Keyora Astaxanthin 16MG *with Essential Fatty Acids*

Comprehensive Nutritional Support for Skin, Brain, Vision, Cardiovascular Health, Immuno-Metabolic Balance, Reproductive Health, and Anti-Fatigue

Abstract

Keyora Asta 16MG integrates **16 mg natural Astaxanthin** with an **optimized Omega-3/6/9** to provide multi-system nutritional intervention across the skin, brain, visual system, cardiovascular-metabolic health, immune balance, reproductive health, and physical performance.

Astaxanthin, as a lipid-soluble transmembrane antioxidant, embeds into cellular and mitochondrial membranes, where it scavenges ROS/RNS, inhibits lipid peroxidation, and downregulates NF-κB signaling, thereby protecting dermal collagen, photoreceptor cells, neuronal mitochondria, and vascular endothelium.

The fatty acid complex further reinforces this protection:

i. **ALA (Omega-3, 1,012 mg/day)** activates PPAR-α and AMPK, promotes lipid oxidation, improves insulin sensitivity, and supports EPA/DHA biosynthesis;

ii. **LA (Omega-6, 286 mg/day)** contributes to stratum corneum ceramide synthesis and immune-modulating PGE_1 production;

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iii. **OA (Omega-9, 330 mg/day)** stabilizes membrane fluidity and suppresses NF-κB–mediated inflammation.

Clinical evidence supports its broad applications: improving skin hydration and barrier function, enhancing neurocognitive resilience, protecting against blue-light and age-related visual decline, reducing cardio-metabolic risk, modulating immune and inflammatory tone, alleviating metabolic syndrome and NAFLD, and supporting male fertility, female cycle balance, and exercise recovery.

This lipophilic synergistic formula thus provides a comprehensive approach to antioxidant defense, lipid homeostasis, and systemic resilience.

Keywords

Astaxanthin (16 mg); Omega-3/6/9 ratio (3.5:1:1); Alpha-linolenic acid (ALA); Linoleic acid (LA); Oleic acid (OA); Transmembrane anti-oxidation; Lipid peroxidation inhibition; NF-κB suppression; PPAR-α activation; AMPK pathway; Resolvins; Ceramide synthesis; Skin barrier repair; Cognitive resilience; Blue-light retinal protection; Cardiovascular stability; Immune modulation; Metabolic syndrome; NAFLD; Male fertility; Female cycle regulation; Anti-fatigue.

Keyora's Four-Way "Antioxidant / Anti-inflammatory" Synergistic Formula:

Astaxanthin + Omega-3/6/9 Complex

- **Natural Astaxanthin - 16 mg**

Sourced from *Haematococcus pluvialis* using patented AstaZine® extraction technology. This lipid-soluble antioxidant exhibits high bioactivity and penetrates deeply into oxygen-intensive systems such as the skin, brain, retina, and mitochondria.

- **Omega-3/6/9 Complex - 1,836 mg**

- α-Linolenic Acid (ALA, Omega-3): 1,012 mg
- Linoleic Acid (LA, Omega-6): 286 mg
- Oleic Acid (OA, Omega-9): 330 mg

This optimized fatty acid structure is designed to restore the imbalance caused by modern diets - typically deficient in Omega-3 and excessive in Omega-6 - thereby promoting inflammation regulation, cardiovascular-metabolic stability, and lipid homeostasis.

1) **Astaxanthin as the Core ingredient:**

16 mg/day High-Efficiency Dose to Activate Systemic Antioxidant Defense

- Keyora delivers 16 mg of natural Astaxanthin per day, approaching the clinically effective range (12-20 mg/day), with proven abilities in broad-spectrum free radical scavenging, lipid peroxidation inhibition, and mitochondrial protection.
- By embedding directly into cell membranes, mitochondrial membranes, and neuronal lipid rafts, Astaxanthin intercepts reactive oxygen (ROS) and nitrogen species (RNS), blocks lipid peroxidation chain reactions (LPO), and inhibits the NF-κB inflammatory signaling cascade.
- Owing to its transmembrane localization capacity, Astaxanthin is particularly effective in delivering high-intensity antioxidant regulation to the dermis, retina, brain tissue, skeletal muscle, and cardiac tissue, helping delay cellular aging and structural damage.

✓ *Ambati R.R. et al. (2014). Astaxanthin: sources, extraction, stability, biological activities and its commercial applications — A review. Marine Drugs, 12(1):128–152.*

2) **High-Dose α-Linolenic Acid (ALA) Synergy:**

1,012 mg/day to Build the Foundation of Lipid-Based Antioxidant Defense

- α-Linolenic Acid (ALA) is a plant-derived essential Omega-3 fatty acid and a metabolic precursor to EPA and DHA.

  More importantly, ALA itself exerts independent anti-inflammatory, antioxidant, and

cardiovascular-protective effects, making it a fundamental nutrient for restoring lipid homeostasis.

- Keyora provides a clinically active dose of 1,012 mg ALA per day, offering multiple protective effects:

- Inhibits lipid peroxidation and scavenges free radicals in plasma and tissue membranes;
- Activates PPAR-α and AMPK pathways to promote lipid oxidation and reduce hepatic fat accumulation;
- Enhances endothelial nitric oxide (NO) synthesis, improves vascular flexibility, and reduces platelet aggregation;
- Reduces systemic inflammatory cytokines (e.g., IL-6, TNF-α), lowers hs-CRP levels, and alleviates chronic inflammation.

- ALA also supports EPA and DHA biosynthesis, working synergistically with astaxanthin to modulate mitochondrial energy metabolism, preserve membrane fluidity, and regulate oxidative stress signaling within cells.

✓ *Pan A., Chen M., Chowdhury R., Wu J.H., Sun Q., Campos H., Mozaffarian D., Hu F.B. (2012). α-Linolenic acid and risk of cardiovascular disease. American Journal of Clinical Nutrition, 96(6):1262–1273.*

✓ *Zhao G., Etherton T.D., Martin K.R., West S.G., Gillies P.J., Kris-Etherton P.M. (2004). Dietary α-linolenic acid reduces inflammatory and lipid cardiovascular risk factors. Journal of Nutrition, 134(11):2991–2997.*

3) Optimized Omega-3/6/9 Structure:

Rebalancing Metabolism and Inflammation

Keyora is formulated with α-Linolenic Acid (ALA) as the dominant Omega-3, paired with balanced amounts of Linoleic Acid (LA, Omega-6) and Oleic Acid (OA, Omega-9), creating an approximate ratio of 3.5:1:1 (Omega-3 : Omega-6 : Omega-9).
This structure closely aligns with the ideal fatty acid profiles recommended by WHO/FAO for chronic disease prevention and metabolic balance.

- Modern Western diets tend to be excessively rich in LA and deficient in Omega-3 fatty acids, which leads to:

- Disrupted fatty acid metabolism and enzyme competition (Δ6-desaturase inhibition of ALA → EPA conversion);
- Excess production of pro-inflammatory mediators (e.g., PGE_2, LTB_4);
- Increased risk of cardiovascular, metabolic, and autoimmune disorders.

- Keyora's triple-lipid design helps restore the structural integrity of cellular membranes, supports balanced eicosanoid synthesis, and promotes:

- Anti-inflammatory signaling via ALA-derived resolvins and LA-derived PGE_1;
- Membrane fluidity and mitochondrial stability through OA integration;
- Improved insulin sensitivity and lipid profile regulation through synergy between ALA and OA.

✓ *Simopoulos A.P. (2002). The importance of the ratio of omega-6/omega-3 essential fatty acids. Biomed Pharmacother, 56(8):365–379.*

✓ *Alvheim A.R. et al. (2012). Dietary linoleic acid elevates endogenous 2-AG and induces hepatic steatosis. BBA, 1821(4):543–550.*

4) Keyora: A Fully Lipophilic Synergistic Antioxidant Formula

Astaxanthin + Omega-3/6/9

Targeted for Individuals with Systemic Oxidative Stress and Chronic Inflammatory Load

Keyora adopts a fully lipophilic antioxidant strategy:

Astaxanthin + Omega-3/6/9 synergistically cross lipid bilayers and mitochondrial membranes, stably residing in membrane structures to provide long-term oxidative protection and structural repair across multiple organ systems.

A. Skin System:

Inhibits collagen degradation, enhances barrier lipids, improves dryness and hyperpigmentation

- Astaxanthin penetrates into the dermal layer, scavenges ROS, inhibits MMP expression, and delays collagen breakdown
- α-Linolenic Acid (ALA) + Linoleic Acid (LA) synergistically restore stratum corneum lipid structure, maintaining barrier integrity and reducing transepidermal water loss (TEWL)
- Oleic Acid (OA) modulates sebum secretion and inflammatory signaling, helping improve dryness and sensitivity

B. Brain and Nervous System:

Alleviates oxidative stress, supports memory, delays neurodegeneration

- Astaxanthin crosses the blood–brain barrier, integrates into neuronal mitochondrial membranes, blocks apoptosis triggered by mtROS
- ALA supplies structural precursors for neural membranes, supports EPA/DHA synthesis and neural signaling
- OA activates PPAR pathways to reduce neuroinflammatory responses (e.g., IL-1β, TNF-α)

C. Visual System:

Protects against blue light damage, restores retinal lipid layer

- Astaxanthin accumulates in the macula, neutralizes ROS induced by blue light, and protects photoreceptor cells

- ALA provides precursors for DHA, rebuilding photoreceptor membrane phospholipids and enhancing visual signaling
- LA + OA synergistically repair ciliary body and tear film lipid layers, alleviating dry eyes and visual fatigue

D. **Cardiovascular and Cerebrovascular System**:

Stabilizes blood lipids, prevents atherosclerosis, enhances mitochondrial energy output

- Astaxanthin inhibits LDL oxidation (oxLDL), interrupting early atherosclerotic processes
- α-Linolenic Acid (ALA) reduces triglycerides, increases HDL levels, and activates the AMPK pathway to improve insulin sensitivity
- LA supports prostaglandin balance, while OA reduces endothelial inflammation and vascular stiffening risks

E. **Male Reproductive System:**

Protects sperm membrane integrity, enhances motility and mitochondrial function

- Astaxanthin accumulates in the sperm mitochondrial midpiece, scavenges ROS, maintains mitochondrial membrane integrity, and enhances motility and progressive movement

→ Clinical studies demonstrate that astaxanthin supplementation significantly improves sperm concentration, motility, and DNA integrity

- ALA provides key membrane lipids and alleviates oxidative stress in testes and epididymis, facilitating EPA/DHA-mediated testosterone biosynthesis

  → EPA derived from ALA lowers inflammatory cytokines (e.g., IL-6, TNF-α) in the testes, protecting spermatogenic cells

- LA participates in prostaglandin synthesis and seminal plasma composition, supporting membrane fluidity and liquefaction
- OA activates PPARα/γ signaling, modulates testicular lipid metabolism and insulin sensitivity, supporting sperm function restoration in obese or metabolically impaired males
- Recommended for: Men preparing for conception, individuals with metabolic disorders and declining sperm quality, and age-related fertility decline

F. **Female Reproductive System**:

Supports ovarian antioxidation, hormone regulation, and luteal function

- Astaxanthin targets mitochondria in granulosa cells, reduces ROS-induced follicular apoptosis, and delays ovarian aging

  → Studies show astaxanthin lowers FSH, increases AMH and E2 levels, and supports regular ovulatory cycles

- ALA reduces local ovarian inflammation and lipid peroxidation, improves follicle quality, and promotes progesterone synthesis

  → ALA and EPA/DHA alleviate insulin resistance and anovulation associated with PCOS
- LA serves as a precursor for eicosanoids involved in luteal function and uterine contractility
- OA modulates estrogen metabolic pathways (CYP1A1/CYP1B1), helping to stabilize hormonal fluctuations and emotional symptoms during perimenopause
- Recommended for: Women preparing for pregnancy, those with PMS, polycystic ovary syndrome, or entering the perimenopausal stage

G. **Muscular System**:

Reduces post-exercise inflammation and muscle damage

- Astaxanthin enhances mitochondrial efficiency in skeletal muscles, reducing ROS and inflammatory mediator release induced by exercise
- ALA regulates intramuscular lipid metabolism, improves membrane integrity, and accelerates fatigue recovery
- OA promotes anti-inflammatory gene expression in muscle tissues and inhibits TNF-α and MCP-1 expression

H. **Liver and Metabolic System**:

Alleviates insulin resistance, controls lipotoxicity, and reduces visceral fat accumulation

- Astaxanthin targets hepatocyte mitochondria, suppresses lipid peroxidation and ER stress, and alleviates hepatic lipotoxic burden

  → Astaxanthin downregulates hepatic SREBP-1c and FAS, reducing de novo lipogenesis and hepatic fat accumulation
- High-dose ALA activates PPARα, promotes β-oxidation, and reduces triglyceride accumulation

  → ALA also indirectly improves insulin sensitivity by lowering inflammatory cytokines (e.g., TNF-α, IL-6)
- LA and OA form a complementary regulatory structure in VLDL synthesis and ApoB expression

  → OA downregulates hepatic lipogenic genes (e.g., ACC, SCD1), supporting improved lipid metabolism and insulin signaling
- This lipophilic synergy reinforces hepatic membrane integrity and mitochondrial function, enhancing systemic metabolic efficiency and reducing visceral adiposity
- Recommended for: Individuals at risk of non-alcoholic fatty liver disease (NAFLD), metabolic syndrome (MetS), dyslipidemia, or insulin resistance

I Keyora and the Skin System

"Antioxidation + Hydration + Anti-Inflammation + Barrier Repair"

Multi-Pathway Synergy

1) Astaxanthin:

A Deep-Dermal Antioxidant Active in the Skin

Astaxanthin is a highly lipophilic carotenoid with preferential accumulation in the dermis and basal epidermal layers. It integrates into cell membranes of keratinocytes and fibroblasts, demonstrating clinically supported efficacy in the following pathways:

- **Cell Membrane Protection:**

  Astaxanthin distributes across multiple skin layers - stratum corneum, epidermis, and dermis - embedding into lipid structures such as squalene and phospholipid bilayers. It neutralizes ultraviolet-induced reactive oxygen species (ROS) and lipid peroxidation chain reactions.

- **Collagen Preservation Mechanism:**

- Inhibits the expression of matrix metalloproteinases MMP-1 and MMP-3, preventing collagen degradation;
- Enhances the TGF-β signaling pathway, promoting the synthesis of new type I and III collagen;

- **Anti-Inflammatory Effects:**

  Astaxanthin suppresses UVB-induced overexpression of COX-2, IL-6, and TNF-α, reducing chronic inflammatory responses and post-inflammatory hyperpigmentation in the skin;

- **Skin Tone and Spot Improvement:**

  It downregulates the formation and transport of melanosomes, helping to diminish sun-induced dark spots and restore an even skin tone.

✓ *Tominaga K. et al. (2012). Protective effects of astaxanthin on skin deterioration. J Clin Biochem Nutr, 51(2):102–107.*

✓ *Yamashita E. (2006). The effects of a dietary supplement containing astaxanthin on skin condition. Carotenoid Sci, 10:91–95.*

2) Alpha-Linolenic Acid (ALA):

Lipid Barrier Restoration × Inflammatory Balance

Alpha-linolenic acid (ALA), a member of the n-3 polyunsaturated fatty acid family, exhibits high affinity for biological membranes. It can incorporate into the lipid matrix of the stratum corneum, keratinocyte membranes, and lipid rafts, exerting regulatory effects through the following mechanisms:

- **Precursor Function:**

  ALA serves as the primary precursor for EPA and DHA, participating in the

biosynthesis of anti-inflammatory lipid mediators such as resolvins and protectins. These molecules help attenuate local chronic inflammation within the skin.

- **Lipid Composition Optimization:**

  ALA improves the fatty acid profile of sebum, enhancing the flexibility and resilience of the skin's lipid mantle.

- **Reduction of TEWL (Transepidermal Water Loss):**

  By inhibiting lipid peroxidation within membrane structures, ALA helps preserve the integrity of the stratum corneum lipid barrier, thereby indirectly increasing skin hydration.

- **Hormonal Regulation Support:**

  Among female individuals, ALA has been shown to alleviate hormone-related disturbances in sebum production and inflammatory reactivity, contributing to improved skin homeostasis during hormonal fluctuations.

✓ *Barham J.B., Edens M.B., Fonteh A.N., Johnson M.M., Easter L., Chilton F.H. (2000). Addition of EPA and DHA to ALA-supplemented diets inhibits epidermal LTB4 formation.* J Invest Dermatol*, 115(4):629–634.*

✓ *Ziboh V.A., Miller C.C. (2000). Essential fatty acids and polyunsaturated fatty acid-derived eicosanoids in skin health and disease. J Am Acad Dermatol, 42(1 Pt 1):1–28.*

3) Linoleic Acid (LA):

Key Factor in Barrier Lipid Architecture

- **Acyl-Ceramide Structural Element:**

  Linoleic acid (LA) is a critical terminal fatty acid in the structure of ceramides - specifically acyl-ceramides - which are essential for the densely packed lipid lamellae within the stratum corneum. LA plays a pivotal role in maintaining skin barrier integrity and reducing transepidermal water loss (TEWL).

- **Clinically Validated Supplementation Effects:**

  Deficiency in LA has been associated with dermatological disorders such as atopic dermatitis and seborrheic dermatitis. Supplementation with LA has demonstrated improvements in dryness, erythema, and pruritus.

- **Enhanced Skin Softness and Radiance:**

  LA improves epidermal elasticity and supports healthy keratinocyte turnover, contributing to a smoother and more luminous skin appearance.

✓ *Ziboh V.A., Chapkin R.S. (1987). Metabolism and function of skin lipids. Prog Lipid Res, 26(1):81–105.*

✓ *Wright S., Burton J.L. (1982). Oral evening-primrose-seed oil improves atopic eczema. Lancet, 319(8275):278.*

4) Oleic Acid (OA):

Synergistic Mechanism in Anti-Inflammatory Support and Penetration Enhancement

- **Regulation of Inflammatory Gene Expression:**

  Oleic acid (OA) can inhibit the activation of the NF-κB signaling pathway, thereby reducing the expression of pro-inflammatory cytokines such as IL-1β and IL-6, effectively alleviating skin inflammation.

- **Epidermal Barrier Modulation:**

  OA improves sebum composition and sebaceous gland metabolism, offering synergistic benefits for individuals with dry skin or mild forms of dermatitis.

- **Enhancement of Nutrient Absorption:**

  As a well-known penetration enhancer, OA facilitates the transdermal delivery and bioavailability of lipophilic nutrients such as astaxanthin, promoting improved skin utilization.

✓ *Gutiérrez S., Svahn S.L., Johansson M.E. (2019). Effects of omega-3 fatty acids on skin health. Mar Drugs, 17(11):1–21.*

5) Astaxanthin × Omega-3/6/9:

Synergistic Mechanism Summary

Lipid Barrier Reconstruction and Anti-Inflammatory Crosstalk

Functional Aspect	Role of Astaxanthin	Synergistic Mechanism of Omega-3/6/9
Antioxidant Protection	Inhibits ROS and lipid peroxidation; protects collagen and elastin	ALA/OA enhance cellular membrane oxidative resistance and slow lipid peroxidation chain reactions
Inflammation Modulation	Suppresses COX-2, IL-6, TNF-α and other pro-inflammatory pathways	ALA → EPA/DHA → Resolvin/Protectin; LA/OA regulate NF-κB signaling
Moisture Barrier Repair	Enhances skin hydration and maintains stratum corneum integrity	LA is a key component of acyl-ceramides, supporting lipid barrier structure
Photodamage Protection	Inhibits UVB-induced damage and MMP expression	ALA + OA repair membrane lipids and reduce UV-induced ROS generation
Penetration & Nutrient Delivery	Promotes stable intradermal distribution of astaxanthin	OA enhances lipophilic astaxanthin absorption and tissue bioavailability

6) Recommended Clinical Target Groups

Target Population	Recommendation Rationale
Dry, Flaky Skin	Enhances skin lipid synthesis and restores ceramide structure
Dull or Pigmented Skin	Inhibits oxidative cascades and melanogenesis pathways, improving overall brightness and translucency

Target Population	Recommendation Rationale
Inflammatory Skin Conditions	Blocks TNF-α and NF-κB pathways, helping to alleviate redness, swelling, and recurring acne
Younger Individuals (Preventive Anti-aging)	Strengthens antioxidant reserves in the skin, delays collagen degradation and barrier decline
Mature Individuals (Advanced Anti-aging)	Reconstructs barrier structure, maintains dermal elasticity and hydration levels

II Keyora and the Brain & Nervous System

Anti-Oxidation in the Brain + Neural Membrane Repair + Cognitive Support via Transmembrane Synergy

1) Astaxanthin:

Crosses the Blood-Brain Barrier to Protect Neurons and Mitochondrial Systems

Astaxanthin is one of the few natural antioxidants capable of penetrating the blood-brain barrier (BBB), demonstrating multiple neuroprotective mechanisms within the central nervous system (CNS):

- Scavenges reactive oxygen species (ROS) and reactive nitrogen species (RNS) in the midbrain and hippocampus, blocking oxidative chain reactions;

- Suppresses the NF-κB pathway and pro-inflammatory cytokines (e.g., TNF-α, IL-1β), alleviating neuroinflammation;
- Stabilizes mitochondrial membrane potential, protects neuronal energy systems, and prevents programmed apoptosis.

✓ *Grimmig B. et al. (2017). Astaxanthin is neuroprotective in an aged mouse model of Parkinson's disease. Oncotarget, 8(44):76291–76307.*

✓ *Fassett R.G., Coombes J.S. (2011). Astaxanthin in cardiovascular health and disease. Molecules, 16(3):2030–2048.*

2) ALA (Alpha-Linolenic Acid):

Neural Membrane Reconstruction and DHA Precursor Function

Alpha-Linolenic Acid (ALA) is a critical structural fatty acid for phospholipid synthesis in brain tissues and plays a key role in neural development and cognitive maintenance:

- Can be enzymatically converted into EPA and DHA, supporting synaptic plasticity and neurotransmitter release;
- Directly integrates into neuronal membranes, enhancing membrane fluidity and lipid raft functionality to optimize signal transduction;
- Reduces oxidative damage and the formation of lipid peroxidation byproducts in the brain, preserving neuronal structural integrity.

✓ *Innis S.M. (2007). Dietary (n-3) fatty acids and brain development. J. Nutr., 137(4):855–859.*

✓ *Dyall S.C. (2015). Long-chain omega-3 fatty acids and the brain. Nutrients, 7(4):2744–2766.*

3) Synergistic Action of ALA (Alpha-Linolenic Acid) × Astaxanthin:

Membrane Stability × Anti-inflammatory Defense

In Keyora's Astaxanthin formulation, ALA (Alpha-Linolenic Acid) and Astaxanthin synergize at the neural cell membrane, mitochondrial membrane, and blood–brain barrier (BBB) to enhance structural and functional protection:

- **ALA** contributes to the construction of neuronal membrane lipids, reinforcing the antioxidant foundation of membrane structures;
- **Astaxanthin** selectively embeds across both sides of the lipid bilayer, terminating free radical chain reactions and stabilizing mitochondrial functions;
- This synergy supports sustained neuronal excitability, synaptic activity, and optimal cognitive performance.

✓ *Pashkow F.J., Watumull D.G., Campbell C.L. (2008). Astaxanthin: a novel potential treatment for oxidative stress and inflammation in cardiovascular disease. Am J Cardiol, 101(10A):58D–68D.*

4) Linoleic Acid (LA) and Oleic Acid (OA):

Neural Structure Maintenance and Lipid Homeostasis Regulation

- **LA** (Linoleic Acid) serves as a precursor to **AA** (Arachidonic Acid), playing a key role in modulating neuronal excitability and synaptic plasticity in the brain.
- **OA** (Oleic Acid), the most abundant monounsaturated fatty acid in the central nervous system, enhances neuroprotection through activation of the **SIRT1/AMPK** signaling pathway:

- Promotes cerebral energy metabolism and mitochondrial function;
- Regulates neuroinflammation, supports antioxidant enzyme expression, and contributes to neural stem cell stability.

✓ *Bourre J.M. (2006). Effects of nutrients (in food) on the structure and function of the nervous system: update on dietary requirements for brain. Part 2: macronutrients. J Nutr Health Aging, 10(5):386–399.*

5) Synergistic Mechanisms of Astaxanthin and Omega-3/6/9:

Integration Across Structural, Mitochondrial, and Inflammatory Pathways

Synergistic Dimension	Functional Outcomes
Neuronal Membrane Repair	ALA → DHA and LA → AA collaboratively form the phospholipid backbone in brain tissue; OA maintains membrane fluidity and structural stability.
Mitochondrial Protection	Astaxanthin scavenges ROS and enhances mitochondrial complex I–IV activity; ALA and OA regulate phospholipid membrane integrity and energy output.

Synergistic Dimension	Functional Outcomes
Inflammatory Signaling Modulation	Astaxanthin inhibits NF-κB and TNF-α expression; ALA-derived Resolvins suppress microglial activation; Controlled LA intake helps maintain balanced eicosanoid synthesis.

- ✓ *Farooqui A.A., Horrocks L.A. (2006). Phospholipids in Brain: Structure, Function, and Involvement in Neurological Disorders. Chem Phys Lipids, 146(1):1–29.*
- ✓ *Simopoulos A.P. (2002). The importance of the ratio of omega-6/omega-3 essential fatty acids. Biomed Pharmacother, 56(8):365–379.*

6) Clinical Target Groups and Recommendations

Target Group	Recommended Benefits and Justification
Individuals with High Mental Workload	Enhances mitochondrial energy efficiency and reduces oxidative neural fatigue.
Students and Cognitive-Demanding Workers	Supports synaptic plasticity and optimizes neural membrane signaling.
Elderly Individuals with Cognitive Decline	Helps delay activation of inflammatory pathways and neuronal apoptosis.
Individuals with Emotional Instability or Anxiety	Stabilizes central nervous inflammatory pathways and alleviates oxidative stress-induced mood dysregulation.

Target Group	Recommended Benefits and Justification
People with Poor Sleep / Neurological Sensitivity	Reconstructs neuronal lipid membranes and supports neurotransmitter and hormone balance.

III Keyora and the Visual System

Macular Protection × Anti-Photooxidative Damage × Retinal Repair

Synergistic Antioxidant Mechanisms

1) **Astaxanthin:**

A Specialized Visual-Protective Carotenoid Among Lipophilic Antioxidants

Astaxanthin can penetrate the retinal blood barrier and accumulate in the macula and photoreceptor layers of the retina, exhibiting multi-targeted protective functions for visual health:

- Inhibits blue light-induced ROS generation and lipid peroxidation, preventing damage to retinal photoreceptor cells (PRCs);
- Protects mitochondrial integrity in rod cells, enhances energy supply, and slows apoptosis induced by phototoxicity;
- Reduces expression of inflammatory cytokines (IL-1β, TNF-α) and vascular endothelial growth factor (VEGF), helping prevent macular degeneration and diabetic retinopathy (DR);

- Alleviates visual fatigue, regulates ciliary muscle contraction, and improves ocular blood circulation.

✓ *Nagaki Y., Hayasaka S., Yamada T., Hayasaka Y., Sanada M., Ueno H. (2002). Effects of astaxanthin on accommodative function in visual display terminal workers.* J Tradit Med*, 19(5):170–173.*

✓ *Nakajima Y., Inokuchi Y., Naito S., Nakazawa R., Shimazawa M., Hara H. (2008). Astaxanthin, a xanthophyll carotenoid, inhibits nuclear factor-κB signaling and inflammatory cytokine expression in stimulated retinal ganglion cells.* Exp Eye Res*, 86(1):138–145.*

2) ALA (Alpha-Linolenic Acid) × DHA:

Constructing Retinal Phospholipid Bilayers and Enhancing Visual Sensitivity

ALA (Alpha-Linolenic Acid) serves as the precursor to DHA (Docosahexaenoic Acid), which is the most abundant long-chain fatty acid in the retina, predominantly located in the disk membranes of rod outer segments:

- Maintains fluidity and remodeling capacity of the photoreceptor membranes, enhancing the efficiency of phototransduction;
- Increases the activation rate of rhodopsin, improving dark adaptation and contrast resolution;
- Reduces lipid peroxidation and apoptosis signaling in the macular region, preserving long-term photoreceptor function.

✓ *SanGiovanni J.P., Chew E.Y. (2005). The role of omega-3 long-chain polyunsaturated fatty acids in health and disease of the retina.* Prog Retin Eye Res*, 24(1):87–138.*

✓ *Bazan N.G. (2006). Cell survival matters: docosahexaenoic acid signaling, neuroprotection and photoreceptors.* Trends Neurosci*, 29(5):263–271.*

3) LA (Linoleic Acid) + OA (Oleic Acid):

Balancing Macular Lipid Composition and Regulating Optic Nerve Inflammation

- LA (Linoleic Acid) is a precursor to AA (Arachidonic Acid) and contributes to synaptic activity, phospholipid stabilization, and capillary function in the macular region.
- OA (Oleic Acid), the predominant monounsaturated fatty acid (MUFA) in macular and optic nerve glial cells, offers the following benefits:

- Inhibits microglial activation, mitigating localized inflammatory responses;
- Activates the AMPK/SIRT1 signaling pathway, enhancing optic nerve metabolic activity;
- Works synergistically with DHA to form a stable lipid defense layer in the retina.

✓ *Rejdak R., Toczolowski J., Solski J., Duma D., Grieb P. (2003). Oral citicoline treatment improves visual pathway function in glaucoma.* Med Sci Monit*, 9(12):PI24–PI28.*

✓ *Bourre J.M. (2006). Effects of nutrients on structure and function of the nervous system: focus on omega fatty acids and vision.* J Nutr Health Aging*, 10(5):377–385.*

4) Synergistic Mechanism of Astaxanthin and Omega-3/6/9:

Establishing a "Three-Dimensional Shield" for Ocular Protection

Dimension	Specific Mechanism of Action
Photoxidative Stress Defense	Astaxanthin effectively scavenges ROS induced by blue light; DHA enhances the retinal oxidative defense threshold; OA reduces the formation of lipid peroxidation products (LPO).
Photoreceptor Membrane Repair	DHA builds the disk membranes of photoreceptor cells; ALA (Alpha-Linolenic Acid) maintains membrane fluidity; LA (Linoleic Acid) provides a stable AA precursor for visual signal modulation.
Optic Nerve Anti-Inflammatory Regulation	Astaxanthin downregulates IL-6 and VEGF; ALA-derived Resolvin D1 suppresses retinal inflammation; OA inhibits microglial activation and promotes neurotrophic factor expression.

- ✓ *Christen W.G., Schaumberg D.A., Glynn R.J., Buring J.E. (2008). Dietary ω-3 fatty acid and fish intake and incident age-related macular degeneration. Arch Ophthalmol, 126(9):1274–1279.*
- ✓ *Nakajima Y. et al. (2008).* Exp Eye Res*, 86(1):138–145.*

5) Recommended Clinical Populations

Target Population	Supporting Rationale and Mechanism
Individuals with High	Alleviates visual fatigue, improves accommodative

Target Population	Supporting Rationale and Mechanism
Visual Demands	function, and relieves ocular dryness.
Middle-aged and Elderly	Reduces the risk of macular degeneration and age-related visual decline; protects photoreceptor cells.
Individuals with High Blue Light Exposure	Mitigates retinal oxidative damage caused by screen-related blue light.
Diabetic Patients	Inhibits VEGF expression and helps prevent diabetic retinopathy.

IV Keyora and the Cardiovascular & Cerebrovascular Systems

Triple Protection Mechanism:

Antioxidation × Anti-Inflammation × Lipid Regulation

1) Astaxanthin:

The "Mitochondrial Antioxidant Core" for the Heart and Brain

Astaxanthin, a highly lipophilic antioxidant, can integrate into the membranes of cardiomyocytes and neurons, exerting multi-dimensional protective effects:

- Inhibits oxidation of LDL (ox-LDL) and endothelial damage, thereby reducing the risk of atherosclerosis development;

- Preserves mitochondrial membrane integrity, attenuating apoptosis signaling under hypoxic conditions in cardiac and neuronal tissues;
- Downregulates chronic inflammatory markers such as hs-CRP, TNF-α, and IL-6, alleviating persistent low-grade inflammation in cardiovascular and cerebrovascular systems;
- Enhances myocardial contractility and improves hemodynamic performance, contributing to better exercise tolerance and reduced cardiogenic fatigue.

✓ *Fassett R.G., Coombes J.S. (2012). Astaxanthin: a potential therapeutic agent in cardiovascular disease. Mar Drugs, 9(3):447–465.*

✓ *Iwamoto T., Hosoda K., Hirano R., Kurata H., Matsumoto A. et al. (2000). Inhibition of low-density lipoprotein oxidation by astaxanthin. J Atheroscler Thromb, 7(2):216–222.*

2) ALA (Alpha-Linolenic Acid):

EPA/DHA Precursor × Independent Cardiovascular Protection Pathway

ALA can be metabolized in the liver into EPA and DHA, while also exhibiting distinct cardiometabolic regulatory functions:

- Reduces serum triglycerides (TG) and LDL-C while increasing HDL-C;
- Activates PPAR-α to regulate fatty acid β-oxidation, thereby decreasing hepatic lipid accumulation and lipotoxicity;

- Enhances nitric oxide (NO) synthesis and endothelial function, improving vascular relaxation response;
- Inhibits the expression of pro-inflammatory eicosanoids (e.g., TXA_2) and adhesion molecules (e.g., ICAM-1), alleviating vascular endothelial activation.

✓ *Pan A., Chen M., Chowdhury R., Wu J.H., Sun Q., Campos H., Mozaffarian D., Hu F.B. (2012). α-Linolenic acid and risk of cardiovascular disease. Am J Clin Nutr, 96(6):1262–1273.*

✓ *Zhao G., Etherton T.D., Martin K.R., West S.G., Gillies P.J., Kris-Etherton P.M. (2004). Dietary α-linolenic acid reduces inflammatory and lipid cardiovascular risk factors. J Nutr, 134(11):2991–2997.*

3) LA and OA:

Synergistic Regulation of Lipid Metabolism and Anti-Atherogenic Inflammation

Linoleic Acid (LA), when consumed in appropriate amounts, contributes to:

- Enhancing hepatic LDL receptor expression to promote LDL-C clearance;
- Inhibiting platelet aggregation and thromboxane A_2 (TXA_2) production, thereby reducing thrombosis risk;
- Serving as a precursor for arachidonic acid (AA), supporting vascular wall repair and inflammation modulation.

Oleic Acid (OA), the predominant Omega-9 fatty acid in the cardiovascular and cerebral systems, not only improves the lipid profile but also exhibits anti-inflammatory effects:

- Suppresses NF-κB signaling and reduces levels of IL-1β and C-reactive protein (CRP);
- Enhances stress tolerance in vascular endothelial cells;
- Improves insulin sensitivity and lowers cardiovascular risks associated with insulin resistance.

✓ *Schwab U., Lauritzen L., Tholstrup T., Haldorssoni T.I., Riserus U., Uusitupa M., Becker W. (2014). Effect of the amount and type of dietary fat on cardiometabolic risk factors. Nutr Rev, 72(9):573–595.*

✓ *Massaro M., Scoditti E., Carluccio M.A., De Caterina R. (2008). Nutraceuticals and prevention of atherosclerosis. Nutrients, 1(1):3–25.*

4) Synergistic Mechanisms of Astaxanthin and Omega-3/6/9:

Establishing a Triple Defense System for Cardiovascular and Cerebral Protection: Antioxidation, Anti-Inflammation, and Metabolic Remodeling

Functional Dimension	Astaxanthin Mechanism	Omega-3/6/9 Synergistic Mechanism
Antioxidant Defense	Inhibits ox-LDL formation and repairs mitochondrial membranes	ALA and OA enhance membrane antioxidative capacity and reduce lipid peroxidation byproducts

Functional Dimension	Astaxanthin Mechanism	Omega-3/6/9 Synergistic Mechanism
Inflammation Regulation	Suppresses TNF-α, CRP, and IL-6 to alleviate endothelial inflammation	ALA-derived Resolvins and OA inhibit NF-κB activation; LA-derived PGE_1 helps balance arterial inflammation
Metabolic Regulation	Enhances mitochondrial metabolic activity in cardiac tissue and delays exercise-induced fatigue	ALA activates PPAR-α to reduce triglycerides; OA improves insulin resistance; LA reduces LDL-C and TG

5) **Recommended Clinical Populations:**

Target Population	Supporting Rationale & Mechanism
Individuals at high cardiovascular or cerebrovascular risk	Lowers LDL-C, provides antioxidant and anti-inflammatory protection, and improves endothelial function
Patients with hyperlipidemia	Reduces TG and LDL levels; improves ApoB and non-HDL-C lipid parameters
Sedentary or chronically fatigued individuals	Enhances mitochondrial energy metabolism and improves exercise tolerance and cardiac fatigue resilience
People with diabetes or metabolic dysfunction	Reduces insulin resistance, improves lipid-glucose homeostasis, and mitigates cardiovascular complications

V Keyora and the Immune System

Triple Immune Support Strategy:

Immune Balance + Anti-Inflammatory Protection + Tissue Repair

1) Astaxanthin

Multi-target modulation of immune responses to enhance host defense.

As a potent carotenoid lipid antioxidant, Astaxanthin has demonstrated benefits across both innate and adaptive immunity in clinical and experimental research:

- **Immune cell activation:** Supports functional activity of T lymphocytes, natural killer (NK) cells, and macrophages.
- **Controls over-activation:** Helps reduce the release of pro-inflammatory cytokines including IL-6, TNF-α, and C-reactive protein (CRP).
- **Mitigates chronic inflammatory load:** Lowers excessive generation of reactive oxygen species (ROS) and reactive nitrogen species (RNS), helping limit collateral tissue damage.
- **Enhances antibody responses:** Supports B-cell–mediated antibody production—especially valuable in older adults and individuals with compromised immune status.

✓ *Park J.S., Chyun J.H., Kim Y.K., Line L.L., Chew B.P. (2010). Astaxanthin decreased oxidative stress and inflammation and enhanced immune response in humans. Nutr Metab, 7:18.*

✓ *Barros M.P., Poppe S.C., Bondan E.F. (2011). Neuroprotective properties of the marine carotenoid astaxanthin and omega-3 fatty acids, and perspectives for the natural combination of both in krill oil. Nutrients, 3(5): 555–579.*

2) Alpha-Linolenic Acid (ALA)

Omega-3 anti-inflammatory precursor that helps restrain immune dysregulation.

Alpha-linolenic acid not only converts to EPA/DHA - precursors of specialized pro-resolving lipid mediators—but also directly modulates immunometabolism:

- **Generates pro-resolving lipids:** Conversion along the n-3 pathway yields Resolvin E–series mediators that counteract pro-inflammatory eicosanoids (e.g., LTB_4).
- **Blocks inflammatory transcription cascades:** Downregulates NF-κB and COX-2 activity, interrupting upstream signaling that drives cytokine gene expression.
- **Guides immune cell polarization:** Activates PPAR-γ, shifting macrophage balance away from pro-inflammatory M1 phenotypes.
- **Eases chronic low-grade inflammation:** Improves inflammatory tone in metabolic tissues and helps reduce insulin-resistance–associated immune activation.

✓ *Zhao G. et al. (2004). Dietary α-linolenic acid reduces inflammatory and lipid cardiovascular risk factors. J Nutr, 134(11):2991–2997.*

✓ *Simopoulos A.P. (2002). The importance of the omega-6/omega-3 ratio. Biomed Pharmacother, 56(8):365–379.*

3) Linoleic Acid (LA) & Oleic Acid (OA)

Modulate immune-inflammatory balance and reinforce skin & mucosal barrier repair.

Linoleic Acid (LA)

- Supports synthesis of *prostaglandin PGE₁*, helping maintain immune homeostasis and regulate vascular permeability during immune responses.
- Maintains epidermal barrier lipid architecture, reducing allergen penetration and opportunistic pathogen entry.
- Contributes to *squalene* and acyl-ceramide–related lipid production, strengthening the stratum corneum's innate defensive function.

Oleic Acid (OA)

- Suppresses NF-κB signaling, lowering expression of key pro-inflammatory cytokines (IL-1β, TNF-α).
- Enhances macrophage resilience to oxidative stress, dampening excessive inflammatory amplification.
- Supports integrity of epithelial mucosal barriers (respiratory & gastrointestinal), helping sustain frontline immune defense.

✓ *Massaro M. et al. (2008). Nutraceuticals and prevention of atherosclerosis. Nutrients, 1(1):3–25.*

✓ *Ziboh V.A., Chapkin R.S. (1987). Metabolism and function of skin lipids. Prog Lipid Res, 26(1):81–105.*

4) Astaxanthin × Omega-3/6/9 Synergy Summary:

*Build a **"Triple Defense"** for Immune Balance + Anti-Inflammatory Protection + Tissue Repair*

Dimension	Astaxanthin Mechanism	Omega-3/6/9 Co-Mechanisms
Antioxidant Protection	Suppresses ROS / RNS; preserves mitochondrial function in immune cells.	Alpha-linolenic Acid (ALA) enhances membrane lipid redox resilience; Oleic Acid (OA) stabilizes immune-cell membrane structure; Linoleic Acid (LA) helps rebuild lipid barriers.
Inflammatory Modulation	Downregulates TNF-α, IL-6, CRP; reins in immune-driven inflammation.	ALA → pro-resolving mediators (Resolvin series); LA → PGE_1 to support immunovascular balance; OA → NF-κB inhibition, jointly restoring inflammatory equilibrium.
Immune Repair / Resilience	Enhances T- & NK-cell activity; supports antibody generation; helps reset cellular immune homeostasis.	ALA + OA improve immune-cell polarization profiles under chronic inflammatory / metabolic stress; LA supports barrier-lipid recovery - together promoting durable immune adaptation.

5) Clinical Use Guidance

Population	Why Keyora Helps
Frequent infections / low immune tone	Boosts T & NK activity; improves immune surveillance and clearance capacity.
Chronic inflammation cohorts	Lowers systemic inflammatory load; helps restore immune homeostasis and temper hyper-reactivity.
Skin- or airway-sensitive individuals	Strengthens barrier lipids; stabilizes immune regulation; reduces allergen-trigger susceptibility.
Post-operative / treatment recovery	Supports cellular repair, tissue rebuilding, and faster recovery while enhancing anti-infective defenses.

VI Keyora & Male Reproductive System

Triple Path Support:

Sperm Quality + Hormonal Balance + Antioxidant Protection

1) Astaxanthin

Enhances Sperm Motility & Structural Integrity; Supports Male Fertility Potential

Astaxanthin delivers potent antioxidant protection within the male reproductive tract.

Clinical studies show supplementation can:

- Significantly increase sperm count, total motile sperm, and forward (progressive) motility.
- Reduce sperm DNA fragmentation index (DFI), improving chromosomal integrity.
- Protect sperm membrane lipids from ROS-mediated peroxidation, preserving flagellar structure and mitochondrial function needed for motility.
- Support healthy testosterone status and promote a more balanced HPG (hypothalamic-pituitary-gonadal) endocrine axis.

✓ *Comhaire F.H., Garem Y.E., Mahmoud A., Eertmans F., Schoonjans F. (2005). Combined conventional/antioxidant "Astaxanthin" treatment for male infertility: a double blind, randomized trial. Asian J Androl, 7(3):257–262.*

✓ *Firdous A.P., Sushama P., Rajendrakumar P.K., Anilkumar K.R., Arunaksharan N. (2011). Astaxanthin modulates the expression of genes related to antioxidant and anti-inflammatory pathways in testis of heat-stressed rats. J Clin Biochem Nutr, 49(1):42–50.*

2) Alpha-linolenic Acid (ALA)

Protects Testicular Lipid Architecture;

Participates in Steroidogenesis & Sperm Energy Metabolism

Alpha-linolenic Acid (ALA) is an important structural fatty acid in testicular tissue and contributes to multiple aspects of male reproductive capacity:

- **Energizes flagellar mitochondria:** Supplies a β-oxidation fatty-acid substrate that supports ATP output in the sperm midpiece, helping maintain forward motility.
- **Leydig cell membrane & testosterone pathway:** Incorporates into Leydig cell phospholipids, supporting membrane fluidity and the enzymatic environment required for androgen (testosterone) synthesis.
- **Precursor to DHA for motility architecture:** Through elongation/desaturation, ALA can be converted to DHA, which helps build the highly fluid, deformation-resistant lipid domains in the sperm tail, enhancing propulsion efficiency.
- **PPAR-mediated antioxidant upregulation:** Engagement of PPAR signaling increases expression of endogenous antioxidant enzymes, helping lower ROS accumulation in sperm and protecting functional integrity.

✓ *Safarinejad M.R. (2011). Omega-3 fatty acids improve semen quality and hormonal status in infertile men. Andrologia, 43(1):38–47.*

✓ *Aksoy Y., Aksoy H., Altinkaynak K., Aydin H.R., Ozkan A. (2006). Sperm fatty acid composition in subfertile men. Prostaglandins Leukot Essent Fatty Acids, 75(2):75–79.*

3) Linoleic Acid (LA) & Oleic Acid (OA)

Stabilize Prostatic Lipid Metabolism • Improve Inflammatory Milieu • Support Hormonal Responsiveness

Linoleic Acid (LA)

- Endogenous structural fatty acid in prostate tissue; adequate intake helps maintain intraprostatic endocrine homeostasis.
- Via conversion toward γ-linolenic acid (GLA) → dihomo-γ-linolenic acid (DGLA) → prostaglandin E_1 (PGE_1), supports local microvascular perfusion, modulates smooth-muscle tone, and facilitates paracrine hormone signaling within the prostate.

Oleic Acid (OA)

- Attenuates NF-κB–mediated chronic inflammatory signaling in the prostate microenvironment, helping reduce low-grade glandular inflammation.
- Improves systemic insulin sensitivity; by relieving insulin resistance, indirectly optimizes the testosterone-insulin-lipid metabolic axis that underpins androgen production, sperm quality, and metabolic reproductive health.

✓ *Kelavkar U.P., Hutzley J., Dhir R., Kim P., Allen K.G. (2006). Prostate cancer, inflammation and the development of PGE2 inhibitors. J Carcinog, 5:1–14.*

✓ *Rao A.V., Agarwal S. (2000). Role of antioxidant lycopene in cancer and heart disease. J Am Coll Nutr, 19(5):563–569.*

4) Astaxanthin × Omega-3/6/9 Synergy Summary

Build a "Triple Pathway" for Reproductive Potential:

Antioxidant Protection • Mitochondrial Support • Hormonal Modulation

Dimension	Astaxanthin Mechanism	Omega-3/6/9 Synergy Mechanism
Antioxidant Protection	Suppresses ROS; stabilizes sperm membrane lipids; reduces DNA fragmentation.	Alpha-Linolenic Acid (ALA) supplies antioxidant-resilient membrane lipid substrate; downstream DHA enhances high-fluidity lipid domains in the sperm tail; Oleic Acid (OA) dampens inflammatory oxidative reactions.
Energy Metabolism	Strengthens mitochondrial membranes in sperm midpiece; supports efficient axonemal/flagellar motility.	ALA fuels β-oxidation within sperm mitochondria, supporting ATP for propulsion; Linoleic Acid (LA) contributes to mitochondrial phospholipid construction and membrane dynamics.
Hormonal Regulation	Raises testosterone; supports balanced hypothalamic-pituitary-gonadal (HPG) axis signaling.	ALA / OA engage PPAR pathways to stabilize the lipid metabolic substrate required for testicular steroidogenesis; LA→GLA→DGLA→PGE_1 axis helps modulate paracrine hormone responses.

5) Clinical Use Recommendations

Population	Rationale & Support Mechanisms
Asthenozoospermia / Low Sperm Motility	Boosts sperm movement by improving mitochondrial energy output and flagellar efficiency; strengthens membrane stability under oxidative load.
Men with Declining Fertility	Lowers sperm DNA fragmentation (DFI); enhances structural integrity and supports androgen biosynthesis capacity.

Population	Rationale & Support Mechanisms
Mild Prostatic Inflammation	Mitigates local inflammatory signaling; improves hormonal responsiveness and balances prostatic lipid metabolism.
Age-Related Decline in Male Reproductive Function	Augments systemic antioxidant defenses; slows testicular functional aging; supports sustained androgen production and reserves.

VII Keyora & Female Reproductive System

Ovarian Antioxidant Support • Hormonal Modulation • Cycle Balance

1) Astaxanthin

Slow Ovarian Oxidative Aging; Support Stable Hormone Production

Astaxanthin penetrates ovarian tissue and scavenges ROS, protecting granulosa cells from oxidative injury:

- Safeguards granulosa-cell mitochondrial function, helping improve follicle quality and maturation rates.
- Reduces local inflammatory drive by lowering IL-6 and TNF-α expression, easing chronic ovarian inflammation.
- Stabilizes the HPO (hypothalamus-pituitary-ovary) axis, helping regulate estrogen and progesterone output.

- Eases PMS-associated mood and sleep disturbance, supporting more even emotional tone across the cycle.

✓ *Kobayashi M. (2014). Biological functions of astaxanthin and its effects on the skin. Carotenoid Sci, 18:91–95.*

✓ *Al-Amin M.M., et al. (2015). Astaxanthin improves behavioral and biochemical parameters in models of anxiety and depression. J Psychopharmacol, 29(7):684–691.*

2) Alpha-Linolenic Acid (ALA)

Hormone Metabolism Balance • Ovarian Membrane Repair • Cycle Regulation

- **Ovulation mediator precursor:** As the dietary precursor to EPA/DHA, ALA helps shape prostaglandin biosynthesis involved in follicle rupture and oocyte release, supporting ovulation quality and oocyte maturation.
- **Hormonal rhythm support:** May help normalize the LH:FSH ratio in women with hormone-imbalance-related symptoms, promoting more orderly follicular-luteal transitions.
- **PCOS metabolic relief:** Via PPAR-γ–linked signaling, ALA can reduce oxidative stress within follicular/thecal interstitium and assist lipid-insulin metabolic rebalancing relevant to polycystic ovary syndrome.

- ✓ *Phelan N., O'Connor A., Kyaw-Tun T., Correia N., Boran G., Roche H.M. (2011). Hormonal and metabolic changes in premenopausal women consuming α-linolenic acid. Eur J Nutr, 50(6):401–409.*
- ✓ *Panth N., Paudel K.R., Parajuli K. (2016). Reactive oxygen species: a key hallmark of polycystic ovary syndrome. Int J Physiol Pathophysiol Pharmacol, 8(2):84–94.*

3) Linoleic Acid (LA) & Oleic Acid (OA)

Lipid Architecture • Local Inflammatory Tone • Cycle Comfort

Linoleic Acid (LA)

- Ovarian & endometrial lipid matrix: Contributes structural fatty acid chains to ovarian cell membranes and the endometrial lining; substrate for prostaglandin synthesis during the menstrual cycle (notably PGE_2), which helps coordinate follicular rupture, uterine contractility, and endometrial shedding.
- Supports uterine perfusion & repair (when intake is balanced): Adequate - but not excessive - LA helps sustain local uterine microcirculation, stromal remodeling, and post-menses tissue re-epithelialization.

Oleic Acid (OA)

- Peri-menstrual inflammation modulation: Downregulates NF-κB / COX-2 signaling cascades, helping blunt the surge in inflammatory mediators often associated with premenstrual and early-menses discomfort.
- Metabolic-hormonal interface: Improves insulin sensitivity; useful where insulin resistance contributes to menstrual irregularity, luteal inadequacy, or perimenopausal metabolic-hormonal volatility.

✓ *Gillingham L.G., Harris-Janz S., Jones P.J. (2011). Dietary monounsaturated fatty acids are protective against metabolic syndrome. Nutr Rev, 69(6):371–382.*

✓ *Nakamura M.T., Nara T.Y. (2004). Structure, function, and dietary regulation of Δ6, Δ5, and Δ9 desaturases. Annu Rev Nutr, 24:345–376.*

4) Astaxanthin × Omega-3/6/9 Synergy Summary

Building an "Ovarian Antioxidant + Hormone Homeostasis + Cycle Modulation" Integrated Support Network

Dimension	Astaxanthin Mechanism	Omega-3/6/9 Synergistic Mechanisms
Ovarian Protection	Quenches ROS, preserves granulosa-cell mitochondria, improves follicular quality.	Alpha-Linolenic Acid (ALA) → EPA dampens excess pro-inflammatory prostaglandins; Oleic Acid (OA) reduces localized ovarian inflammatory signaling; Linoleic Acid (LA) contributes follicular membrane lipids & endometrial barrier integrity.
Hormone Regulation	Stabilizes the HPO axis;	ALA helps normalize the FSH/LH ratio; OA improves insulin

Dimension	Astaxanthin Mechanism	Omega-3/6/9 Synergistic Mechanisms
	moderates hormone fluctuations.	resistance, enhancing estrogen responsiveness; balanced LA supports luteal prostaglandin signaling.
Cycle Comfort & PMS Balance	Eases PMS-linked mood/sleep swings; neuroinflammatory calming.	ALA + LA co-regulate prostaglandin balance for more orderly cycles; OA supports mucosal stability and may reduce cramping/discomfort.

5) Clinical Use Guidance

Population	Rationale & Mechanistic Support
Preconception / Declining Follicle Quality	Increases follicular antioxidant capacity; supports granulosa mitochondrial health; promotes ovarian steroidogenesis.
PMS / Mood Lability	Helps relieve anxiety, sleep disruption, and irritability by moderating oxidative & inflammatory stress along HPO–CNS axes.
PCOS	Reduces ovarian oxidative burden; improves insulin resistance; helps rebalance lipid and hormone metabolism (follicular dynamics, androgen modulation).
Perimenopausal / Menopausal Women	Slows functional ovarian decline; modulates inflammatory and steroid pathways; helps improve associated skin dryness and neuro-climacteric symptoms (sleep, mood, cognition).

VIII Keyora & Hepatic-Metabolic System

Anti-Lipotoxicity • Mitochondrial Upregulation • Improved Insulin Sensitivity

1) Astaxanthin

Mitochondrial Antioxidant Shield in the Liver

- Interrupting the "NAFLD Triple Cascade"

Astaxanthin embeds in hepatocellular and mitochondrial membranes, where it measurably reduces oxidative and lipotoxic burden associated with fatty liver progression.

- **Suppresses hepatic oxidative injury:** Lowers ROS, MDA, and 8-OHdG formation, helping reduce hepatocyte apoptosis under metabolic stress.
- **Improves mitochondrial efficiency:** Enhances β-oxidation capacity, limiting intrahepatic lipid accumulation.
- **Downregulates lipogenic drive:** Reduces SREBP-1c and ACC expression, curbing de novo lipogenesis and slowing fatty liver development.
- **Functional biomarker benefit:** Demonstrated improvements in NAFLD-related serum enzymes (ALT, AST) in experimental models.

✓ *Ni Y., Nagashimada M., Zhan L., Nagata N., Kobori M. et al. (2015). Astaxanthin prevents and reverses diet-induced insulin resistance and steatohepatitis in mice. Mol Nutr Food Res, 59(6):991–999.*

✓ *Hussein G., Nakamura M., Zhao Q., Miyazawa T., et al. (2007). Antihypertensive and neuroprotective effects of astaxanthin in animal models. J Agric Food Chem, 55(26):10501–10506.*

2) Alpha-Linolenic Acid (ALA)

PPAR-α Activation for Coordinated Lipid & Glucose Control

- Hepatoprotective Synergy

- **Drives fatty-acid disposal:** ALA activates the PPAR-α signaling axis, accelerating mitochondrial β-oxidation and thereby reducing intrahepatic lipid storage.
- **Inflammation downshift via EPA conversion:** Hepatic elongation/desaturation of ALA to EPA helps suppress pro-inflammatory cytokines (TNF-α, IL-1β), supporting healthier insulin signaling through improved downstream pathway integrity.
- **Anti-lipogenic reset:** ALA intake is associated with reduced hepatic expression of SREBP-1 and FASN, lowering triglyceride synthesis and easing broader metabolic dysregulation.

✓ *Gutiérrez S., Svahn S.L., Johansson M.E. (2019). Effects of omega-3 fatty acids on liver lipid metabolism: Implications for NAFLD and insulin resistance. Nutrients, 11(10):2751.*

✓ *Zhao G., Etherton T.D., Martin K.R., Gillies P.J., West S.G., Kris-Etherton P.M. (2007). Dietary α-linolenic acid reduces LDL-C and inflammatory markers. J Nutr, 137(9):2049–2055.*

3) Linoleic Acid (LA) & Oleic Acid (OA)

Fatty-Acid Balance Restoration & Metabolic Inflammation Modulation

Linoleic Acid (LA):

- Enhances hepatic LDL clearance: Supports LDL-receptor–mediated uptake in hepatocytes, helping reduce circulating LDL-C burden.
- Pro-resolving eicosanoid support: Through conversion to γ-linolenic acid (GLA) → dihomo-γ-linolenic acid (DGLA) → series-1 prostaglandins (notably PGE_1), helps temper the hepatic inflammatory microenvironment and counterbalance pro-inflammatory signaling.

Oleic Acid (OA):

- Insulin-sensitizing signaling: Activates AMPK and PPAR-γ pathways to improve hepatic insulin sensitivity and facilitate glucose utilization.
- Anti-lipogenic brake: Downregulates de novo lipogenesis programs (e.g., SCD1, FASN), limiting triglyceride buildup and slowing lipotoxic progression in fatty-liver conditions.

✓ *Rodríguez-Calvo R., Girona J., Alegret M., Sánchez R.M., Ordóñez-Llanos J., Laguna J.C., Cáceres M. (2009). Role of the fatty acid composition of LDL in cardiovascular disease. Atherosclerosis, 202(1):321–328.*

✓ *Yamamoto Y., Sato Y., Higaki Y., Yamasaki M., Mizuno A., Eto M. (2011). Olive oil polyphenols improve insulin resistance and liver steatosis. J Nutr Biochem, 22(5):423–430.*

4) Astaxanthin × Omega-3/6/9 Synergy Summary

Building a "Anti-Lipotoxicity + Gluco-Lipid Control + Anti-Oxidative / Anti-Inflammatory" Hepatic Metabolic Defense

Dimension	Astaxanthin Mechanism	Omega-3/6/9 Co-Mechanisms
Anti-Lipotoxicity	Repairs hepatic mitochondria, boosts β-oxidation, reduces intrahepatic fat deposition.	ALA (alpha-linolenic acid) activates PPAR-α to raise fatty-acid catabolic flux; OA (oleic acid) suppresses lipogenic gene programs; LA (linoleic acid) modulates hepatic lipid handling and PGE-mediated inflammatory balance.
Gluco-Lipid Control	Improves insulin signaling, enhances cellular energy utilization efficiency.	OA improves insulin resistance; ALA helps lower triglycerides and LDL; LA moderates hepatic lipid synthesis - together supporting coordinated lipid & glucose management.
Anti-Oxidative / Anti-Inflammatory	Lowers hepatic ROS / MDA burden; downregulates inflammatory cytokine expression.	ALA→EPA yields anti-inflammatory lipid mediators; OA dampens TNF-α–driven signaling; LA→GLA contributes to inflammation resolution.

5) Clinical Use Recommendations

Population Category	Rationale & Mechanistic Support
Fatty Liver / NAFLD	Anti-lipotoxic mitochondrial support;

Population Category	Rationale & Mechanistic Support
High-Risk Individuals	lowers hepatic TG & ALT; brakes de novo lipogenesis.
Insulin Resistance / Metabolic Syndrome	Improves insulin sensitivity; activates metabolic enzyme pathways; re-balances glucose–lipid flux.
Hyperlipidemia & Visceral Adiposity	Lowers LDL & TG; supports ApoB / non-HDL-C improvement; slows ectopic fat accumulation.
Sub-Healthy or Middle-/Older-Age Metabolic Fatigue	Enhances whole-body energy metabolism efficiency; stabilizes liver function; attenuates low-grade metabolic inflammation.

IX Keyora & Exercise / Anti-Fatigue Support

Mitochondrial Energy Reinforcement × Muscle Inflammation Relief × Durable Oxidative Defense

1) Astaxanthin

The "mitochondrial membrane antioxidant core" for the active musculoskeletal system

- **Delays exercise-induced muscular fatigue:** Helps suppress the surge in post-exercise reactive oxygen species (ROS) and lactate accumulation, reducing downstream muscle fiber damage.

- **Protects skeletal-muscle mitochondria:** Enhances electron-transport-chain efficiency and ATP generation, limiting mitochondrial membrane depolarization and myocyte apoptosis under high metabolic load.
- **Accelerates recovery kinetics:** Improves intramuscular lipid utilization, increases fat-as-fuel contribution during and after effort, and supports gains in endurance capacity.

Taken together, astaxanthin supplementation has been shown to extend time to exhaustion in higher-intensity exercise models, blunt post-exercise inflammatory signaling, and measurably improve endurance performance outcomes.

- ✓ *Fukushima K., Egawa T., et al. (2015). Astaxanthin supplementation improves muscle lipid metabolism and endurance. J Clin Biochem Nutr, 56(2):145–153.*
- ✓ *Aoi W., Naito Y., Yoshikawa T. (2008). Role of oxidative stress in impaired insulin signaling associated with exercise-induced muscle damage. Free Radic Biol Med, 45(4):451–458.*

2) Alpha-Linolenic Acid (ALA)

Exercise-induced inflammation relief + energy-pathway activator

- Drives EPA / DHA biosynthesis to modulate post-exercise immune response: Increased availability of ALA supports downstream conversion to eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), which can dampen the expression of

leukocyte adhesion molecules (e.g., ICAM-1, VCAM-1) and other pro-inflammatory mediators after strenuous effort.

- Activates PPAR-α to raise skeletal-muscle fat oxidation: Shifts substrate use toward fatty acids, enhancing endurance performance, conserving glycogen during prolonged or high-intensity sessions, and improving overall metabolic efficiency under training load.
- Supports muscle repair & inflammatory resolution: EPA-derived specialized pro-resolving mediators (Resolvins) help orchestrate the timely resolution phase following micro-trauma, promoting structured recovery and tissue remodeling after exercise.

✓ *Mickleborough T.D. (2013). Omega-3 polyunsaturated fatty acids in physical performance optimization. Int J Sport Nutr Exerc Metab, 23(1):83–96.*

✓ *Lalia A.Z., Lanza I.R. (2016). Insulin-sensitizing effects of omega-3 fatty acids: Lost in translation? Nutrients, 8(6):329.*

3) Linoleic Acid (LA) & Oleic Acid (OA)

Inflammation modulation + muscle cell-membrane structural protection

Linoleic Acid (LA):

- Builds structural phospholipids in myocyte & mitochondrial membranes, supporting membrane fluidity, ion transport, and overall cellular resilience under training stress.

- Converts to γ-Linolenic Acid (GLA) → PGE_1–series eicosanoids, which help regulate localized post-exercise inflammatory tone, easing stiffness, soreness, and recovery discomfort.

Oleic Acid (OA):

- Activates PPARγ to blunt oxidative injury and downstream profibrotic TGF-β signaling in exercised muscle, supporting healthy remodeling rather than scarring.
- Facilitates myocellular glucose handling, improving insulin sensitivity and glucose–lipid partitioning during and after exercise to sustain output and accelerate recovery.

✓ *You L., Wang N., Cui X., Chen Y., Chen L., Zhang Y. (2020). The relationship between oleic acid intake and muscle strength in elderly adults: A cross-sectional study. Front Nutr, 7:606836.*

✓ *Li Y., Xu S., Zhang X., Yi Z., Cai Y., Shi Z., Han C. (2017). Linoleic acid ameliorates muscle damage by regulating oxidative stress and inflammation via the NF-κB and Nrf2 pathways. Food Funct, 8(10):3553–3563.*

4) Astaxanthin × Omega-3/6/9 Synergy Overview

"Mitochondrial Protection × Fat-Fuel Support × Anti-Inflammatory Recovery"

- a three-axis anti-fatigue platform

Dimension	Astaxanthin Mechanism	Omega-3/6/9 Synergistic Mechanisms
Oxidative	Suppresses exercise-induced ROS and	Alpha-Linolenic Acid (ALA)/EPA reinforce antioxidant lipid

Dimension	Astaxanthin Mechanism	Omega-3/6/9 Synergistic Mechanisms
Defense	post-training CK rise; preserves mitochondrial ultrastructure in working muscle.	membranes; Oleic Acid (OA) stabilizes mitochondrial phospholipid domains; Linoleic Acid (LA) supports repair of exercised sarcolemmal membrane lipids.
Lipid Fuel Support	Promotes greater reliance on fat oxidation during effort, sparing glycogen and extending endurance.	ALA activates PPAR-α to upshift β-oxidation; OA improves insulin sensitivity and substrate switching for efficient glucose-fat co-utilization.
Inflammation Recovery	Dampens exercise-triggered inflammatory mediators (IL-6, CRP), accelerating functional recovery.	ALA-derived Resolvins help terminate post-exercise inflammation; LA → PGE_1 modulates localized muscle soreness & microvascular tone; OA broad anti-inflammatory support helps preserve myofiber architecture.

5) Clinical Use Recommendations

Population	Rationale & Mechanistic Support
Regular exercisers / training & fitness populations	Boost mitochondrial energy throughput, reduce perceived and biochemical fatigue, and shorten inflammatory recovery windows between sessions.
Easily fatigued / sedentary & low-metabolic-flexibility individuals	Enhance β-oxidation capacity and lipid fuel availability; activate PPAR pathways to help re-entrain healthier metabolic rhythms when initiating activity programs.

Population	Rationale & Mechanistic Support
Older adults / sarcopenia or muscle-loss risk	Slow age-related declines in muscle mitochondrial function, support myocyte membrane integrity, and reinforce antioxidant defenses that protect against atrophy-driving oxidative damage.

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