



ASHOKA INSTITUTE OF TECHNOLOGY & MANAGEMENT

DEPARTMENT OF PHARMACY

Ashoka Engineering Chauraha, Paharia, Sarnath, Varanasi

Name Of Unit	Metabolic Pathways in Higher Plants and Their Determination
Subject /Course	Pharmacognosy and Photochemistry-II
Subject/Course ID	BP 504T
Class: B.Pharm.	Semester 5th
Course Coordinator	Mr. Anubhav Gupta

Learning Outcome

To outline the metabolic pathway in higher plants and their biogenetic studies.

Module Content Topic

- The basic metabolic pathways producing secondary metabolites .
- Shikimic acid pathway
- Shikimic acid pathway produced secondary metabolites .
- The Acetate (acetate-malonate) pathway producing Fatty acids .
- The Acetate-Mevalonate (Isoprenoid) pathway
- The Acetate-Mevalonate (Isoprenoid) pathway produced secondary metabolites .
- The Amino acid Pathway
- Radioactive isotopes in the investigation of biogenetic studies- Tracer techniques .

UNIT 01 METABOLIC PATHWAYS IN HIGHER PLANTS AND THEIR DETERMINATION

INTRODUCTION

Higher Plants:

The plants which are fully developed and have vascular tissues (with veins) to distribute resources throughout them are called Higher plants or vascular plants.

Metabolism:

The sum of all the enzyme mediated reactions occurring in the cell is collectively called as **metabolism**.

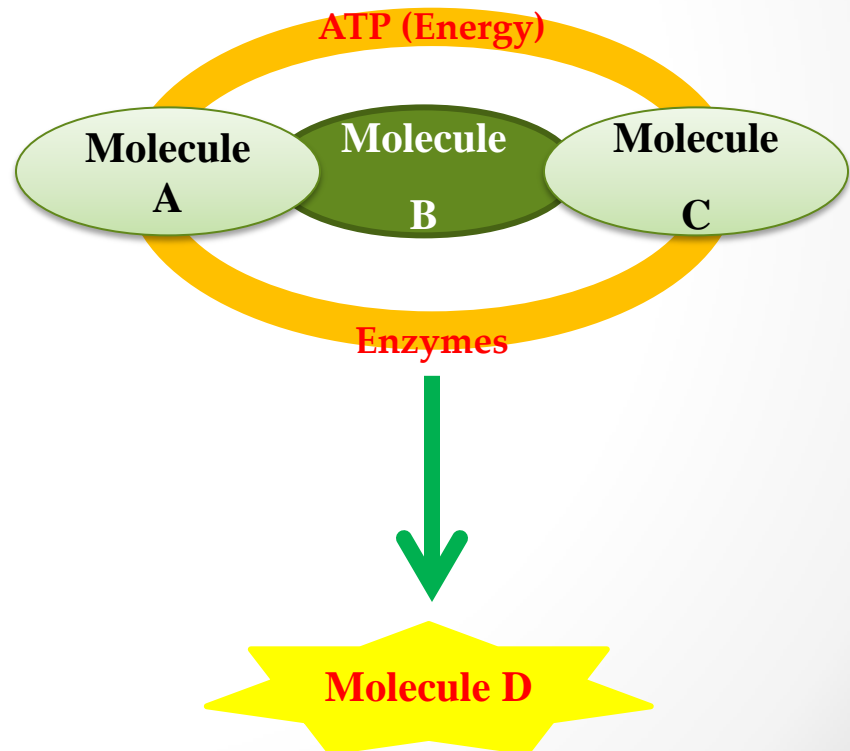
Biosynthesis:

It is the process of conversion of large organic compound from smaller subunits within a living organisms with the help of enzymes.

Biosynthesis can also be called as anabolism, since simple compounds are joined together to form macromolecule or complex chemicals by enzymes.

e.g.,

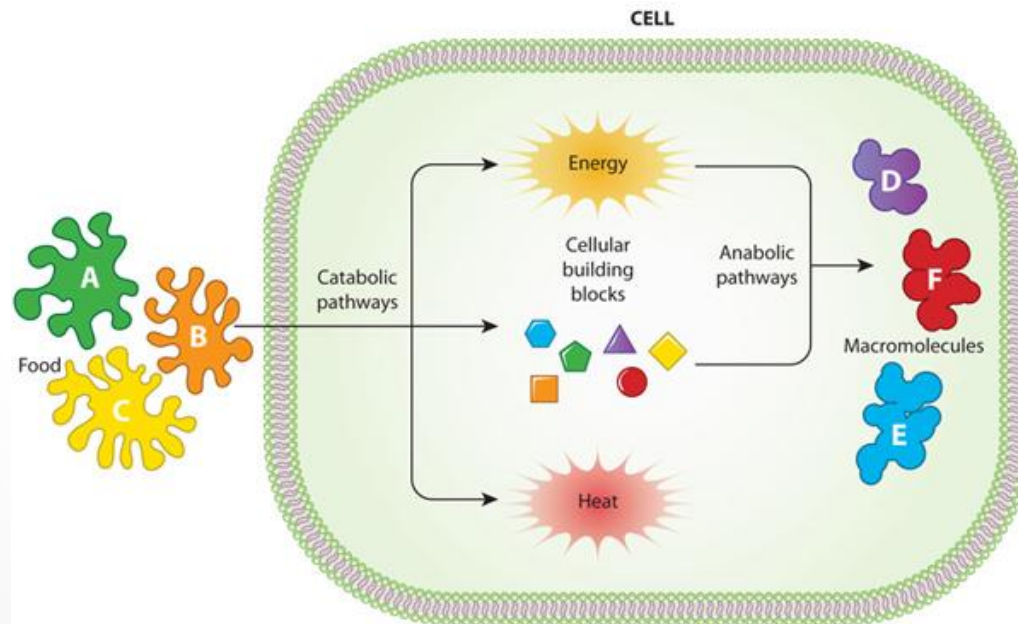
- i. Bone development
- ii. Mineralization
- iii. Muscle Gain
- iv. Formation of Glucose from CO₂.



Metabolic Pathways:

The sequential reactions occurring inside any organisms in an particular order and regulated way are known as metabolic pathways, and the compound formed during the process is called **Metabolite**.

During the process of metabolism many intermediate metabolites are formed which is used to denote the chemical pathway of metabolism.



Functions of Metabolism:

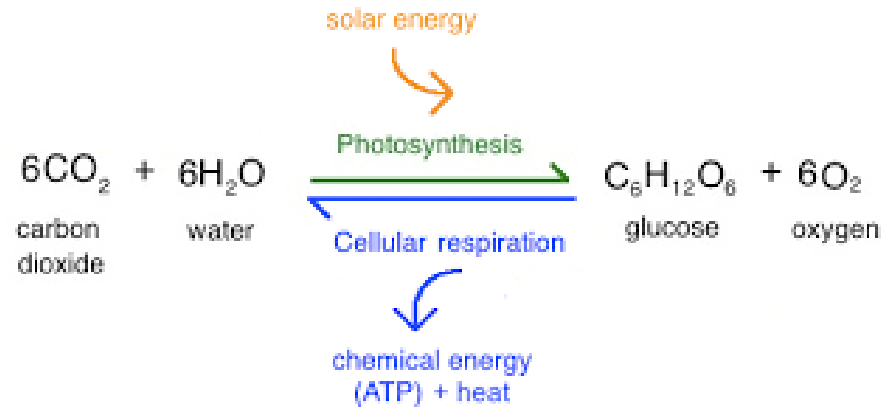
- Gives energy (ATP) by degradation of energy rich biomolecules.
- To combine building blocks into proteins, nucleic acids lipids and various cellular components.
- Transforms biomolecules building blocks or precursors needed for the synthesis of macromolecules.
- Forms and degrade biomolecules required in specialized cells.

Types of Metabolites

Primary Metabolites	Secondary Metabolites
They are the basic plant constituents like sugars, amino acids, coenzyme A, Mevalonic acid and lipids.	They are big synthesized from the primary metabolites like alkaloids, glycosides, tannins, flavonoids, terpenoids volatile oils.
They are widely distributed in plants in large quantities at most smallest cellular levels.	They are more limited distribution, restricted taxonomic group.
Directly involved in growth, development and reproduction.	Aren't directly involved in growth & development.
Not expensive to isolate them from plants.	Have pharmacological action on humans.
Starch from potato is easy to isolate while quinine from Cinchona is tougher task.	Serve as defensive and protective chemicals against predators and stress.
	Expensive to isolate.

Basic Metabolic Pathway

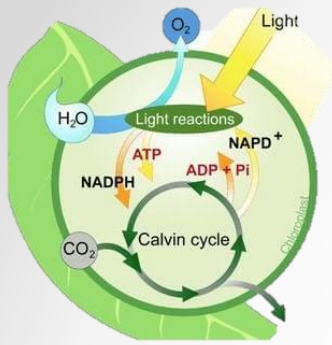
Basic metabolic pathways detail the formation or biosynthesis of mandatory plant metabolites from very basic unit in the plants i.e. photosynthesis.



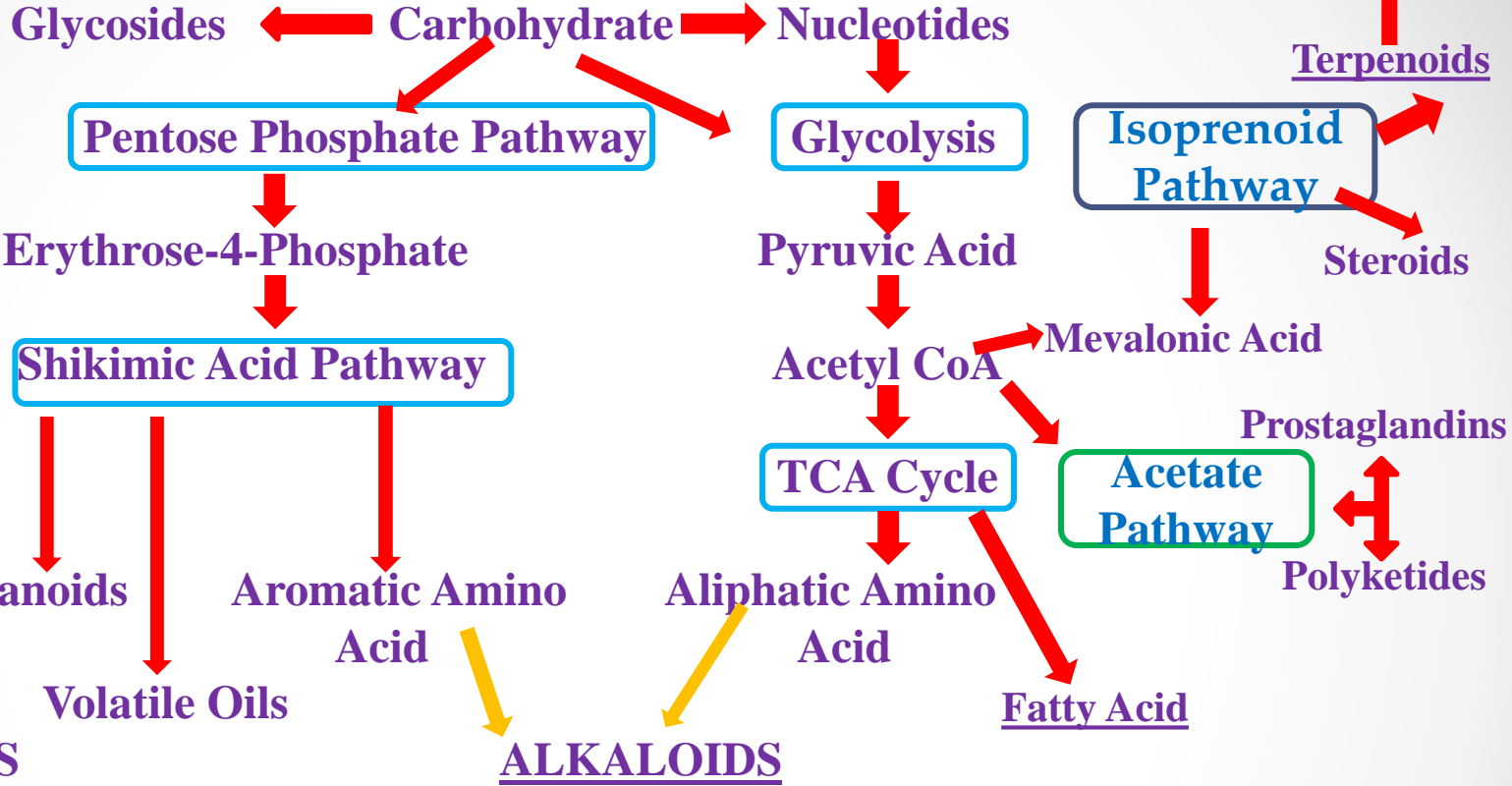
The important building blocks used in biosynthesis of secondary metabolites are derived from intermediates like:-

- Acetyl coenzyme A (acetyl - Co A) (Acetate Pathway)
- Shikimic Acid (Shikimate Pathway)
- Mevalonic Acid (mevalonate Pathway)
- 1- deoxy xylulose 5-phosphate (Deoxyxylulose Phosphate Pathway)

- Some amino acids also contribute into natural product synthesis. e.g., synthesis of various hormones.
- Plants take water and air (CO₂) from nature and through photosynthesis with the help of sunlight manufacture carbohydrates.
- From carbohydrates other plant primary metabolites are synthesized by them like sugars, amino-acids, fatty acids.
- These essential amino acids build up the larger constituents in plants while humans take them from their diet.
- Now, other secondary metabolites are synthesized from primary ones through their respective pathways



PHOTOSYNTHESIS

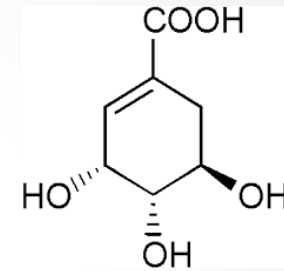


- ✓ COUMARINS
- ✓ LIGNINS
- ✓ FLAVONOIDS
- ✓ TANNINS

SHIKIMIC ACID PATHWAY

➤ It is a metabolic pathway for biosynthesis of aromatic amino acid.

1. Phenylalanine
2. Tyrosine
3. Tryptophan



➤ `The Shikimic Acid Pathway converts simple carbohydrate precursors derived from glycolysis & the pentose phosphate pathway into aromatic amino acid.`

➤ Shikimic acid is a cyclitol and a cyclohexane derivative of carboxylic acid.

➤ **Shikimic acid** is a key intermediate from carbohydrates for the synthesis of C_6-C_3 phenyl-propane derivatives.

➤ Shikimic acid is also the part of hydrolysable tannins.

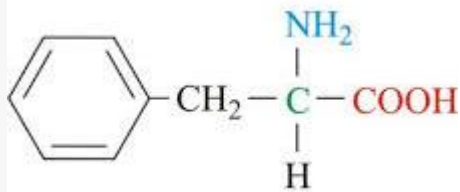
➤ The name `Shikimic Acid` comes from Japanese flower **Shikimi** (Star-anise, *Illicium anisatum*) from which it was first isolated in **1885** by John Frederick Ekyman.

➤ It occurs in plant, animals & fungi but not in animal.

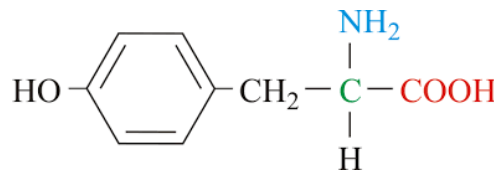


SHIKIMIC ACID PATHWAY

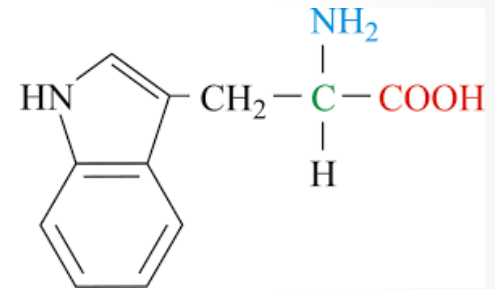
- **The Shikimate Pathway (shikimic acid pathway)** is a seven-step metabolic pathway used by bacteria, archaea, fungi, algae, some protozoans, and plants for the biosynthesis of folates and aromatic amino acids (phenylalanine, tyrosine, and tryptophan).



Phenylalanine



Tyrosine



Tryptophan

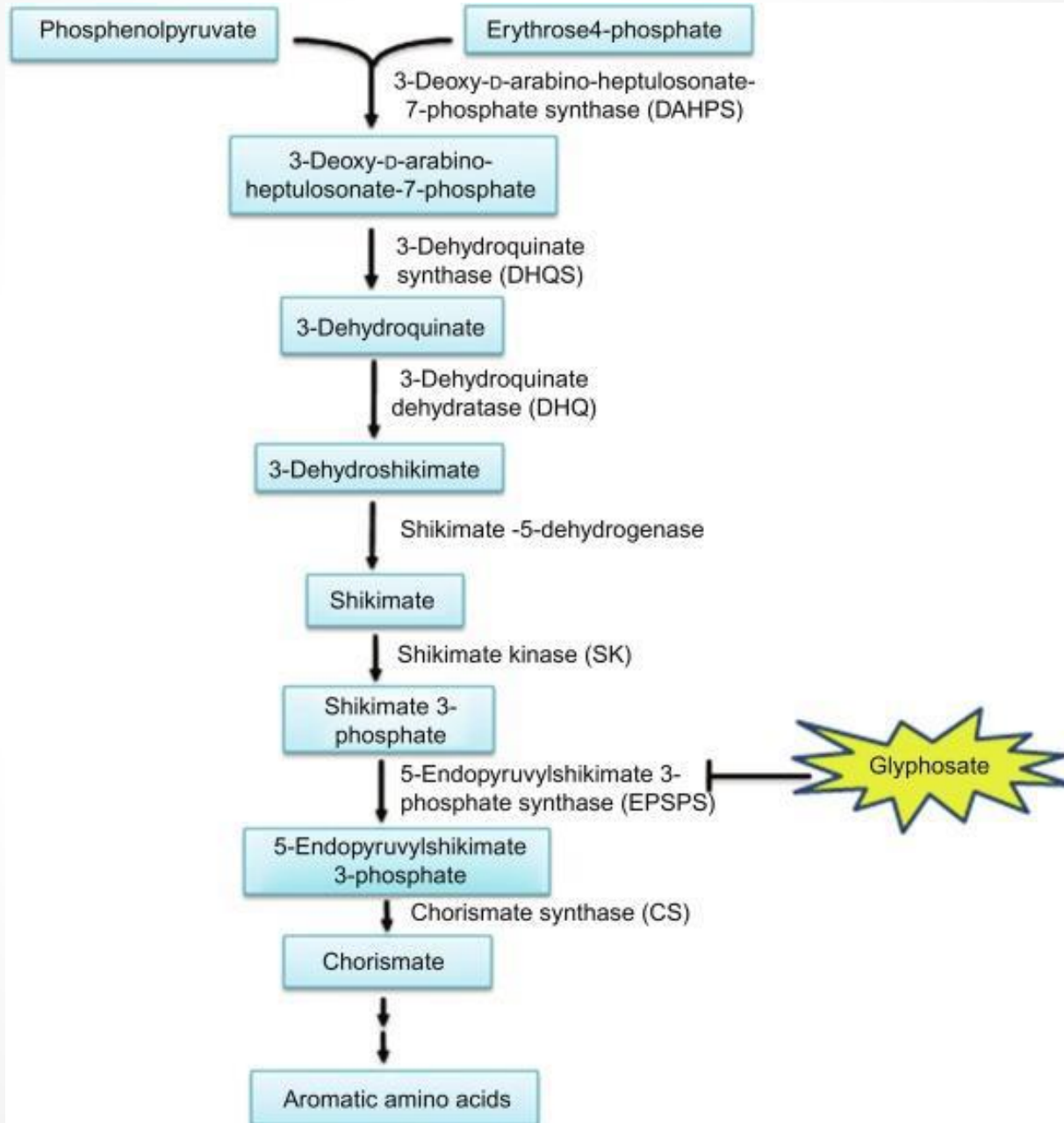
- The pathway starts with two substrates:

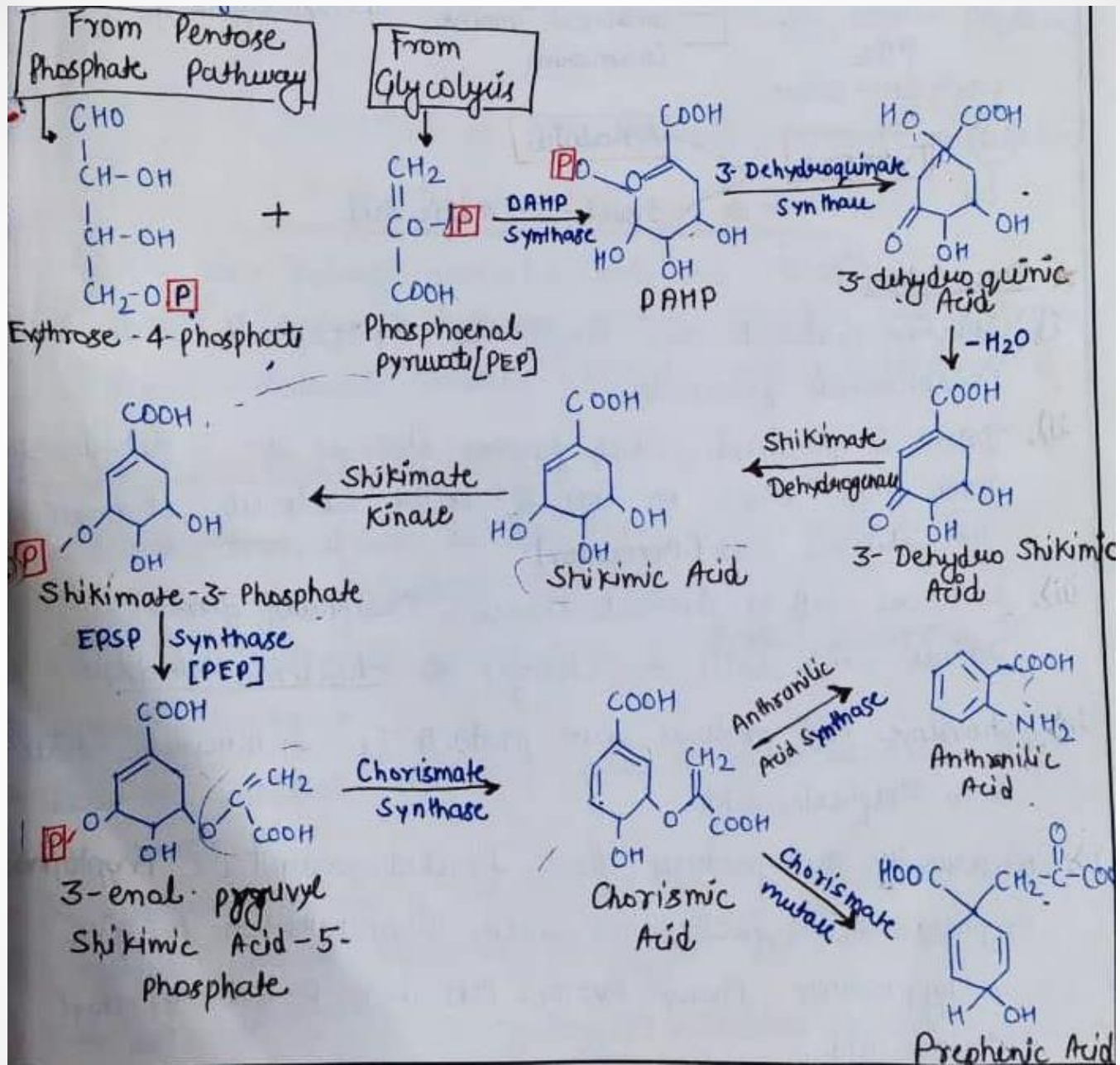
Phosphoenol pyruvate and

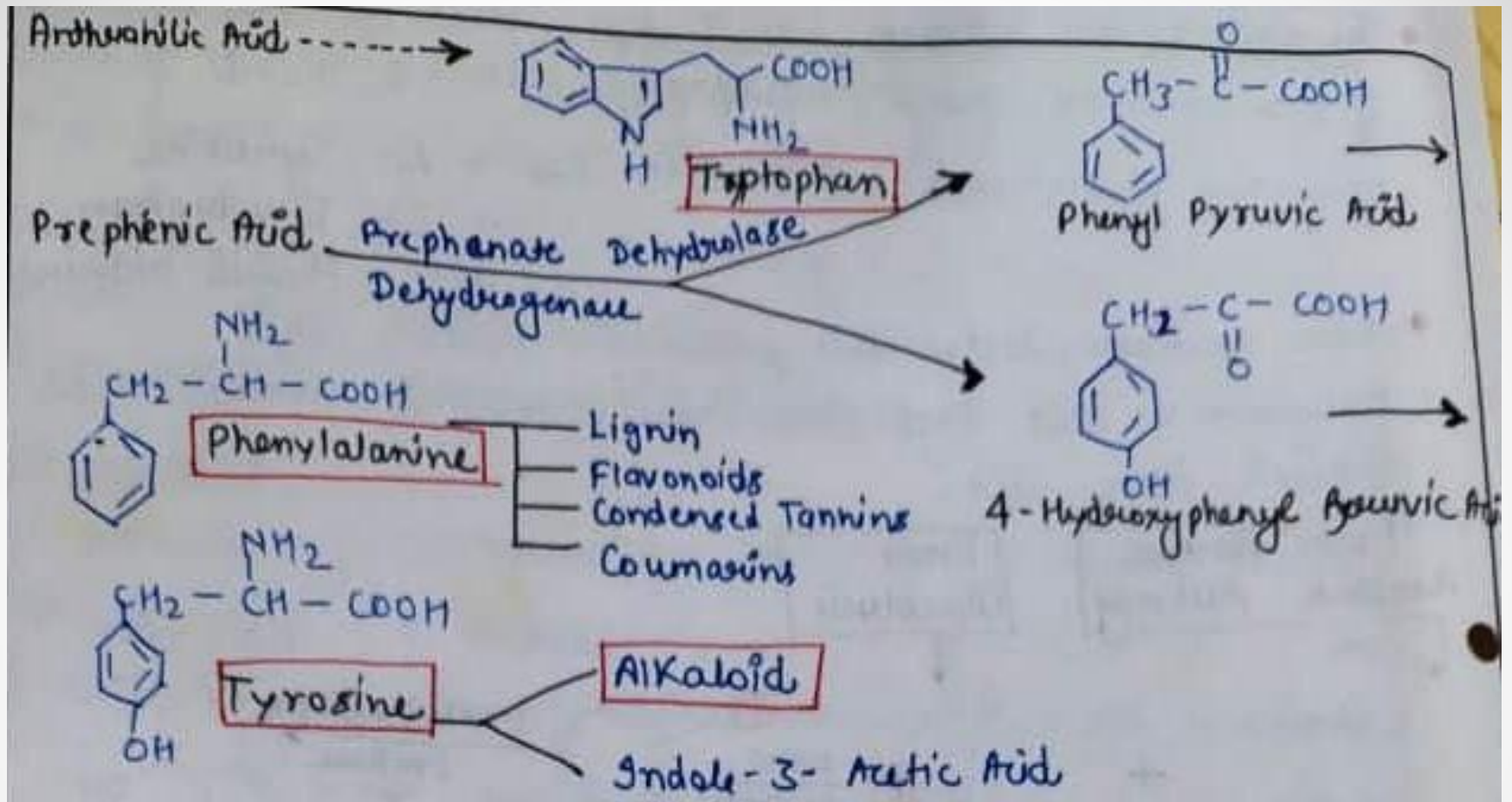
Erythrose-4-phosphate

- It ends with **chorismate**, a substrate for the three aromatic amino acids.

SHIKIMIC ACID PATHWAY







Note:

1. $\text{P} = \text{PO}_3\text{H}$ = Phosphate Group
2. DAHP = 3-Deoxy D-arabino-heptulosonic acid-7-phosphate

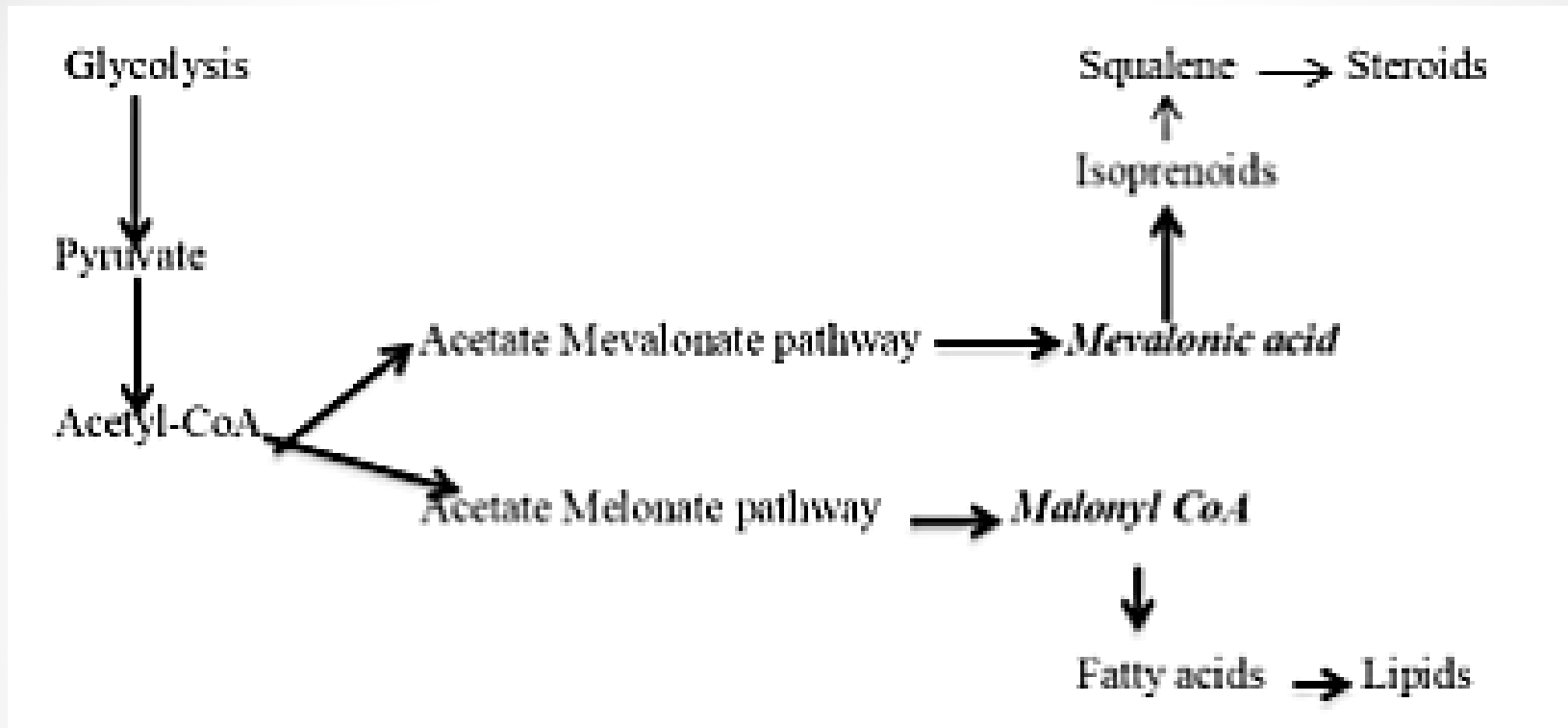
ACETATE PATHWAY(S)

There are two pathways associated with the Acetate.

- i) **Acetate - Mevalonate Pathway (Isoprenoid Pathway)** produces **Steroids and Terpenoids**.
- ii) **Acetate - Malonate Pathway** produce **Fatty acid and Thioesters**.

- ❖ **Terpenoids** are oxygenated derivatives of combination of isoprene units, also called as isoprenoids.
- ❖ Isoprene unit are composed of C₅H₈ hydrocarbon molecules.
- ❖ Terpenoids when attached to protein are called **steroids or sterols**.
- ❖ **Fatty acids** can be defined as **carboxylic acids with long aliphatic chains** that can be saturated or unsaturated, **eg.**, Oleic Acid, Linoleic Acid, Stearic Acid.
- ❖ **Thioester** is defined as a reactive compound formed by the conjugation of a fatty acid with a free SH group.

ACETATE PATHWAY(S)



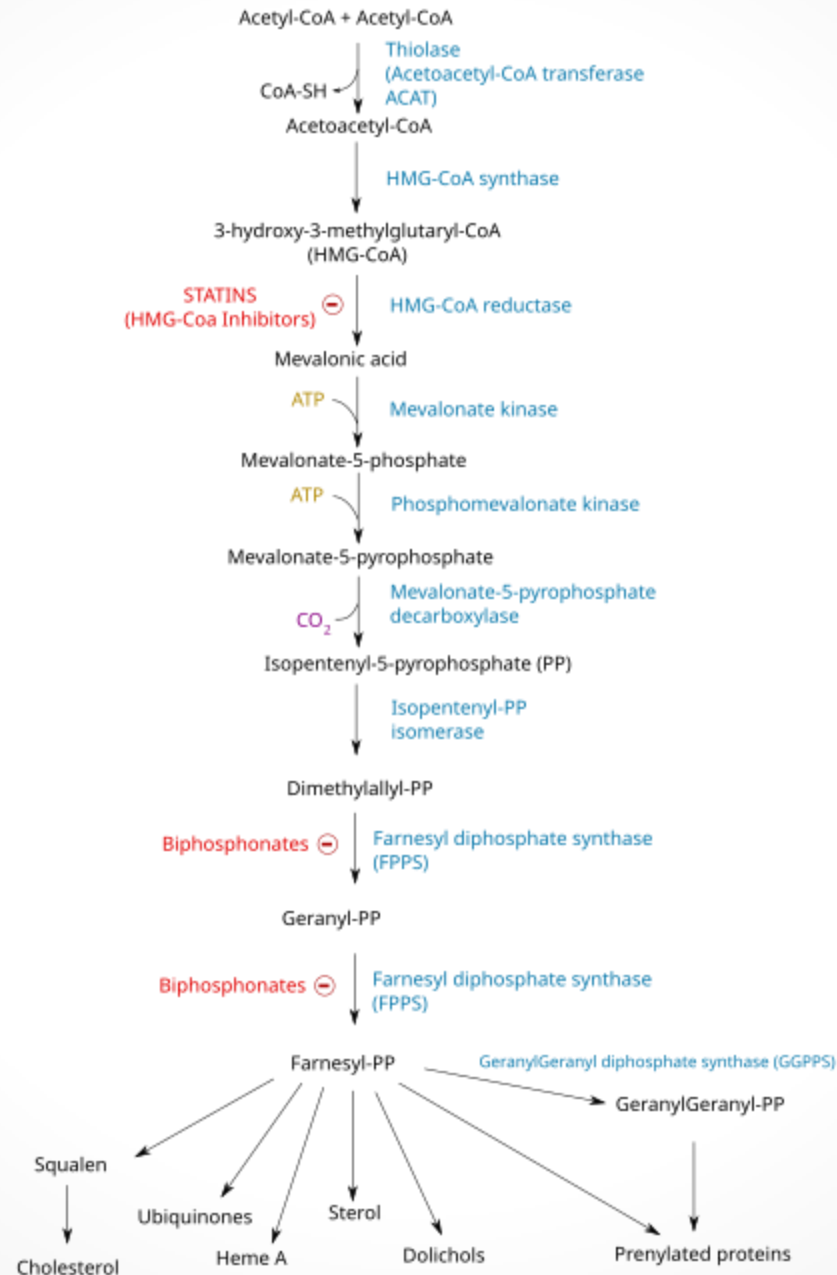
ACETATE MEVALONATE PATHWAY (Isoprenoid Pathway)

- Earlier, it was believed that acetic acid is involved in synthesis of cholesterol, squalene and rubber like compounds, which was supported by discovery of Acetyl Coenzyme A in biogenetic pathways.
- Later on mevalonic acid was found to be associated with the output.
- This pathway is utilized in the biosynthesis of essential secondary metabolites such as isoprenoids (terpenoids) and steroids.
- This pathway is found in eukaryotes, archaebacterias and other.
- In this pathway, two most important 5 carbon compound is produced, called **3-Isopentenyl Pyrophosphate (IPP)** and **Dimethyl Allyl Pyrophosphate (DMAPP)** respectively.
- IPP and DMAPP via squalene produce two different skeleton containing compounds that is steroid and Triterpenoids.

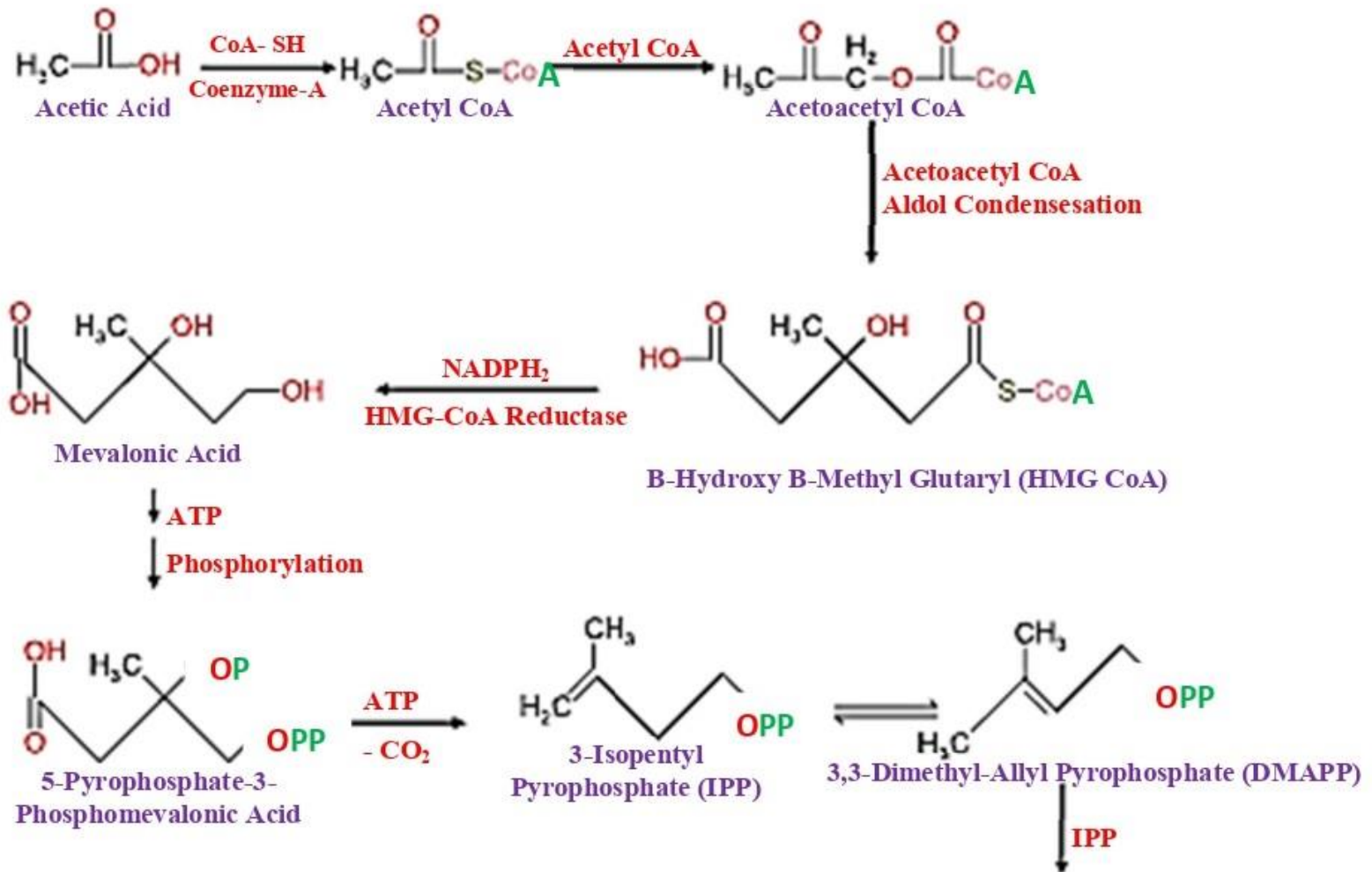
ACETATE MEVALONATE PATHWAY (Isoprenoid Pathway)

- It also produce vast range of monoterpenoids, sesquiterpenoids, diterpenoids, carotenoids, polyprenols etc.
- Pathway begins with **acetyl CoA** molecule produced from pyruvic acid, which is the end product of glycolysis.
- First two molecules of Acetyl CoA forms Acetoacetyl CoA through Claisen condensation.
- 3rd molecule of acetyl CoA forms β hydroxy β methyl glutaryl CoA by aldol condensation.
- Next on reduction gives it to mevalonic acid, which is the main precursor of terpenoid biosynthesis.

ACETATE MEVALONATE PATHWAY (Isoprenoid Pathway)

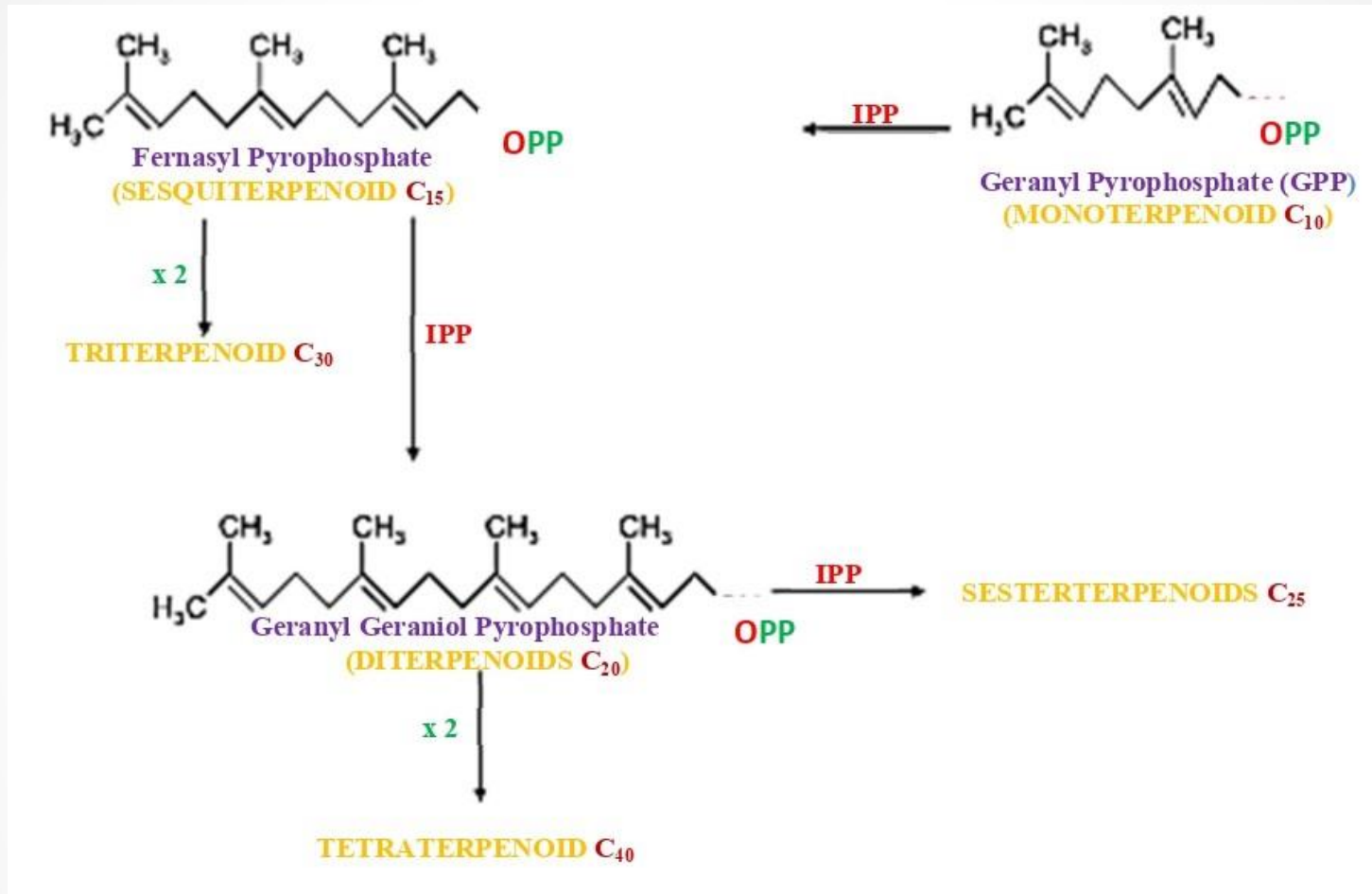


ACETATE MEVALONATE PATHWAY (Isoprenoid Pathway)



Structural representation of Acetate Mevalonate Pathway

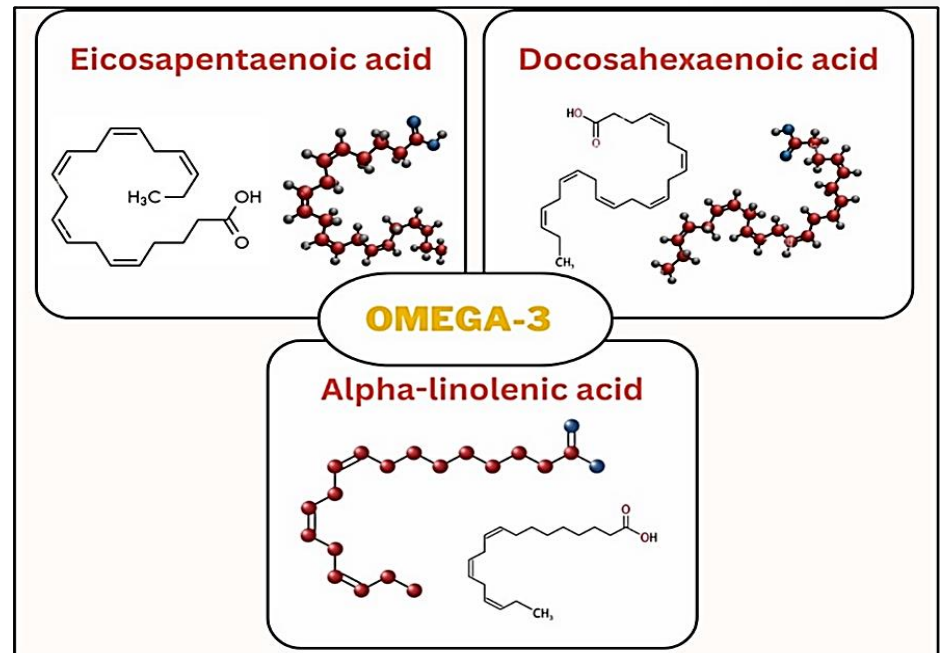
ACETATE MEVALONATE PATHWAY (Isoprenoid Pathway)



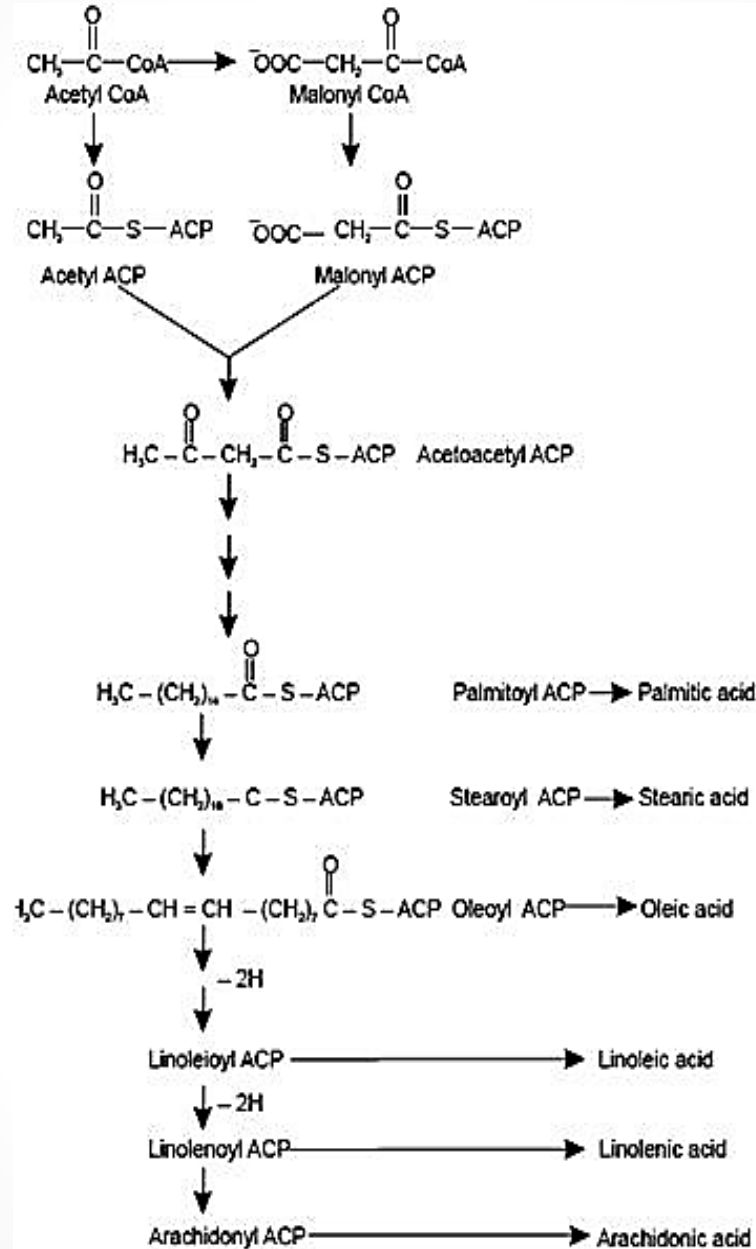
Structural representation of Acetate Mevalonate Pathway

ACETATE MALONATE PATHWAY (Polyketide Pathway)

- Acetate-Malonate pathway includes synthesis of fatty acids and aromatic compounds with the help of secondary metabolites.
- Main precursors of Acetate-Malonate Pathway are **Acetyl-CoA** and **Malonyl-CoA**.
- End product of this pathway can be saturated or unsaturated fatty acids or polyketides, hence also known as **polyketide pathway**.
- Acetate pathway operates with the involvement of **acyl carrier protein** to yield fatty acyl thioesters of ACP.
- These acyl thioesters forms the important intermediates in fatty acid synthesis.



ACETATE MALONATE PATHWAY (Polyketide Pathway)



Structural representation of Acetate Malonate Pathway

AMINO ACID PATHWAY

- Amino acids are organic compounds that contain both amino (-NH₂) and carboxylic group (-COOH).
- There are too many amino acids in nature but only α -amino acids comprise proteins.
- There are 20 amino acids in the genetic code.
- Plants and bacteria can synthesize almost 20 amino acids but mammals (including humans) lack this tendency. Humans can't synthesize 9 amino acids.
- These 9 amino acids which humans cannot synthesize are termed as essential amino acids. These amino acids come from their diet.
- The non-essential amino acids (11) are synthesized by simple pathways, whereas biosynthesis of essential amino acids are complex.
- Nitrogen atom in the amino acid enters in this pathway by glutamate and glutamine.

- All amino acids are derived from intermediates in glycolysis, citric acid cycle, and pentose phosphate pathway.
- The 3 aromatic amino acids (L-tyrosine, L-tryptophan, L-phenylalanine) come from shikimic acid pathway.

AMINO ACIDS

ESSENTIAL

Can't be created by the body & have to be consumed

- Tryptophan
- phenylalanine
- Methionine
- leucine
- valine
- Threonine
- histidine
- lysine
- isoleucine

Branched chain amino acids (BCaa's)

Make up 35% of the essential aa's in muscles

NON-ESSENTIAL

Can be created by the body From Essential amino acids

- Tyrosine
- proline
- glutamic acid
- alanine
- aspartic acid
- arginine
- serine
- glycine
- cysteine
- ornithine
- asparagine



EXAMPLES OF VEGAN ESSENTIAL AMINO ACID SOURCES



Spirulina



Oatmeal



Beans



Chia Seeds



Broccoli



Nut Butters



Hemp Seeds



Quinoa



Nuts

BIOSYNTHESIS OF AMINO ACID

