



Lecture six – Theoretical
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Second: Stage
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Introduction to the General Biosynthesis
Pathway of Secondary Metabolites

What Are Secondary Metabolites?

Secondary metabolites are specialised compounds that, whilst not essential for basic survival, play crucial roles in plant defence and ecological interactions. These remarkable molecules include antibiotics, pigments, aromatic compounds, and protective toxins.

Unlike primary metabolites such as sugars and amino acids that support fundamental life processes, secondary metabolites enable plants to thrive in complex environmental conditions and fend off threats.





Why Are Secondary Metabolites Important?



Defence Mechanisms

Protect plants against herbivores, pathogens, and environmental stresses through chemical warfare and deterrent compounds.



Ecological Interactions

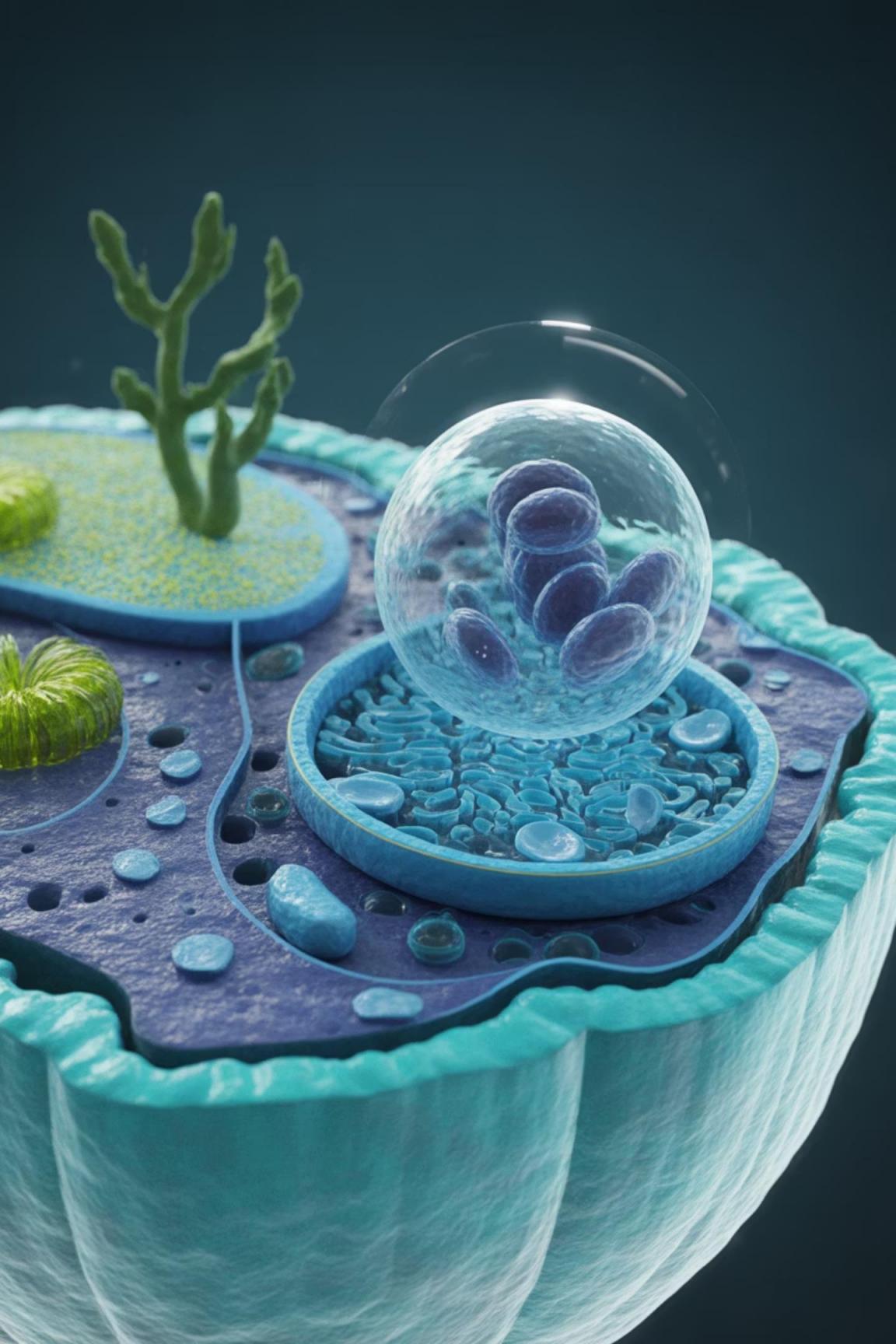
Attract pollinators and seed dispersers through vibrant colours and enticing scents that facilitate reproduction.

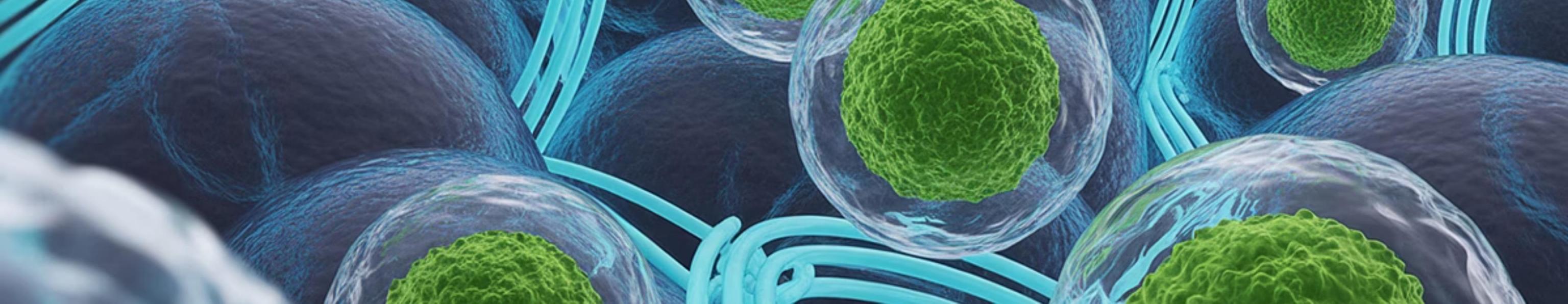


Human Applications

Provide invaluable resources for pharmaceuticals, agriculture, and industry—from life-saving medicines to natural pesticides.

Overview of Biosynthesis in Plants





Plants as Biosynthetic Factories

01

Simple Starting Materials

Plants begin with basic molecules like glucose derived from photosynthesis.

02

Enzyme-Catalysed Pathways

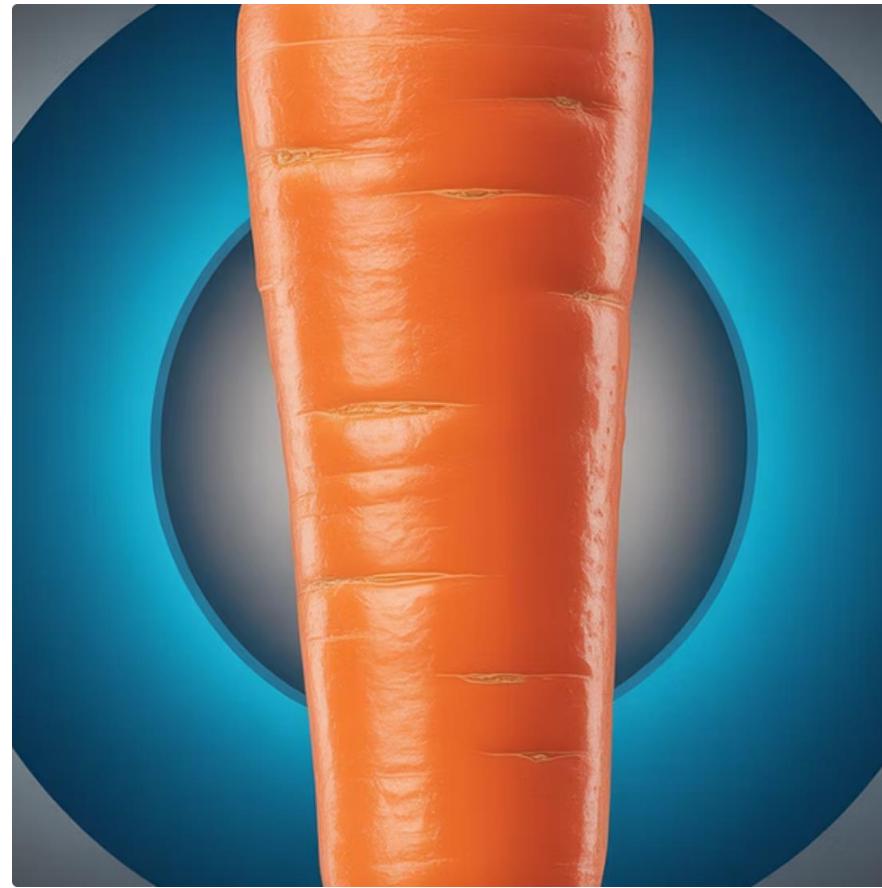
Sophisticated multi-step biochemical pathways orchestrated by specific enzymes transform precursors.

03

Complex Products

Primary metabolism provides essential precursors that feed into secondary metabolite production pathways.

Major Chemical Groups of Secondary Metabolites



Terpenoids

The largest class, encompassing over 40,000 compounds including carotenoids, steroids, and essential oils. Built from isoprene units.



Phenolics

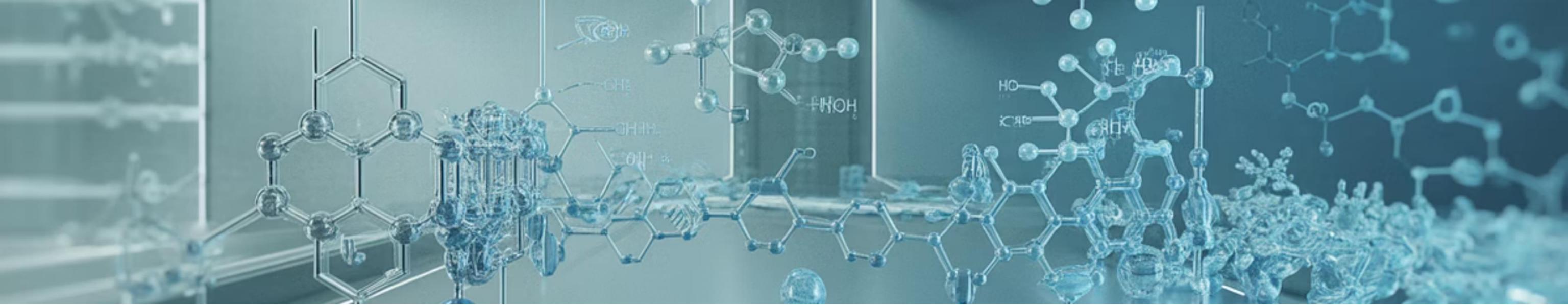
Aromatic compounds including flavonoids, tannins, and lignins that provide colour, astringency, and structural support.



Nitrogen-Containing Compounds

Alkaloids and other nitrogen-rich metabolites, often with potent pharmacological activities like morphine and caffeine.

The Main Biosynthetic Pathways



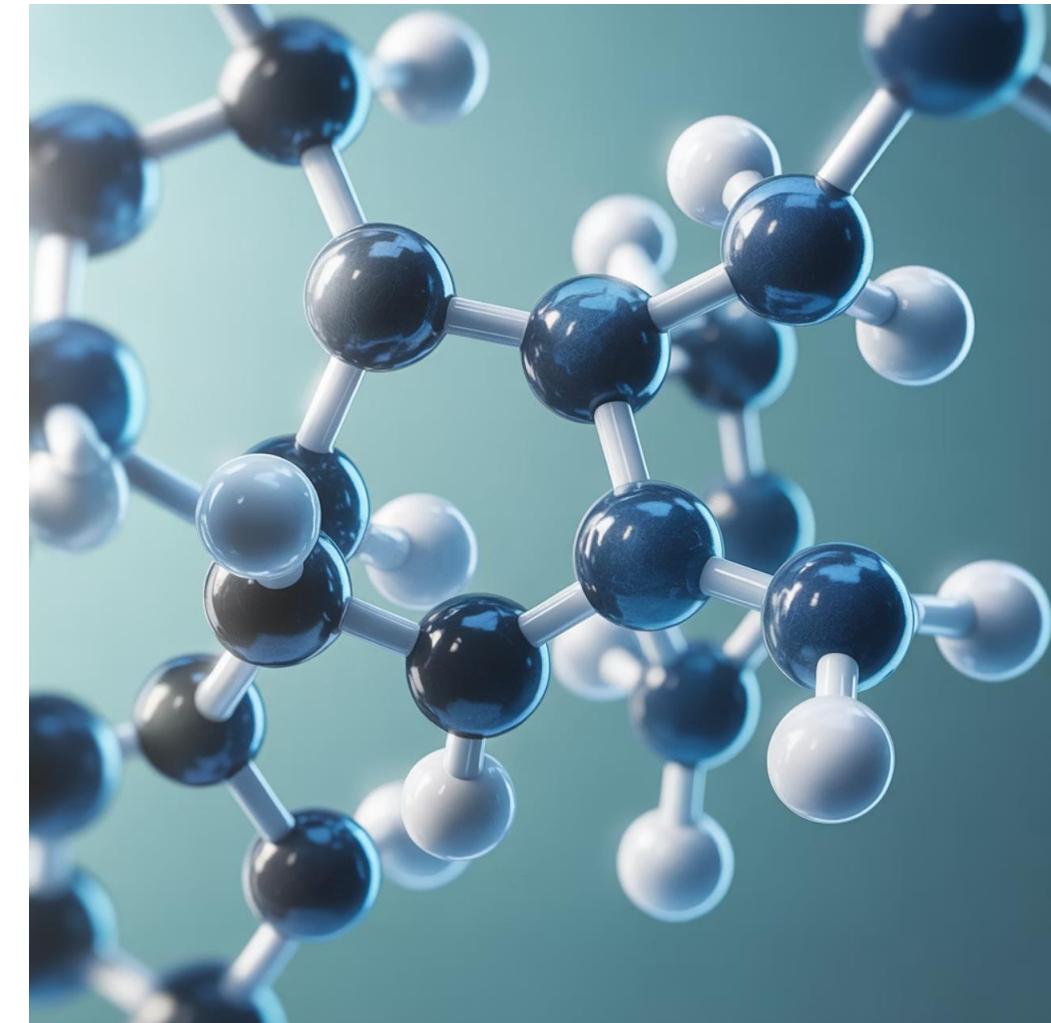
The Shikimic Acid Pathway

This fundamental pathway converts erythrose-4-phosphate and phosphoenolpyruvate—simple carbohydrate derivatives—into aromatic amino acids. It serves as the gateway to thousands of phenolic compounds, alkaloids, and other aromatic secondary metabolites.

Key Enzymes

- 3-dehydroquinate synthase
- Shikimate kinase
- Chorismate synthase

These enzymes work sequentially to build the aromatic ring structures that form the backbone of numerous plant defence compounds and signalling molecules.



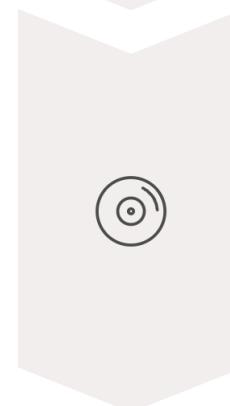


The Acetate-Mevalonate Pathway



Acetyl-CoA Starting Point

The pathway begins with this universal metabolic building block.



IPP and DMAPP Formation

Produces isopentenyl pyrophosphate (IPP) and dimethylallyl pyrophosphate (DMAPP)—the universal five-carbon building blocks.



Terpene Construction

Assembles monoterpenes (C₁₀), sesquiterpenes (C₁₅), diterpenes (C₂₀), and triterpenes (C₃₀) through sequential addition of isoprene units.

The Acetate-Malonate Pathway



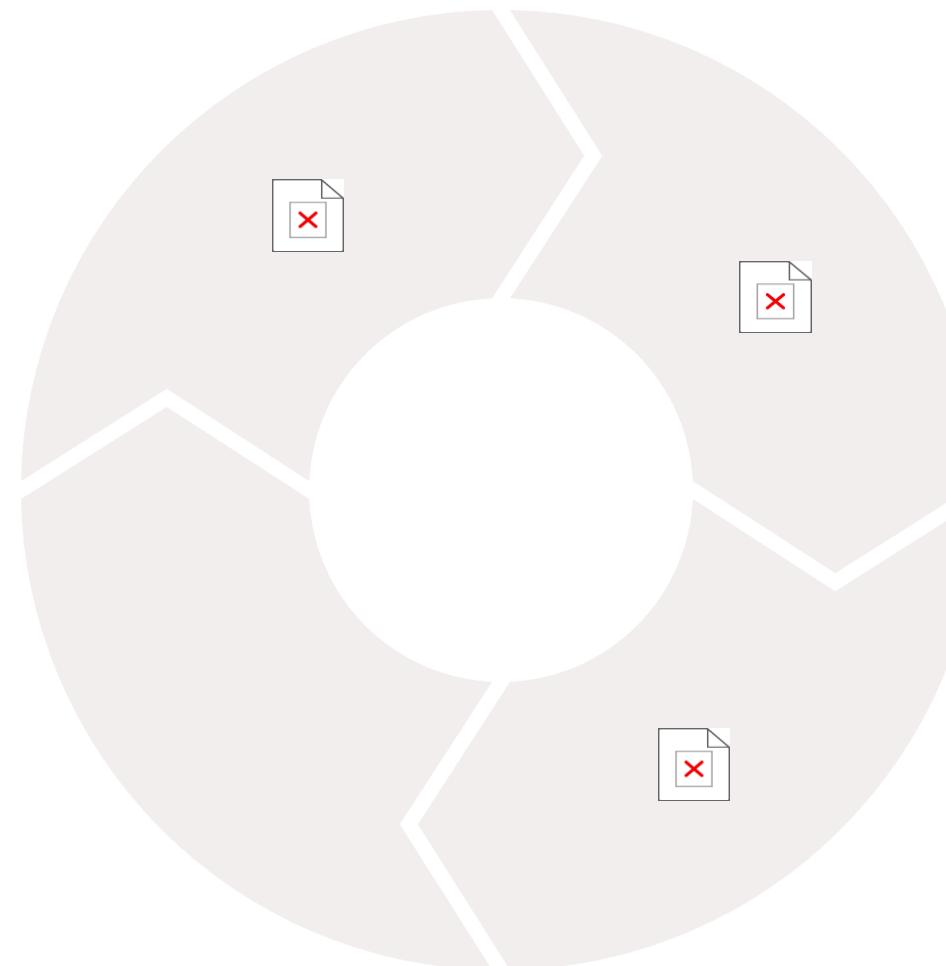
This pathway employs malonyl-CoA and acetyl-CoA as fundamental building blocks to construct fatty acid-derived metabolites. Through iterative condensation reactions, it produces complex polyketides and phenolic compounds.

Major Products

- **Polyketides with diverse biological activities**
- **Flavonoids providing colour and antioxidant properties**
- **Other phenolic compounds for plant defence**

The pathway's versatility enables production of structurally diverse metabolites through variations in chain length and cyclisation patterns.

Amino Acid Derived Pathways



Glutamine

Nitrogen donor for numerous alkaloid biosynthetic routes.

Ornithine

Precursor to tropane alkaloids like atropine and cocaine.

Tryptophan

Generates indole alkaloids with diverse pharmacological effects.

Tyrosine

Source of benzylisoquinoline alkaloids including morphine.

These amino acid-derived pathways produce nitrogen-containing secondary metabolites, particularly alkaloids, which often exhibit potent biological activities and serve as valuable pharmaceuticals.



Integration and Regulation

Interconnection with Primary Metabolism

Metabolic Branch Points

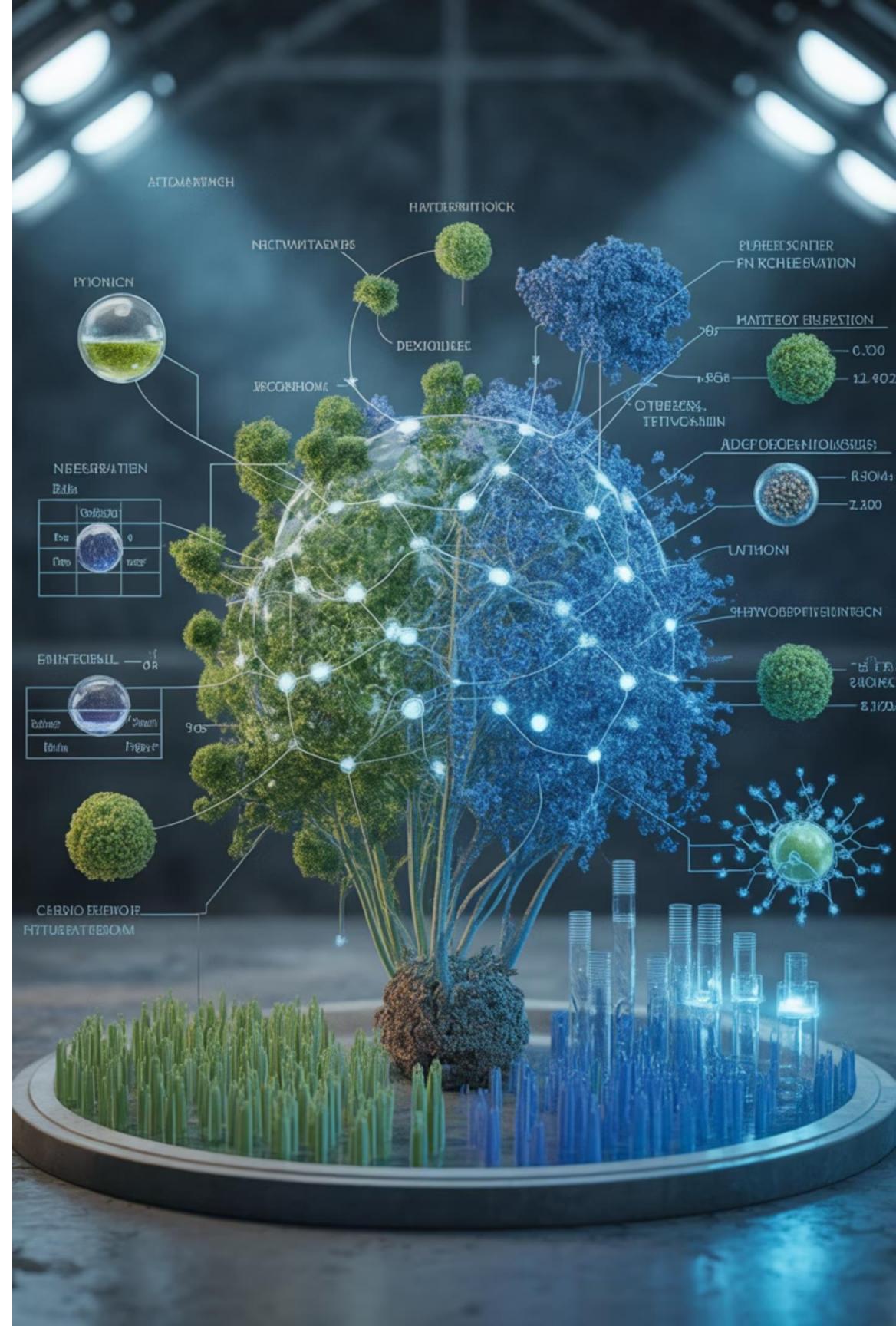
Secondary metabolite pathways strategically branch from primary metabolic intermediates, ensuring efficient resource allocation between growth and defence.

Developmental Regulation

Production depends on plant developmental stage, tissue type, and circadian rhythms, with expression patterns tightly coordinated with growth needs.

Environmental Response

Elicitor molecules—signals of stress or pathogen attack—can dramatically enhance production, activating defence-related biosynthetic cascades within hours.



Ecological and Industrial Significance

Ecological Roles

Secondary metabolites mediate crucial plant-environment interactions, from chemical warfare against herbivores to symbiotic relationships with beneficial microorganisms. They shape entire ecosystems through allelopathy and species interactions.



Industrial Applications

These compounds provide life-saving medicines (morphine, aspirin, taxol), natural flavours and fragrances, eco-friendly pesticides, and industrial chemicals. Biotechnological advances in metabolic engineering aim to sustainably increase production whilst reducing environmental impact.





Conclusion: The Power of Plant Secondary Metabolism

Vital for Survival

Secondary metabolites are indispensable for plant survival in competitive ecosystems and provide invaluable resources for human societies.

Pathway Understanding

Understanding biosynthetic pathways enables innovation in agriculture, medicine, and sustainable chemistry through targeted metabolic engineering.

Future Directions

Future research focuses on sustainable production methods, synthetic biology approaches, and discovering novel metabolites with unprecedented applications.

The intricate biosynthetic pathways of secondary metabolites represent millions of years of evolutionary refinement—a chemical library that continues to inspire scientific discovery and technological innovation.

Question:

Research a common medicinal plant in Iraq and write a short paragraph (5–6 lines) that includes:

Its main secondary metabolites

Its medical uses

How it protects itself from the environment using these compounds





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