Anti-diabetic (AMPK activation); Antifungal, antiviral.

Clinical

Resveratrol's poor oral bioavailability (~1%) due to rapid metabolism limits clinical efficacy. Newer formulations use cyclodextrin complexes, nanoparticles, and transresveratrol micronized powder to enhance absorption.

★ Point

'French Paradox' = High fat diet + high red wine consumption in France → lower CVD than expected. Resveratrol in red wine = the proposed explanation. SIRT1 activation by resveratrol = anti-ageing mechanism. Both are exam favorites!


FLAVONOIDS — COMPLETE CLASSIFICATION

Flavonoids are **polyphenolic compounds based on the C₆-C₃-C₆ skeleton (flavan nucleus)**: two phenyl rings (A and B) connected by a pyran ring (C). They constitute the **largest group of plant polyphenols** (~8,000 known compounds). All flavonoids share the basic 15-carbon flavone backbone.

Flavone Backbone	Basic structure: 2-Phenylchromen-4-one. Rings: A-ring (phenol from acetate), B-ring (phenol from shikimate), C-ring (pyran with carbonyl). Classification based on the degree of oxidation and substitution of the C-ring.
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Flavonoid Class	Structural Feature	Examples	Source
Flavonols	3-OH on C-ring (3-hydroxyflavones)	Quercetin, Rutin, Kaempferol	Onions, apples, tea
Flavanones	Saturated C2-C3 bond in C-ring	Naringin, Hesperidin, Eriodyctiol	Citrus fruits
Flavones	Double bond at C2-C3, no 3-OH	Apigenin, Luteolin, Chrysin	Parsley, chamomile
Isoflavones	B-ring at C3 (not C2)	Genistein, Daidzein, Glycitein	Soybean, legumes
Flavanols (Catechins)	3-OH, no 4-one; fully reduced	EGCG, ECG, EC, EGC	Green tea, cocoa
Anthocyanidins	C-ring oxidized, no 4-one carbonyl	Cyanidin, Delphinidin, Pelargonidin	Berries, grapes, red cabbage
Chalcones	Open C-ring (linear structure)	Xanthohumol, Butein	Hops, saffron
Biflavonoids	Two flavone units linked	Ginkgetin (Gingko)	Gingko, conifers

Rutin

 Rutin (Quercetin-3-rutinoside)	
Source / Occurrence	Buckwheat (<i>Fagopyrum esculentum</i>) — RICHEST source (~1.5% in leaves); Rue plant (<i>Ruta graveolens</i> — name origin); Elderflowers; Citrus fruit peel; Asparagus; Apple skin; Black tea.
Chemical Nature	C ₂₇ H ₃₀ O ₁₆ — Flavonol glycoside. Quercetin (aglycone) + Rutinose disaccharide (glucose + rhamnose) at C-3 position. Molecular weight: 610.52 g/mol. Yellow crystalline powder. Water-soluble (due to sugar moiety) — unlike most flavonoids. Hydrolyzed in gut to quercetin + rutinose by intestinal enzymes.
Mechanism of Action	Capillary wall strengthening (reduces permeability and fragility) — inhibits hyaluronidase. Antioxidant (ROS scavenger, chelates metal ions Fe ²⁺ /Cu ²⁺). Anti-inflammatory (COX and lipoxygenase inhibition). Antiplatelet (ADP-induced aggregation ↓). Antiviral (inhibits neuraminidase).
Medicinal Uses / Health Benefits	Capillary fragility (primary indication — bruising, varicosities); Chronic venous insufficiency; Diabetic retinopathy; Haemorrhoids

(venous congestion ↓); Anti-inflammatory; Antioxidant; Antiviral; Cataracts prevention; Nephroprotection.

Exam Trick

Rutin = Quercetin + Rutinose (glucose + rhamnose). Rutin is the **GLYCOSIDE**; Quercetin is the **AGLYCONE**. Rutin is more water-soluble than quercetin. Rutin's clinical use = **CAPILLARY FRAGILITY** treatment. Very commonly asked!

Naringin

Naringin

Source / Occurrence	Citrus fruits — PRIMARY : Grapefruit (<i>Citrus paradisi</i>) — gives bitter taste; also present in Bitter orange (<i>Citrus aurantium</i>), pomelo, tangerine. Found mainly in peel and albedo (white inner layer) of citrus peel.
Chemical Nature	C ₂₇ H ₃₂ O ₁₄ — Flavanone glycoside. Naringenin (aglycone — a flavanone) + Neohesperidose disaccharide (glucose + rhamnose) at C-7. Molecular weight: 580.54 g/mol. Intensely bitter taste. Hydrolyzed by naringinase enzyme → Naringenin (active aglycone). Saturated C ₂ -C ₃ bond (flavanone class).
Mechanism of Action	Antioxidant (ROS neutralization). Anti-inflammatory (COX-2 ↓, TNF-α ↓, IL-6 ↓). Anti-atherogenic (LDL oxidation ↓, cholesterol absorption ↓). Anti-adipogenic (fat cell formation ↓). Antidiabetic (GLUT4 ↑, AMPK activation). CYP3A4 inhibition — CRITICAL drug interaction mechanism (grapefruit juice effect).
Medicinal Uses / Health Benefits	Cardiovascular protection; Anti-obesity (adipogenesis ↓); Antioxidant; Anti-inflammatory; Osteoporosis prevention (osteoblast stimulation ↑); Anti-diabetic; Anti-cancer; Neuroprotection.

Clinical

GRAPEFRUIT JUICE INTERACTION: Naringin (and furanocoumarins in grapefruit) **IRREVERSIBLY** inhibit intestinal CYP3A4 → 'Grapefruit Juice Effect' → drastically increases bioavailability of many drugs (Statins, Calcium channel blockers, Cyclosporine, Benzodiazepines, HIV protease inhibitors). **FATAL** drug interactions have been reported. One glass of grapefruit juice can affect CYP3A4 for up to 72 hours!

Quercetin

Quercetin

Source / Occurrence	Onions (<i>Allium cepa</i>) — RICHEST dietary source (~300 mg/kg in yellow onion skin); Apples (with skin), capers, broccoli, berries, tea, red grapes, kale, cherry tomatoes. Outer layers have 4× more quercetin than inner layers.
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Chemical Nature	C ₁₅ H ₁₀ O ₇ — Flavonol (3-hydroxyflavone). Aglycone (no sugar). Five hydroxyl groups (3, 5, 7, 3', 4' positions). Quercetin-3-O-rutinoside = RUTIN. Molecular weight: 302.24 g/mol. Yellow crystalline powder. Poorly water-soluble. Most abundantly consumed flavonoid in human diet (estimated 25-50 mg/day).
Mechanism of Action	Multi-target: MAPK pathway inhibition, NF-κB ↓, AP-1 ↓. Inhibits tyrosine kinase and PI3K/Akt pathway → anticancer. Potent antioxidant (5-hydroxyl groups = multiple radical donation sites). COMT enzyme inhibition → antihypertensive (catecholamine metabolism ↓). Anti-histamine (mast cell stabilization). Antiviral (SARS-CoV-2 main protease inhibition — recent data).
Medicinal Uses / Health Benefits	Anti-inflammatory (arthritis, allergy); Antioxidant; Anticancer (prostate, colon, breast); Antiviral (COVID-19 — emerging data, influenza); Antihypertensive; Anti-allergic (alternative to cromolyn sodium); Cardioprotective; Anti-diabetic; Neuroprotective.

Remember

Quercetin is the PARENT molecule of Rutin. Quercetin = aglycone (no sugar). Rutin = quercetin + rutinose disaccharide. Quercetin is the MOST ABUNDANT flavonoid in the human diet. Its poor bioavailability (~10%) is enhanced when consumed with piperine (black pepper) or as quercetin phytosome.

Anthocyanidins

Anthocyanidins / Anthocyanins	
Source / Occurrence	Berries (blueberries, blackberries, raspberries, strawberries), red/purple grapes, red cabbage, purple sweet potato, elderberries, red onion skin, hibiscus flower, black rice, red wine.
Chemical Nature	Anthocyanidins = aglycone form. Anthocyanins = anthocyanidins + sugar (glycoside form — more stable, naturally occurring). C-ring: Pyranil ring with positive charge at oxygen (oxo-carbonyl structure — flavylum cation). Color: pH-dependent — red (acidic), purple (neutral), blue (alkaline). Major anthocyanidins: Cyanidin (red), Delphinidin (blue-purple), Pelargonidin (orange-red), Malvidin (mauve/purple — dominant in red wine).
Mechanism of Action	Potent antioxidant (ORAC value highest among plant polyphenols). NF-κB ↓, COX-2 ↓ → anti-inflammatory. Inhibit MMP-2 and MMP-9 → anti-metastatic. Improve insulin sensitivity (GLUT4 ↑). Reduce platelet aggregation. Visual pigment (rhodopsin) regeneration support. Vascular endothelial protection (eNOS ↑).

Medicinal Uses / Health Benefits	Eye health (improved night vision — bilberry/Vaccinium myrtillus used by WWII RAF pilots); CVD (endothelial function ↑, atherosclerosis ↓); Cancer prevention; Obesity (adipogenesis ↓); Anti-diabetic; Urinary tract infection prevention (blueberry vs E. coli adherence); Neuroprotection; Cognitive health.
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Exam Trick	Anthocyanins change colour with pH — RED in acid, BLUE in base. This is also why red cabbage turns blue when you add baking soda (alkaline) and red when you add vinegar (acid). This property is asked in MCQs. Also: Anthocyanidins (no sugar) vs Anthocyanins (with sugar glycoside).
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Catechins (Flavanols)

Catechins (Flavanols)	
Source / Occurrence	Green tea (Camellia sinensis) — RICHEST source. Catechins are 15-30% of dry weight of green tea leaves. Also: White tea, black tea (reduced during oxidation), cocoa/dark chocolate, apples, pears, cherries, grapes. EGCG = 60-80% of total catechins in green tea.
Chemical Nature	C-ring: Fully reduced pyran ring (no carbonyl, no double bond). Two asymmetric carbons → multiple stereoisomers. Main catechins in green tea: EGCG (Epigallocatechin-3-gallate) — MOST ABUNDANT and active; ECG (Epicatechin-3-gallate); EGC (Epigallocatechin); EC (Epicatechin). Galloylated catechins (EGCG, ECG) have gallic acid ester at C-3. Molecular weight of EGCG: 458.37 g/mol.
Mechanism of Action	EGCG — most studied polyphenol: Inhibits EGFR (Epidermal Growth Factor Receptor) → anticancer. Inhibits DHFR (dihydrofolate reductase) — like methotrexate. Activates AMPK (anti-obesity, anti-diabetic). Thermogenesis ↑ (synergistic with caffeine). Inhibits amyloid-β aggregation (anti-Alzheimer). Antiviral (influenza neuraminidase inhibition). Inhibits angiogenesis (VEGF ↓).
Medicinal Uses / Health Benefits	Weight management (thermogenesis ↑, fat oxidation ↑); Cardiovascular (LDL ↓, endothelial function ↑); Cancer prevention (breast, prostate, lung, colon — EGFR inhibition); Type 2 diabetes prevention; Neuroprotection (Parkinson's, Alzheimer's); Anti-viral; Anti-bacterial (dental caries — catechins inhibit S. mutans).

Clinical

EGCG at HIGH doses (>800 mg/day) can cause LIVER TOXICITY (hepatotoxicity) — documented in case reports. Green tea extract supplements have been associated with drug-induced liver injury. Always counsel patients about DOSE LIMITS. This is a clinical safety point examiners love.

Flavones

Flavones are characterized by a **double bond at C2-C3 and a carbonyl at C4**, but **NO hydroxyl at C3** (distinguishing from flavonols). dietary flavones:

Flavone	Source	Chemical Features	Health Benefits
Apigenin	Chamomile, parsley, celery, artichoke	4',5,7-trihydroxyflavone; low MW (270.24)	Anxiolytic (GABA-A modulation), anti-inflammatory, anticancer (prostate, breast), antiviral
Luteolin	Parsley, thyme, celery, broccoli, olive oil	3',4',5,7-tetrahydroxyflavone; catechol B-ring	Anti-inflammatory, anti-allergic (mast cell ↓), anticancer, neuroprotective
Chrysin	Propolis, honey, passionflower	5,7-dihydroxyflavone (minimal substitution)	Aromatase inhibitor → anti-estrogenic; anxiolytic; anti-inflammatory
Tangeritin	Citrus peel (mandarin)	5-methoxyflavone; 4 methoxy groups	CNS protective, anti-cancer (colon), anti-inflammatory
Baicalein	Scutellaria baicalensis root	5,6,7-trihydroxyflavone	Antiviral (COVID-19 — 3CLpro inhibitor), anticancer, antioxidant

★ Point

Apigenin from chamomile tea acts on GABA-A receptors (like benzodiazepines, but non-addictive) → mild anxiolytic and sedative. This explains chamomile tea's relaxing effect — a HIGH-YIELD MCQ point!

PREBIOTICS & PROBIOTICS

Definitions & Differences

Parameter	Probiotic	Prebiotic	Synbiotic
Definition	Live microorganisms which, when administered in adequate amounts, confer a health benefit on the host (WHO/FAO 2001)	Non-digestible food ingredients that selectively stimulate growth/activity of beneficial gut bacteria (Gibson & Roberfroid, 1995)	Combination of probiotic + prebiotic in one product
Nature	Living organisms (bacteria, yeast)	Non-living food compound (oligosaccharides, fiber)	Both combined

Parameter	Probiotic	Prebiotic	Synbiotic
Example	Lactobacillus acidophilus, Bifidobacterium	FOS (Fructo-oligosaccharides), Inulin	Yakult + FOS
Site of action	Colon — colonize	Colon — fermented by resident bacteria	Colon — both mechanisms
Effect	Directly modulates gut microbiome	'Feeds' beneficial bacteria → SCFA production	Synergistic gut health

Fructo-oligosaccharides (FOS)

Fructo-oligosaccharides (FOS) — Prebiotic

Source / Occurrence	Jerusalem artichoke (<i>Helianthus tuberosus</i>) — richest plant source; Chicory root (<i>Cichorium intybus</i>) — commercial inulin/FOS extraction; Garlic, onion, leek, asparagus, banana, wheat, rye, barley, dahlia tuber.
Chemical Nature	Short-chain β -D-fructans. Oligomers of fructose with a terminal glucose unit. GF2 (kestose), GF3 (nystose), GF4 (fructosyl-nystose). Linkage: $\beta(2\rightarrow1)$ glycosidic bonds — RESISTANT to human digestive enzymes (salivary/pancreatic amylase, intestinal disaccharidases) → reach colon INTACT. Molecular weight range: 500–1000 Da. Sweet taste (~0.3–0.6x sucrose). Classified as: Oligofructose (DP 2–8) and Inulin (DP 10–60, long-chain FOS).
Mechanism of Action	Selective fermentation by beneficial bacteria (<i>Bifidobacterium</i> , <i>Lactobacillus</i>) → SCFA (Short Chain Fatty Acids: Acetate, Propionate, Butyrate). Butyrate = preferred energy source for colonocytes + antiproliferative in colon cancer. Acidification of colon (pH ↓) → inhibits pathogen growth. Calcium and Magnesium absorption ↑. Bile acid metabolism alteration → cholesterol ↓.
Medicinal Uses / Health Benefits	Prebiotic (gut microbiome modulation); Constipation relief; Colon cancer prevention (butyrate production); Mineral absorption (Ca, Mg) ↑; Blood glucose regulation (low glycemic index); Immune modulation (secretory IgA ↑); Dysbiosis treatment; Weight management (satiety ↑); Cholesterol reduction.

Exam Trick

FOS are NOT digested by human enzymes because they have $\beta(2\rightarrow1)$ bonds — humans only have α -glucosidases. They reach the colon INTACT to be fermented by *Bifidobacterium*. The product BUTYRATE is the — it's anti-

cancer (colon), anti-inflammatory, and feeds colonocytes. Very commonly asked in 5-mark questions!

Lactobacillus — Probiotics

Lactobacillus spp. — Probiotic	
Source / Occurrence	Natural habitat: Human gut (GI tract), vagina; Fermented dairy (yogurt, kefir, cheese, buttermilk), fermented vegetables (kimchi, sauerkraut, pickles), miso, tempeh. Commercial sources: <i>L. acidophilus</i> (LA-5), <i>L. rhamnosus</i> GG (LGG), <i>L. plantarum</i> , <i>L. casei</i> Shirota (Yakult).
Chemical Nature	Gram-positive, rod-shaped (bacilli), non-spore-forming, facultative anaerobes. Lactic acid bacteria (LAB). Produce primarily L-lactic acid from glucose (homofermentative) or also ethanol and CO ₂ (heterofermentative). Chemoorganotrophs — no respiration. Resistant to acidic conditions (survive stomach pH 2-4). species for human health: <i>L. acidophilus</i> , <i>L. rhamnosus</i> GG, <i>L. casei</i> , <i>L. plantarum</i> , <i>L. fermentum</i> .
Mechanism of Action	Competitive exclusion of pathogens (colonization resistance — occupy adhesion sites). Antimicrobial substance production: bacteriocins (nisin, lacticin), H ₂ O ₂ , lactic acid (pH ↓). Immunomodulation: Toll-Like Receptor (TLR) signaling, secretory IgA ↑, Treg cells ↑, Th1/Th2 balance. Vitamin K2 and B-group synthesis. Lactase production → improve lactose digestion. Short-chain fatty acid (SCFA) production.
Medicinal Uses / Health Benefits	Antibiotic-associated diarrhea (AAD) prevention (<i>L. rhamnosus</i> GG — Grade A evidence); Irritable Bowel Syndrome (IBS); Traveller's diarrhea; Vaginal infections (Bacterial Vaginosis, candidiasis); Eczema/Allergy prevention (neonates — <i>L. rhamnosus</i> GG); Immune system enhancement; Lactose intolerance; <i>Helicobacter pylori</i> eradication adjunct; Reduction of cholesterol.

★ Point

L. rhamnosus GG (LGG) is the MOST STUDIED probiotic strain. It is the only probiotic with Grade A evidence for PREVENTION of Antibiotic-Associated Diarrhea (AAD). Brand example: Culturelle. Always specify the strain — not just 'Lactobacillus' — because effects are STRAIN-SPECIFIC!

Lactobacillus Species	Strain	Proven Benefit
<i>L. rhamnosus</i>	GG (LGG)	AAD prevention, IBS, eczema in infants — most evidence
<i>L. acidophilus</i>	NCFM, LA-5	Lactose digestion, vaginal health, IBS

Lactobacillus Species	Strain	Proven Benefit
L. casei	Shirota (Yakult)	Immunity, GI transit time, H. pylori adjunct
L. plantarum	299v	IBS (abdominal pain), gut permeability ('leaky gut')
L. bulgaricus	(yogurt starter)	Lactose digestion, part of yogurt starter culture with S. thermophilus
L. fermentum	CECT5716	Mastitis, immune function, oxidative stress ↓

PHYTOESTROGENS — ISOFLAVONES, DAIDZEIN, GENISTEIN, LIGNANS

Phytoestrogens are **plant-derived compounds with estrogen-like activity** — they can **mimic, modulate, or block** the effects of endogenous estrogen. They act as **SERMs (Selective Estrogen Receptor Modulators)** — agonists at ER- β (protective) and partial antagonists at ER- α (anti-proliferative in breast cancer).

Isoflavones — Overview

Isoflavones are the **most potent class of phytoestrogens**. They differ from flavones by having the **B-ring attached at C3 (not C2)** of the chromanone ring. This structural difference confers estrogenic activity (similar to 17 β -estradiol binding orientation at ER).

Isoflavone	Aglycone/Glycoside	Chemical Formula	ER Binding Affinity (relative)	Source
Genistein	Aglycone	C ₁₅ H ₁₀ O ₅ (270.24)	ER- β : 87-fold higher than ER- α	Soybean, fava beans
Genistin	Glycoside (7-O-glucoside of genistein)	C ₂₁ H ₂₀ O ₁₀ (432.38)	Requires hydrolysis → genistein	Soybean (major storage form)
Daidzein	Aglycone	C ₁₅ H ₁₀ O ₄ (254.24)	ER- β : ~20-fold higher than ER- α	Soybean, kudzu root
Daidzin	Glycoside (7-O-glucoside of daidzein)	C ₂₁ H ₂₀ O ₉ (416.38)	Requires hydrolysis	Soybean (major storage form)
Glycitein	Aglycone	C ₁₆ H ₁₂ O ₅ (284.26)	Weakest binding	Soybean (only ~5% of total)
Equol	Daidzein metabolite (gut bacteria)	C ₁₅ H ₁₄ O ₃ (242.27)	SERM — stronger than daidzein	Not in plants — produced in gut

Daidzein

Daidzein	
Source / Occurrence	Soybean (<i>Glycine max</i>) — PRIMARY source (0.1–0.5 g/100g dry weight); Kudzu root (<i>Pueraria lobata</i>) — traditional Chinese medicine source; Miso, tofu, tempeh, soy milk (fermented soy products have higher aglycone content — more bioavailable).
Chemical Nature	C ₁₅ H ₁₀ O ₄ — Isoflavone (4',7-dihydroxyisoflavone). B-ring at C-3 position (distinguishes from flavones). Two phenolic hydroxyl groups (4' and 7 positions). No hydroxyl at C-5 (unlike genistein). Molecular weight: 254.24 g/mol. Metabolized by gut bacteria to EQUOL (S-equol — active SERM) and O-desmethylangolensin. Only ~30% of Asians and Westerners are 'equol producers' — determines responsiveness to soy.
Mechanism of Action	ER-β selective agonism → promotes bone formation (osteoblast ↑, osteoclast ↓ — osteoprotective). Inhibits tyrosine kinase (weaker than genistein). Antioxidant. Anti-inflammatory (COX ↓). Metabolism to equol by <i>Lactococcus</i> , <i>Slackia isoflavoniconvertens</i> in colon.
Medicinal Uses / Health Benefits	Menopausal hot flashes (especially in equol producers); Osteoporosis prevention; Cardiovascular protection (LDL ↓, endothelial function ↑); Prostate health (BPH symptom relief); Breast cancer risk reduction; Antioxidant protection.

Genistein (Note: 'Geebustin' in syllabus = Genistein)

⚠ Exam Trick


'Geebustin' written in the PCI syllabus is a TYPO/Incorrect spelling for GENISTEIN. In your exam, write GENISTEIN. Both Genistein and Daidzein are isoflavones from soybean — examiners may ask you to differentiate them.

🌿 Genistein (5,7,4'-Trihydroxyisoflavone)

Source / Occurrence	Soybean (<i>Glycine max</i>) — PRIMARY source (most abundant isoflavone in soy); Fava beans (<i>Vicia faba</i>), chickpeas, peanuts, kudzu. Commercial source: Soy isoflavone extracts standardized to ≥40% genistein.
Chemical Nature	C ₁₅ H ₁₀ O ₅ — Isoflavone. THREE hydroxyl groups at positions 5, 7, and 4' (more OH than daidzein → stronger antioxidant and stronger binding). B-ring at C-3. Molecular weight: 270.24 g/mol. More potent phytoestrogen than daidzein. Naturally occurring as genistin (7-O-glucoside) in intact soybean; hydrolyzed by gut bacteria to genistein.

Mechanism of Action	Protein tyrosine kinase (PTK) inhibitor — most potent natural PTK inhibitor known (inhibits EGFR, Her2/neu, BCR-ABL). Inhibits VEGF → anti-angiogenic. Topoisomerase II inhibitor → DNA damage in cancer cells. ER-β agonist (SERM). Aromatase inhibition → reduces estrogen synthesis. AMPK activation. Inhibits NF-κB, reduces IL-6, TNF-α.
Medicinal Uses / Health Benefits	Breast cancer (ER+ and ER- — anti-proliferative via PTK inhibition and antiangiogenic); Prostate cancer (tyrosine kinase ↓, apoptosis ↑); Menopausal symptoms (hot flushes, vaginal atrophy); Osteoporosis (osteoblast ↑ via ER-β activation); Cardiovascular (LDL ↓, endothelial function ↑); Type 2 Diabetes (insulin sensitivity ↑).

Lignans

 Lignans (Plant Lignans → Mammalian Lignans)	
Source / Occurrence	Flaxseeds (<i>Linum usitatissimum</i>) — RICHEST source of SDG (Secoisolariciresinol Diglucoside); Sesame seeds (Sesamin, Sesamol); Whole grains (rye, wheat bran); Berries; Broccoli; Green tea; Cashews.
Chemical Nature	Plant lignans: Phenylpropanoid dimers. SDG (Secoisolariciresinol Diglucoside) = primary plant lignan in flaxseed. Pinoresinol, Lariciresinol, Matairesinol — other plant lignans. SDG is converted by intestinal bacteria (Bacteroides, Clostridium) to mammalian lignans: ENTEROLACTONE and ENTERODIOL — these are the biologically active forms. Enterolactone and Enterodiol have weak estrogenic + antiandrogenic activity.
Mechanism of Action	Enterolactone/Enterodiol: ER-β preferential agonism (phytoestrogenic). Antioestrogenic at ER-α (competitive inhibitor of E2 binding → reduced breast cancer cell proliferation). SHBG (Sex Hormone Binding Globulin) ↑ → reduces free estrogen/testosterone. 5-α-reductase inhibition → reduces DHT → prostate cancer prevention. Antioxidant. Anti-inflammatory (NF-κB ↓).
Medicinal Uses / Health Benefits	Breast cancer prevention (especially postmenopausal ER+ breast cancer); Prostate cancer (5-α-reductase inhibition, DHT ↓); Menopausal symptoms; Cardiovascular (LDL ↓, LDL oxidation ↓); Osteoporosis; Anti-diabetic; Anti-inflammatory; Constipation (fiber component).

Phytoestrogen Class	Compound	Source	Chemical Class	ER Preference	Use
Isoflavones	Genistein	Soybean	Flavonoid (isoflavone)	ER- β >>> ER- α	Menopause, cancer
Isoflavones	Daidzein	Soybean, kudzu	Flavonoid (isoflavone)	ER- β > ER- α	Bone health, menopause
Lignans	SDG \rightarrow Enterolactone	Flaxseed	Phenylpropanoid	ER- β > ER- α	Breast/prostate cancer
Coumestans	Coumestrol	Sprouted legumes	Benzofuranone derivative	ER- α & ER- β	Weakest phytoestrogen
Stilbenes	Resveratrol	Grapes	Stilbene	ER- β	Anti-ageing, CVD

Exam Trick

Phytoestrogen potency order: Coumestrol > Genistein > Daidzein > Formononetin > SDG (lignans). However, coumestans are rare in common foods; Genistein is the most clinically important. ER- β preference of phytoestrogens is WHY they protect against breast cancer (ER- β activation is anti-proliferative) despite being estrogenic — the EXAM PARADOX.

TOCOPHEROLS — VITAMIN E

Tocopherols are **fat-soluble phenolic compounds** that constitute **Vitamin E** — the major lipid-soluble chain-breaking antioxidant in biological membranes. They protect against peroxidation of polyunsaturated fatty acids (PUFAs) in cell membranes. The word tocopherol comes from Greek 'tokos' (childbirth) + 'pherein' (to carry) — initially discovered as essential for animal reproduction.

Chemical Nature of Tocopherols

All tocopherols share the **chroman-6-ol ring system** (chromanol nucleus) with a **phytyl side chain**. The four forms (α , β , γ , δ) differ in the **number and position of methyl groups** on the chromanol ring.

Form	Methyl Groups on Ring	Biological Activity (Vitamin E)	Best Source	Special Notes
α -Tocopherol	5, 7, 8 positions (trimethyl)	100% — MOST BIOLOGICALLY ACTIVE	Wheat germ oil, sunflower oil, almonds	Preferred by α -TTP (transfer protein) \rightarrow retained in body
β -Tocopherol	5, 8 positions (dimethyl)	~50%	Wheat germ, cereals	Uncommon in food
γ -Tocopherol	7, 8 positions (dimethyl)	~10–25%	Corn oil, soybean oil, walnuts, pecans	MOST ABUNDANT in American diet; better nitrate stress protection

Form	Methyl Groups on Ring	Biological Activity (Vitamin E)	Best Source	Special Notes
δ -Tocopherol	8 position only (monomethyl)	~1–10%	Soybean oil, canola oil	Lowest biological activity but strongest anticancer (prostate)
Tocotrienols ($\alpha, \beta, \gamma, \delta$)	Same as tocopherols but UNSATURATED side chain (3 double bonds)	Less vitamin E activity but SUPERIOR neuroprotection, anti-cancer	Palm oil, rice bran oil, annatto	Penetrate brain more efficiently than tocopherols

Mechanism of Action of Tocopherols

- Chain-breaking antioxidant: Donates $H\bullet$ to lipid peroxy radicals ($LOO\bullet$) \rightarrow tocopheroxy radical ($Toc\bullet$) + $LOOH$ (stable). Terminates lipid peroxidation chain reaction.
- Tocopheroxy radical ($Toc\bullet$) is regenerated by Vitamin C (ascorbic acid) — hence Vitamin C 'spares' Vitamin E.
- Inhibits protein kinase C (PKC) \rightarrow reduces platelet aggregation and smooth muscle proliferation.
- Inhibits LOX-5 and COX \rightarrow anti-inflammatory (independent of antioxidant activity).
- Gene regulation: Inhibits NF- κ B, reduces ICAM-1 expression \rightarrow anti-atherosclerotic.
- Immune function: Enhances T-cell proliferative response, natural killer cell activity.

Sources & Health Benefits

Health Benefit	Mechanism	Evidence
Cardiovascular protection	LDL oxidation \downarrow (prevents foam cell formation), platelet aggregation \downarrow , endothelial function \uparrow	Moderate (observational strong; RCT mixed results)
Cancer prevention	Antioxidant \rightarrow DNA damage \downarrow ; γ -Tocopherol traps nitrosamines (anti-nitrosative)	Prostate cancer: SELECT trial (inconclusive); γ -Tocopherol has emerging evidence
Neuroprotection	Membrane PUFA protection, mitochondrial function \uparrow	Alzheimer's — high-dose α -Tocopherol slows functional decline (RCT evidence)
Reproductive health	Named for 'bearing children' — prevents fetal resorption in animals; fertility support	Historical origin; human evidence limited
Immune enhancement	T-lymphocyte proliferation \uparrow , NK cell activity \uparrow	Elderly — Vitamin E supplementation (200 IU) improves immune response (RCT)
Non-alcoholic fatty liver disease (NAFLD)	Reduces hepatic oxidative stress, inflammation	Moderate evidence — Vitamin E 800 IU/day improves histology

Food Source	α -Tocopherol Content	Notes
Wheat germ oil	150 mg/100g — HIGHEST	Best single source of α -tocopherol
Sunflower oil	41 mg/100g	High α -tocopherol: γ -tocopherol ratio
Almonds	26 mg/100g	Best nut source of Vitamin E
Hazelnuts	15 mg/100g	Good Vitamin E + heart-healthy fats
Avocado	2.1 mg/100g	Good everyday food source
Spinach	2 mg/100g	With fat for absorption (fat-soluble)
Rice bran oil	32 mg/100g (mixed tocopherols + tocotrienols)	Rich in tocotrienols — unique

Exam Trick

α -Tocopherol = most biologically active. γ -Tocopherol = most abundant in American diet (soybean, corn oil) but low vitamin E activity. Rice bran oil and palm oil are the richest sources of TOCOTRIENOLS (unsaturated side chain variant of Vitamin E). The IU vs mg conversion: 1 IU natural Vitamin E = 0.67 mg α -tocopherol.

FUNCTIONAL FOODS — CEREALS, SEAFOODS & BEVERAGES

Functional foods are foods that provide benefits **beyond basic nutrition**. This section covers specific plant-based cereals, seafoods, and beverages that have well-documented nutraceutical properties.

Oats (*Avena sativa*)


Oats — *Avena sativa*

Active Compounds	β -Glucan (soluble fiber, PRIMARY active compound); Avenanthramides (unique to oats — phenolic amides); Avenacosides (saponins); Phytic acid; Vitamin E (tocopherols + tocotrienols); B-vitamins; Minerals (Mg, Fe, Zn).
Chemical Nature	β -Glucan: Mixed-linkage (1 \rightarrow 3),(1 \rightarrow 4)- β -D-glucan. Linear polysaccharide. 2.5–8% of oat dry weight (highest in oat bran). High viscosity in GI tract — forms gel. Avenanthramides: Caffeic or ferulic acid amides of anthranilic acid — unique anti-inflammatory phenols found ONLY in oats.

Health Benefits	<p>β-Glucan: Viscous gel in gut \rightarrow slows glucose absorption (reduces glyceemic response), binds bile acids (LDL \downarrow — bile acid sequestrant mechanism), increases satiety (GLP-1 \uparrow, PYY \uparrow), prebiotic (fermented to SCFA). FDA approved health claim: '3g β-Glucan/day reduces risk of CHD'. Avenanthramides: NF-κB \downarrow, NO production \uparrow \rightarrow anti-atherogenic, antipruritic.</p>
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- β -Glucan health claim (FDA, 1997): Consuming 3g/day of oat β -glucan reduces cholesterol by 5–10%, lowering CHD risk.
- Glycemic Index (GI) of oats: Low (55) — ideal for diabetics. Oat bran has even lower GI than rolled oats.
- Avenanthramides: Antipruritic effect — reduces skin itching (used in oatmeal baths for eczema, poison ivy, chickenpox).
- Oat bran vs Oatmeal: Oat bran has 2-3x more β -Glucan — medically superior; Oatmeal has more fiber overall.

Wheat Bran

 Wheat Bran — <i>Triticum aestivum</i> (Outer layer)	
Active Compounds	<p>Insoluble dietary fiber (Arabinoxylan — PRIMARY; cellulose, lignin); Ferulic acid (phenolic acid); Phytosterols; B vitamins (B1, B2, B6, niacin); Minerals (Mg, Fe, Zn, Se); Protein (15-16% dry weight).</p>
Chemical Nature	<p>Arabinoxylan: Major non-starch polysaccharide in wheat bran — arabinose + xylose backbone ($\beta(1\rightarrow4)$ links). Insoluble fiber — not fermented as readily as oat β-glucan. Ferulic acid: hydroxycinnamic acid esterified to arabinoxylan — released on fermentation by colonic bacteria. Phytosterols: β-Sitosterol, Campesterol.</p>
Health Benefits	<p>Colon transit time \downarrow \rightarrow constipation relief (primary benefit — insoluble fiber increases stool bulk and frequency). Colorectal cancer prevention (fiber \uparrow \rightarrow dilution of carcinogens, transit time \downarrow, butyrate production from fermentation). LDL \downarrow (phytosterols). Ferulic acid: potent antioxidant \rightarrow cancer prevention. Weight management (satiety \uparrow, caloric density \downarrow).</p>

- Wheat bran is an **INSOLUBLE** fiber (unlike oat bran which is **SOLUBLE**). Insoluble = bulks stool + speeds transit. Soluble = lowers cholesterol + blunts glucose peaks.
- Contains **PHYTIC ACID** (antinutrient) — binds iron, zinc \rightarrow may reduce mineral absorption. Soaking/fermenting reduces phytic acid.

Rice Bran

Rice Bran — Oryza sativa (Bran layer + germ)

Active Compounds	Rice Bran Oil (RBO) components: γ -Oryzanol (PRIMARY unique compound); Tocotrienols + Tocopherols (Vitamin E); Phytosterols (β -Sitosterol, campesterol); Ferulic acid; PUFA (oleic, linoleic); Inositol; IP6 (Inositol hexaphosphate).
Chemical Nature	γ -Oryzanol: UNIQUE to rice bran — mixture of ferulic acid esters of triterpene alcohols (cycloartenol ferulate, 24-methylenecycloartanyl ferulate). MW ~600 Da. Ferulic acid component = antioxidant + anti-inflammatory. Steryl ferulate component = cholesterol-lowering. Tocotrienols: Unsaturated Vitamin E with superior antioxidant potency and neuroprotection vs tocopherols. IP6 (phytate): Antioxidant, anticancer.
Health Benefits	Cholesterol reduction (γ -Oryzanol + Phytosterols + Tocotrienols — triple mechanism: bile acid sequestration + cholesterol absorption \downarrow + HMG-CoA reductase \downarrow); Menopausal hot flashes (γ -Oryzanol); Antioxidant; Cancer prevention; Sports performance (γ -Oryzanol used by athletes — ergogenic claims, though evidence limited); Diabetes (glycemic control).

★ Point

Rice bran is the ONLY common food source rich in BOTH tocopherols AND tocotrienols simultaneously. γ -Oryzanol is UNIQUE to rice bran — no other food contains it in significant quantities. It is approved in Japan for treatment of menopausal syndrome. EXAM FACT.

Seafoods

Seafoods — Marine Functional Foods

Active Compounds	Omega-3 Fatty Acids: EPA (Eicosapentaenoic acid, 20:5 n-3) and DHA (Docosahexaenoic acid, 22:6 n-3) — PRIMARY active compounds; Astaxanthin (salmon, shrimp); Taurine (shellfish); Selenium; Iodine; Vitamin D; Zinc; High-quality complete protein (PDCAAS ~1.0).
Chemical Nature	EPA (20:5, n-3): Precursor to Series-3 prostaglandins (PGE3 — anti-inflammatory), Series-5 leukotrienes (LTB5 — weak chemoattractant). Competes with arachidonic acid (AA) →

	reduces inflammatory eicosanoid production. DHA (22:6, n-3): Primary structural fat of brain (60% of brain fat is DHA) and retina. Precursor to protectins and resolvins (pro-resolution lipid mediators). Essential for fetal brain and visual development. Sources by omega-3 content: Mackerel > Salmon > Sardines > Anchovies > Herring.
Health Benefits	Cardiovascular (TG ↓↓ up to 50% at pharmacological doses [Vascepa/icosapentaenoic acid]; LDL particle size ↑; platelet aggregation ↓; BP reduction — ~4/3 mmHg; arrhythmia risk ↓); Brain health (fetal brain development, Alzheimer's prevention, depression management); Eye health (DHA in retinal photoreceptors — AMD prevention); Anti-inflammatory (arthritis, IBD, asthma); Neonatal development (DHA supplementation in pregnancy).

Seafood	EPA + DHA (g/100g)	Additional Nutraceuticals	Benefit
Mackerel (Atlantic)	2.6g	Vitamin D, B12, Selenium	Highest omega-3 of common fish
Salmon (wild)	2.2g	Astaxanthin, Vitamin D, protein	Brain health, anti-inflammatory
Sardines	1.5g	Calcium (from bones), Vitamin D, B12	Budget omega-3 source
Tuna (bluefin)	1.6g	Selenium, Vitamin D	Mercury concern — limit intake
Shrimp	0.3g	Astaxanthin, Iodine, Selenium	Antioxidant carotenoid
Oysters	0.8g	Zinc (highest natural source ~5.3mg/oyster), B12	Immune function, testosterone
Seaweed (Nori)	Variable	Fucoidan, iodine, fucoxanthin	Anti-cancer, thyroid health

Clinical	FDA-approved omega-3 drugs: Lovaza (omega-3-acid ethyl esters) and Vascepa (icosapentaenoic acid — pure EPA). Vascepa reduces cardiovascular events by 25% in high-risk patients — REDUCE-IT trial (2018). The daily dose in supplements: 1-2g EPA+DHA; for TG reduction: 2-4g/day (prescription doses).
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Coffee

Coffee — Coffea arabica / Coffea canephora

Active Compounds	Caffeine (PRIMARY alkaloid — 60–180 mg/cup); Chlorogenic acids (CGA — PRIMARY polyphenol, ~200–550 mg/cup); Cafestol and Kahweol (diterpenes — in unfiltered coffee); Trigonelline (alkaloid → nicotinic acid on roasting); Melanoidins (formed during roasting); Polyphenols (caffeic acid, ferulic acid, p-coumaric acid).
Chemical Nature	Chlorogenic Acids (CGAs): Esters of quinic acid + hydroxycinnamic acids (caffeic, ferulic, p-coumaric acid). PRIMARY functional compounds. Reduce glucose absorption (inhibit G6Pase and SGLT1). Strong antioxidant (DPPH scavenging). Anti-inflammatory (NF-κB ↓). Caffeine: Adenosine receptor antagonist → CNS stimulation, alertness ↑, fatigue ↓, thermogenesis ↑. Cafestol/Kahweol (unfiltered coffee — boiled, espresso): Inhibit bile acid transport → LDL ↑ (negative cardiovascular effect of unfiltered coffee). FILTERED COFFEE removes cafestol/kahweol via paper filter.
Health Benefits	Type 2 diabetes prevention (CGAs → glucose absorption ↓; 3-5 cups/day = 25-35% reduced T2DM risk in meta-analyses); Liver protection (cirrhosis, liver cancer, NAFLD — 50% risk reduction with 2+ cups/day); Neuroprotective (Parkinson's disease risk ↓ by ~30%; Alzheimer's risk ↓); CVD (moderate consumption: endothelial function ↑, filter essential); Weight management (caffeine → thermogenesis, appetite ↓); Sports performance (caffeine = ergogenic aid, IOC-recognized).

Exam Trick

UNFILTERED coffee (boiled, French press, espresso) contains cafestol + kahweol → raises LDL cholesterol. FILTERED coffee (paper filter removes diterpenes) does NOT raise LDL. Instant coffee has minimal diterpenes. This filtering distinction is a HIGH-YIELD exam trick for coffee questions!

Tea (*Camellia sinensis*)

**Tea —
*Camellia sinensis***

Active Compounds	Green Tea: EGCG (Epigallocatechin-3-gallate) — PRIMARY — 30-40% dry weight catechins; L-Theanine (unique amino acid); Caffeine; Flavonols (quercetin, kaempferol); Vitamin C. Black Tea: Theaflavins (TF1, TF2a, TF2b, TF3) and Thearubigins — formed by oxidation of catechins during fermentation. Oolong Tea: Intermediate polyphenol profile.
Chemical Nature	Tea types by processing: (1) Green tea — unoxidized; (2) Oolong — partially oxidized; (3) Black tea — fully oxidized/fermented; (4) White tea — minimal processing. EGCG (MW 458.37) — most potent catechin: gallate ester of epigallocatechin. L-Theanine (γ-

	glutamylethylamide): UNIQUE to tea — increases α -wave brain activity → calm alertness. Theaflavins (black tea): Benzotropolone dimers from oxidation of catechin + epicatechin pairs — strong antioxidant; BZ structure responsible for characteristic tea color.
Health Benefits	Cardiovascular (meta-analysis: 3 cups green tea/day → 25% ↓ CVD risk; EGCG → endothelial function ↑, LDL ↓, platelet aggregation ↓); Cancer prevention (EGCG → EGFR inhibition, angiogenesis ↓, apoptosis ↑ — liver, prostate, breast, colon cancer data); Weight management (EGCG + caffeine → thermogenesis ↑, fat oxidation ↑); Neuroprotection (EGCG → amyloid aggregation ↓; L-Theanine → stress ↓, cognitive performance ↑ with caffeine); Antidiabetic (CGAs, catechins → insulin sensitivity ↑); Antimicrobial (dental caries ↓).

Tea Type	Catechin Content	Theaflavin Content	Caffeine	Compound
White tea (minimal processing)	Very high (similar to green)	None	Low	EGCG, ECG
Green tea (unoxidized)	High (~200-400 mg/cup)	None (~0%)	Moderate	EGCG (60-80% of catechins)
Oolong tea (partially oxidized)	Moderate	Low-moderate	Moderate	Mix of catechins + theaflavins
Black tea (fully oxidized)	Very low (~10% of green)	High (~40 mg/cup)	Highest	Theaflavins, Thearubigins
Herbal teas (Chamomile, etc.)	None (no <i>Camellia sinensis</i>)	None	None	Apigenin, bisabolol, etc.

★Point

L-Theanine + Caffeine combination in tea produces 'calm alertness' — improves attention and focus WITHOUT the jitteriness of caffeine alone. This synergy is UNIQUE to tea among beverages. Pure coffee has caffeine but no L-Theanine. This is a clinically and pharmacologically important point!

Master Comparison Table — All Functional Foods

Functional Food	Primary Active Compound	Chemical Class	Top Health Claim
Oats	β -Glucan	Mixed-linkage polysaccharide	Cholesterol ↓ (FDA claim), glycemic control
Wheat Bran	Arabinoxylan + Ferulic acid	Non-starch polysaccharide + hydroxycinnamic acid	Constipation, colorectal cancer prevention
Rice Bran	γ -Oryzanol	Ferulic acid ester of triterpene alcohol	Cholesterol ↓, menopausal symptoms (UNIQUE)

Functional Food	Primary Active Compound	Chemical Class	Top Health Claim
Seafoods	EPA + DHA	Omega-3 PUFA (n-3)	CVD (TG ↓↓), brain/fetal development
Coffee	Chlorogenic acids	Quinic acid + hydroxycinnamic acid ester	T2DM prevention, liver protection
Green Tea	EGCG	Flavanol (catechin gallate)	CVD, cancer prevention, weight management
Black Tea	Theaflavins	Benzotropolone dimers (oxidized catechins)	Cardiovascular, antioxidant

DEFINITIONS GLOSSARY —

Phytochemical	Non-nutritive bioactive compounds produced by plants as secondary metabolites that confer significant health benefits when consumed by humans.
Carotenoid	Fat-soluble C40 tetraterpene pigments (yellow/orange/red) classified as carotenes (no oxygen: β -Carotene, Lycopene) or Xanthophylls (with oxygen: Lutein, Zeaxanthin).
Provitamin A	Carotenoids that can be converted to Vitamin A (retinol) in the body. β -Carotene (100%), α -Carotene (50%), β -Cryptoxanthin (50%) are provitamin A carotenoids. Lycopene and Lutein are NOT provitamin A.
Xanthophyll	Oxygenated carotenoid containing one or more oxygen-containing functional groups (hydroxyl, ketone, epoxide). Examples: Lutein (2 \times OH), Zeaxanthin (2 \times OH), Astaxanthin (2 \times ketone + 2 \times OH).
Diallyl Sulfide (DAS)	Organosulfur thioether from garlic with ONE sulfur atom [(CH ₂ =CHCH ₂) ₂ S]; inhibits CYP2E1 and induces Phase II detox enzymes; anticancer and hepatoprotective.
Allyl Trisulfide (DATS)	Most potent garlic organosulfur compound with THREE sulfur atoms [(CH ₂ =CHCH ₂) ₂ S ₃]; induces apoptosis, G2/M arrest, H ₂ S production; strongest anticancer polysulfide.
Resveratrol	Trans-stilbene polyphenol (3,4',5-trihydroxystilbene, C ₁₄ H ₁₂ O ₃) from red grapes; activates SIRT1 (anti-ageing), eNOS (vasodilation), AMPK; associated with the 'French Paradox'.

Flavone Backbone	C6-C3-C6 (15-carbon) skeleton with two aromatic rings (A and B) connected by a pyran ring (C). Double bond at C2-C3 and carbonyl at C4; NO hydroxyl at C3 in pure flavones.
Rutin	Quercetin-3-rutinoside — flavonol glycoside (quercetin aglycone + rutinose disaccharide). Water-soluble; reduces capillary fragility; richest in buckwheat.
Naringin	Flavanone glycoside (naringenin + neohesperidose) responsible for grapefruit bitterness; inhibits intestinal CYP3A4 → 'Grapefruit Juice Effect' drug interaction.
EGCG	Epigallocatechin-3-gallate — most abundant and active catechin in green tea; inhibits EGFR (anticancer), DHFR, VEGF; activates AMPK; potent antioxidant.
Anthocyanin	Glycosidic form of anthocyanidin pigments (flavylium cation structure); pH-dependent color (red/purple/blue); potent antioxidant; found in berries, grapes, red cabbage.
Prebiotic	Non-digestible food ingredient that selectively stimulates growth or activity of beneficial bacteria (Bifidobacterium, Lactobacillus) in the colon. (Gibson & Roberfroid, 1995)
Probiotic	Live microorganisms which, when administered in adequate amounts, confer a health benefit on the host. (WHO/FAO definition, 2001). Example: Lactobacillus rhamnosus GG.
FOS (Fructo-oligosaccharides)	Short-chain fructans with $\beta(2\rightarrow1)$ linkages; resist human digestion; fermented by Bifidobacterium in colon → SCFA (especially butyrate) production; classified as prebiotic.
Phytoestrogen	Plant-derived compounds with structural similarity to 17β -estradiol that can bind estrogen receptors (preferentially ER- β). Examples: Isoflavones (genistein), Lignans (SDG), Coumestans.
SERM	Selective Estrogen Receptor Modulator — compound that acts as estrogen agonist at some tissues (bone, CV) and antagonist at others (breast). Natural SERMs: Genistein, Daidzein, Tamoxifen (synthetic).

Genistein	5,7,4'-Trihydroxyisoflavone from soybean; potent phytoestrogen; inhibits protein tyrosine kinase (PTK), VEGF, topoisomerase II; strongest natural anticancer isoflavone.
α-Tocopherol	Most biologically active form of Vitamin E (100% activity); chromanol ring with phytyl side chain; three methyl groups at positions 5, 7, 8; primary chain-breaking lipid antioxidant.
γ-Oryzanol	Unique to rice bran oil; ferulic acid esters of triterpene alcohols; reduces LDL cholesterol (triple mechanism), menopausal symptoms; approved in Japan as drug for climacteric disorders.

QUESTION BANK — 2 MARK QUESTIONS

Q. Q1. What is Lycopene? Why does it have no provitamin A activity?

Ans: Lycopene is an acyclic carotene (C₄₀H₅₆) — the bright red pigment of tomatoes (primary source). It has NO ionone rings at either end of the polyene chain. Provitamin A activity requires a β -ionone ring (which serves as the cleavage site for β -carotene-15,15'-oxygenase to produce retinal/retinol). Since Lycopene has NO β -ionone ring, it CANNOT be converted to Vitamin A, and therefore has zero provitamin A activity. It is, however, the MOST POTENT singlet oxygen quencher among carotenoids.

Q. Q2. Differentiate between Carotenes and Xanthophylls.

Ans: Carotenes: Pure hydrocarbon carotenoids — contain only Carbon and Hydrogen (no oxygen). Examples: β -Carotene (C₄₀H₅₆), Lycopene (C₄₀H₅₆). Generally orange/red pigments. May have provitamin A activity (if β -ionone ring present). Xanthophylls: Oxygenated carotenoids — contain Carbon, Hydrogen, AND Oxygen (as hydroxyl, ketone, epoxide groups). Examples: Lutein (C₄₀H₅₆O₂ — 2 \times OH), Zeaxanthin (C₄₀H₅₆O₂ — 2 \times OH). Generally yellow pigments. NO provitamin A activity.

Q. Q3. What is the 'Grapefruit Juice Effect'? Name the compound responsible.

Ans: The 'Grapefruit Juice Effect' refers to the significant INCREASE in bioavailability of certain drugs when co-administered with grapefruit juice, due to inhibition of intestinal CYP3A4 enzyme. The primary compound responsible is NARINGIN (a flavanone glycoside) along with FURANOCOUMARINS (bergamottin, 6',7'-dihydroxybergamottin). Naringin and furanocoumarins irreversibly inhibit intestinal CYP3A4, preventing first-pass metabolism of drugs like statins (simvastatin, lovastatin), calcium channel blockers (felodipine), cyclosporine, and benzodiazepines — leading to dangerously elevated plasma drug levels.

Q. Q4. What are the four forms of Tocopherol? Which is the most biologically active?

Ans: The four forms of Tocopherol (Vitamin E) are: α -Tocopherol, β -Tocopherol, γ -Tocopherol, and δ -Tocopherol. They differ in the number and position of methyl groups on the chromanol ring. α -Tocopherol is the MOST BIOLOGICALLY ACTIVE form (100% vitamin E activity) — it has three methyl groups at positions 5, 7, and 8 on the chromanol ring and is preferentially retained in the body by α -Tocopherol Transfer Protein (α -TTP) in the liver. γ -Tocopherol is most abundant in the American diet but has only ~10-25% of α -Tocopherol's biological activity.

Q. Q5. Define Prebiotic. Give two examples with their mechanism.

Ans: Prebiotic (Gibson & Roberfroid, 1995): A non-digestible food ingredient that selectively stimulates the growth and/or activity of one or more bacteria in the colon, thus improving host health. Examples: (1) FOS (Fructo-oligosaccharides) — short-chain $\beta(2\rightarrow1)$ fructans; resist human digestion; fermented by Bifidobacterium \rightarrow SCFA (butyrate, propionate, acetate); mechanism: butyrate = colonocyte energy + antiproliferative in cancer; (2) Inulin — longer-chain polyfructan from chicory root; similarly fermented by Lactobacillus and Bifidobacterium \rightarrow similar SCFA production and calcium absorption enhancement.

Q. Q6. What is EGCG? State its chemical class and two anticancer mechanisms.

Ans: EGCG (Epigallocatechin-3-Gallate) is the primary and most potent catechin in green tea (*Camellia sinensis*). Chemical class: Flavanol (also called catechin or flavan-3-ol) — fully reduced C-ring with gallic acid ester at C-3 (gallate moiety = galloylated catechin). Molecular weight: 458.37 g/mol. Two anticancer mechanisms: (1) EGFR (Epidermal Growth Factor Receptor) tyrosine kinase inhibition \rightarrow blocks cell proliferation signaling \rightarrow apoptosis; (2) Anti-angiogenic — inhibits VEGF expression and secretion \rightarrow prevents tumour neovascularization \rightarrow tumour starvation.

Q. Q7. Differentiate between Genistein and Daidzein.

Ans: Both are isoflavones from Soybean (*Glycine max*). Genistein (C₁₅H₁₀O₅): THREE hydroxyl groups (5, 7, 4' positions) — MW 270.24; stronger estrogenic activity, stronger PTK inhibition, more potent anticancer. Daidzein (C₁₅H₁₀O₄): TWO hydroxyl groups (7 and 4' positions, NO hydroxyl at C-5) — MW 254.24; weaker estrogenic activity; metabolized to EQUOL by gut bacteria (~30% of people). differences: Genistein has an additional C-5 hydroxyl; Genistein is more potent anticancer (tyrosine kinase inhibitor); Daidzein \rightarrow Equol conversion is clinically significant for menopausal symptom relief.

Q. Q8. What is γ -Oryzanol? State its source and two health benefits.

Ans: γ -Oryzanol is a mixture of ferulic acid esters of triterpene alcohols (cycloartenol ferulate, 24-methylenecycloartanyl ferulate, β -sitosterol ferulate). It is UNIQUE to RICE BRAN OIL (*Oryza sativa*) — the most distinctive compound of rice bran. Health benefits: (1) Cholesterol reduction — acts via triple mechanism: phytosterol component blocks dietary cholesterol absorption; ferulic acid component is antioxidant (prevents LDL oxidation); also reduces HMG-CoA reductase activity \rightarrow LDL \downarrow ; (2) Menopausal symptom relief — reduces hot flushes and climacteric complaints; approved in Japan as a pharmaceutical for menopausal syndrome.

QUESTION BANK — 5 MARK QUESTIONS

- **Q1. Write a note on Carotenoids as nutraceuticals — occurrence, chemical nature, and health benefits. (5 marks)**
- **Q2. Write a detailed note on Flavonoids as nutraceuticals with classification and examples. (5 marks)**
- **Q3. Differentiate between Prebiotics and Probiotics. Explain FOS and Lactobacillus in detail. (5 marks)**
- **Q4. Write a note on Phytoestrogens — types, chemical nature, and role in cancer prevention. (5 marks)**
- **Q5. Write a note on Oats, Coffee, and Tea as functional foods. (5 marks)**

QUESTION BANK — 10 MARK QUESTIONS

- **Q1. Define Phytochemicals. Describe the occurrence, chemical nature, mechanism, and health benefits of Carotenoids (α -Carotene, β -Carotene, Lycopene, Xanthophylls, and Lutein). (10 marks)**
- **Q2. Write a comprehensive account of Flavonoids as nutraceuticals covering Rutin, Naringin, Quercetin, Anthocyanidins, Catechins, and Flavones. (10 marks)**
- **Q3. Write a note on Functional Foods — covering Oats, Wheat Bran, Rice Bran, Seafoods, Coffee, and Tea with their active compounds and health benefits. (10 marks)**

PREVIOUS-YEAR STYLE QUESTIONS

#	Question	Marks
1	Write a note on Carotenoids — classify them, describe their chemical nature and health benefits with special reference to Lycopene and Lutein.	10
2	Explain the nutraceutical significance of Flavonoids. Write in detail about EGCG (catechin) and Quercetin.	5
3	Define Prebiotic and Probiotic. Write a detailed note on FOS and Lactobacillus as nutraceuticals.	5
4	Write a note on Phytoestrogens — Isoflavones, Genistein, Daidzein, and Lignans with their chemical nature and role in cancer prevention.	10
5	Describe the nutraceutical properties of Tea and Coffee as functional beverages. Compare Green Tea and Black Tea.	5

TOP 15 MCQs — WITH ANSWERS & EXPLANATIONS

Q1. Which carotenoid is the MOST POTENT singlet oxygen quencher?

- (A) β -Carotene
- (B) α -Carotene
- (C) Lycopene**
- (D) Lutein

✓ Correct: (C) Lycopene

Explanation: Lycopene has the LONGEST conjugated double bond chain (11 double bonds) among common carotenoids, making it the most potent singlet oxygen quencher — approximately 2× more potent than β -Carotene. It is the bright red pigment of tomatoes and has NO provitamin A activity (no ionone ring).

Q2. β -Carotene yields how many molecules of Vitamin A (retinol) upon cleavage?

- (A) One (1)
- (B) Two (2)**
- (C) Three (3)
- (D) Four (4)

✓ **Correct: (B) Two (2)**

Explanation: β -Carotene has TWO β -ionone rings (one at each end), is cleaved centrally by β -carotene-15,15'-oxygenase, yielding TWO molecules of retinal \rightarrow TWO retinol. α -Carotene has only ONE β -ionone ring \rightarrow yields only ONE retinol (50% provitamin A activity).

Q3. The 'French Paradox' is attributed to which nutraceutical compound?

- (A) Quercetin
- (B) Resveratrol**
- (C) EGCG
- (D) Lycopene

✓ **Correct: (B) Resveratrol**

Explanation: The 'French Paradox' — low CVD rates in France despite high dietary fat — is attributed to RESVERATROL (trans-stilbene polyphenol) from red wine and grape skins. Resveratrol activates SIRT1 (sirtuin/anti-ageing enzyme), eNOS (vasodilation), and AMPK.

Q4. Naringin is responsible for the bitter taste of grapefruit and also causes a significant drug interaction by inhibiting:

- (A) CYP2D6
- (B) CYP1A2
- (C) CYP3A4**
- (D) CYP2C9

✓ **Correct: (C) CYP3A4**

Explanation: Naringin (and furanocoumarins) from grapefruit juice IRREVERSIBLY inhibit intestinal CYP3A4. This prevents first-pass metabolism of many drugs — statins, calcium channel blockers, cyclosporine, benzodiazepines — increasing their plasma levels and risk of toxicity. One glass of grapefruit juice affects CYP3A4 for up to 72 hours.

Q5. Which form of Vitamin E (Tocopherol) has the HIGHEST biological activity?

- (A) γ -Tocopherol
- (B) δ -Tocopherol
- (C) β -Tocopherol
- (D) α -Tocopherol**

✓ **Correct: (D) α -Tocopherol**

Explanation: α -Tocopherol has the highest biological Vitamin E activity (100% — the reference standard). It has three methyl groups on the chromanol ring (at positions 5, 7, 8). It is also preferentially retained in the body by α -Tocopherol Transfer Protein (α -TTP) in the liver. γ -Tocopherol is most abundant in the diet but has only ~10-25% of α -Tocopherol's biological activity.

Q6. Fructo-oligosaccharides (FOS) resist human digestion because of:

- (A) $\alpha(1\rightarrow4)$ glycosidic bonds
- (B) $\beta(2\rightarrow1)$ glycosidic bonds**
- (C) $\alpha(1\rightarrow6)$ glycosidic bonds
- (D) $\beta(1\rightarrow4)$ glycosidic bonds

✓ **Correct: (B) $\beta(2\rightarrow1)$ glycosidic bonds**

Explanation: FOS have $\beta(2\rightarrow1)$ glycosidic bonds (fructose-fructose linkages). Human digestive enzymes (salivary and pancreatic amylases, brush border disaccharidases) only cleave α -glycosidic bonds. Therefore, FOS pass through the small intestine INTACT and reach the colon where they are fermented by Bifidobacterium and Lactobacillus to produce short-chain fatty acids (SCFA).

Q7. Genistein differs from Daidzein structurally by having an additional hydroxyl group at position:

- (A) C-3
- (B) C-4'
- (C) C-5**
- (D) C-7

✓ **Correct: (C) C-5**

Explanation: Genistein has hydroxyl groups at C-5, C-7, and C-4' (three -OH groups). Daidzein has hydroxyl groups only at C-7 and C-4' (two -OH groups) — MISSING the C-5 hydroxyl. The extra C-5 hydroxyl in Genistein confers stronger antioxidant activity and stronger ER binding compared to Daidzein.

Q8. γ -Oryzanol is uniquely found in:

- (A) Wheat germ oil
- (B) Olive oil
- (C) Rice bran oil**
- (D) Coconut oil

✓ **Correct: (C) Rice bran oil**

Explanation: γ -Oryzanol (mixture of ferulic acid esters of triterpene alcohols) is UNIQUE to RICE BRAN OIL — not found in significant quantities in any other vegetable oil. It is the primary distinguishing functional compound of rice bran. It is approved in Japan as a pharmaceutical for menopausal syndrome (climacteric disorders) and is also used for cholesterol reduction.

Q9. The MOST POTENT organosulfur compound in Garlic with THREE sulfur atoms is:

- (A) Allicin
- (B) Diallyl Sulfide (DAS)
- (C) Diallyl Disulfide (DADS)
- (D) Diallyl Trisulfide (DATS)**

✓ **Correct: (D) Diallyl Trisulfide (DATS)**

Explanation: Diallyl Trisulfide (DATS) has THREE sulfur atoms $[(CH_2=CHCH_2)_2S_3]$ and is the most potent anticancer organosulfur compound from garlic. Potency order: DATS > DADS > DAS (more sulfur atoms = more potent — greater ability to generate H₂S and disrupt cancer cell thiol enzymes). DATS causes G₂/M arrest, caspase-dependent apoptosis, and NRF2 activation.

Q10. Lutein and Zeaxanthin are selectively deposited in the human:

- (A) Liver
- (B) Macula of retina**
- (C) Skin
- (D) Kidney cortex

✓ **Correct: (B) Macula of retina**

Explanation: Lutein and Zeaxanthin (along with meso-Zeaxanthin) are the ONLY carotenoids selectively concentrated in the human MACULA — the central region of the retina responsible for sharp central vision. They form the Macular Pigment and function as a 'blue light filter' and antioxidant shield, preventing age-related macular degeneration (AMD). AREDS2 trial confirmed 25% reduction in AMD progression.

Q11. Which of the following is TRUE about Anthocyanidins?

- (A) They have a fully saturated C-ring
- (B) They show pH-dependent colour change (red in acid, blue in base)**
- (C) They have provitamin A activity
- (D) They are water-insoluble

✓ **Correct: (B) They show pH-dependent colour change (red in acid, blue in base)**

Explanation: Anthocyanidins are FLAVYLIUM CATIONS with a unique C-ring structure (oxo-carbonyl). They show pH-dependent colour change: RED in acidic conditions, PURPLE at neutral pH, BLUE in alkaline conditions. This is because the flavylum cation structure is stabilized/destabilized by proton availability. A famous example: red cabbage turns blue with baking soda (alkaline) and bright red with vinegar (acidic).

Q12. L-Theanine in tea produces its calming effect by:

- (A) Blocking adenosine receptors
- (B) Increasing alpha brain wave activity and modulating GABA/glutamate**
- (C) Inhibiting serotonin reuptake
- (D) Activating GABA-A receptors directly

✓ **Correct: (B) Increasing alpha brain wave activity and modulating GABA/glutamate**

Explanation: L-Theanine (γ -glutamylethylamide) — unique to tea — produces calm alertness by: increasing alpha brain wave (8-14 Hz) activity in the posterior cortex, modulating glutamate neurotransmission (NMDA receptor modulation), and facilitating GABA production. Unlike caffeine (which blocks adenosine receptors), L-Theanine creates alert relaxation without drowsiness. Combined with caffeine in tea, it reduces caffeine's side effects (jitters, anxiety) while enhancing cognitive performance.

Q13. The primary active compound responsible for the anticholesterol effect in Oats is:

- (A) Avenanthramide
- (B) Beta-glucan**
- (C) Phytic acid
- (D) Ferulic acid

✓ **Correct: (B) Beta-glucan**

Explanation: β -Glucan (mixed-linkage (1 \rightarrow 3),(1 \rightarrow 4)- β -D-glucan) is the PRIMARY active compound responsible for oats' cholesterol-lowering effect. It forms a viscous gel in the GI tract that sequesters bile acids (bile acid sequestrant mechanism) \rightarrow forces liver to convert more cholesterol to bile acids \rightarrow LDL \downarrow . FDA approved health claim (1997): consuming 3g/day of β -glucan from oats reduces the risk of coronary heart disease.

Q14. The pro-drug form of Daidzein (active SERM produced by gut bacteria) is called:

- (A) Equol**
- (B) Enterolactone
- (C) Enterodiol
- (D) Formononetin

✓ **Correct: (A) Equol**

Explanation: Equol (specifically S-equol) is produced from DAIDZEIN by intestinal bacteria (*Slackia isoflavoniconvertens*, *Lactococcus* spp.) through reduction of the double bond and ring closure. Equol is a more potent SERM than daidzein, with stronger ER- β binding affinity. Approximately 30% of people (mainly Asian populations with gut microbiome adapted to soy) are 'equol producers' — these individuals may get greater menopausal and bone health benefits from soy consumption.

Q15. Which statement about unfiltered (boiled/French press) coffee is CORRECT?

- (A) It has more chlorogenic acids than filtered coffee
- (B) It contains cafestol and kahweol which raise LDL cholesterol**
- (C) It is safer for hypercholesterolemic patients than filtered coffee
- (D) It has lower caffeine content than filtered coffee

✓ **Correct: (B) It contains cafestol and kahweol which raise LDL cholesterol**

Explanation: Unfiltered coffee (boiled, French press, percolated, espresso) contains CAFESTOL and KAHWEOL — diterpene compounds that inhibit bile acid transport in the intestine, leading to increased LDL cholesterol synthesis. Paper filtration (drip/filtered coffee) REMOVES these diterpenes. Instant coffee has minimal diterpenes. For patients with hypercholesterolemia, FILTERED COFFEE is safer. This is a frequently tested clinical nutraceutical pharmacology point.

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