Levitsky A. P., Selivanskaya I. A. Biosynthetic classification of flavanoids (vitamins P). Journal of Education, Health and Sport. 2026;90:72374. eISSN 2391-8306.
https://dx.doi.org/10.12775/JEHS.2026.90.72374
https://apcz.umk.pl/JEHS/article/view/72374
https://zenodo.org/records/20341068

The journal has had 40 points in Minister of Science and Higher Education of Poland parametric evaluation. Annex to the announcement of the Minister of Education and Science of 05.01.2024 No. 32318. Has a Journal's Unique Identifier: 201159. Scientific disciplines assigned: Physical culture sciences (Field of medical and health sciences);
Health Sciences (Field of medical and health sciences). Punkty Ministerialne 40 punktów. Załącznik do komunikatu Ministra Nauki i Szkolnictwa Wyższego z dnia 05.01.2024 Lp. 32318. Posiada Unikatowy Identyfikator Czasopisma: 201159. Przypisane dyscypliny naukowe: Nauki o kulturze fizycznej (Dziedzina nauk medycznych i nauk o zdrowiu); Nauki o zdrowiu (Dziedzina nauk medycznych i nauk o zdrowiu).
The authors declare that there is no conflict of interests regarding the publication of this paper.
Received: 07.04.2026. Revised: 10.04.2026. Accepted: 20.04.2026. Published: 30.04.2026.

UDC 577.16+615.07+616.3+616.08+612.3

BIOSYNTHETIC CLASSIFICATION OF FLAVANOIDS (VITAMINS P)

A. P. Levitsky[1], I. A. Selivanskaya[2]

[1]Odessa National Technological University, Odessa, Ukraine
[2]Odessa National Medical University, Odessa, Ukraine
irina.selivanskaya@gmail.com

Abstract

Annotation

The vast number of compounds based on the three-membered flavan ring and possessing vitamin P activity requires a specific systematization of flavanoids. Existing classifications, unfortunately, do not take into account the full diversity of these compounds, including their biogenesis.

We have proposed a classification of flavonoids with P-vitamin activity that takes into account their biosynthesis and interconversions. This so-called biosynthetic classification divides all flavonoids into 11 classes: 1 – chalcones, 2 – flavanones, 3 – flavanols, 4 – flavones, 5 – isoflavones, 6 – dihydroflavanol, 7 – flavon-3-ols, 8 – flavandiols (leucoanthocyanidins), 9 – anthocyanidins, 10 – flavan-lignans, 11 – atypical and modified flavanoids.

Key words: flavonoids; vitamin P; biogenesis; classification.

Vitamin P was discovered by Hungarian biochemist Albert Szent-Györgyi in 1936 [1, 2]. While studying the therapeutic effects of vitamin C (ascorbic acid) in experimental scurvy, he discovered the ability of flavanoid compounds to significantly enhance the therapeutic activity of vitamin C. Therapeutic efficacy was assessed by its ability to reduce bleeding, that is, to decrease the permeability of the histo-hematic barriers.

Numerous studies conducted over several decades in various countries [3-6] have demonstrated the presence of vitamin P activity in virtually all compounds based on the three-membered flavan ring (Fig. 1). All flavan-containing compounds are often referred to as bioflavonoids [7]. It has been established that the spectrum of biological action of flavanoids is significantly broader than their effect on capillary permeability. All flavanoids possess antioxidant properties [8-10], exhibit antimicrobial activity [11], and have an anti-inflammatory effect [12, 13].

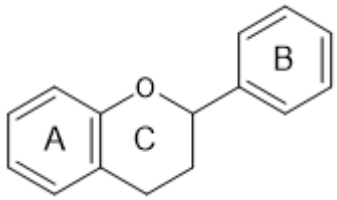
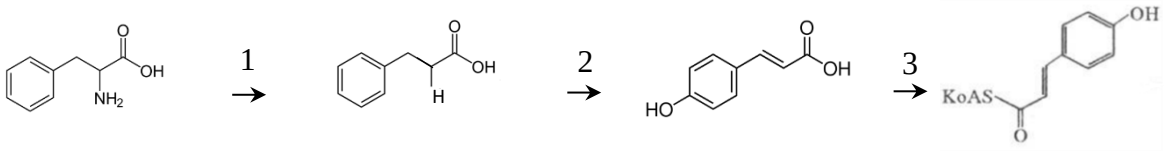


Fig. 1. Flavan

Based on modern concepts of flavanoid biogenesis in plant organisms [14-18], we present a list of biosynthetic reactions that determine the appearance of certain forms of flavanoids.

Stages of flavanoid biosynthesis

I. *Preflavanoid stage*



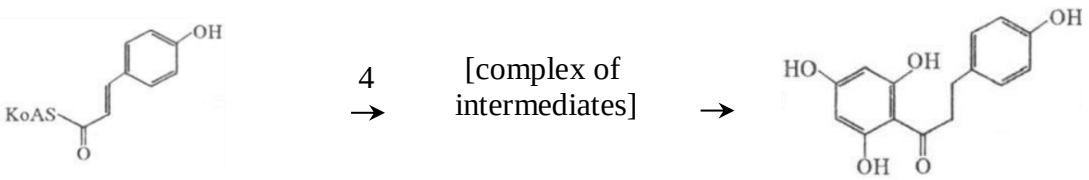
phenylalanine cinnamic acid p-coumaric acid p-coumaryl-CoA

1 – phenylalanine ammiak lyase

2 – cinnamate-4-hydroxylase

3 – 4-coumarate-CoA ligase

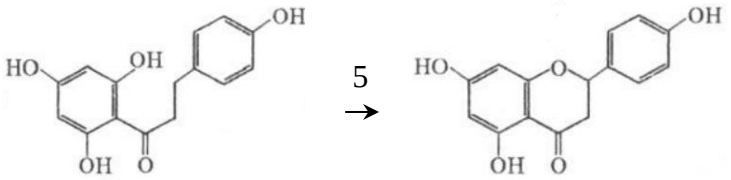
II. *Chalcone biosynthesis stage*



p-coumaryl-CoA naringenin chalcone

4 – chalcone synthase

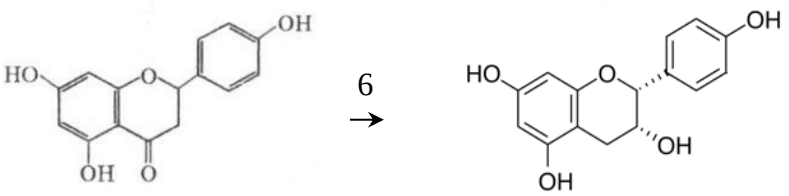
III. *Stage of flavanone biosynthesis*



naringenin chalcone flavan-one

5 – chalcone dehydrogenase

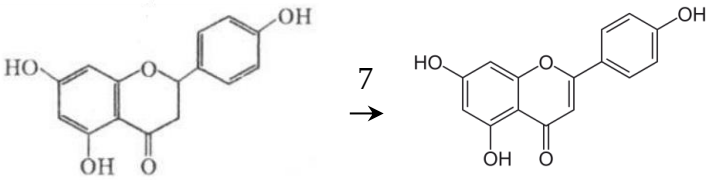
IV. *Stage of flavanol biosynthesis*



flavan-one flavan-ol

6 – dihydroflavanol-4-reductase

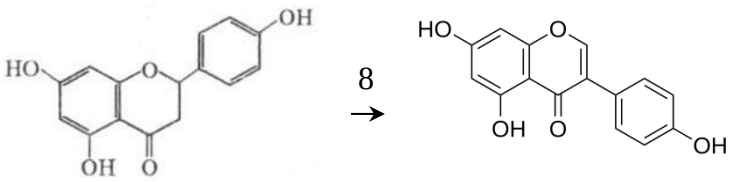
V. *Stage of flavone biosynthesis*



flavan-one flavone

7 – flavan-one-dehydrogenase

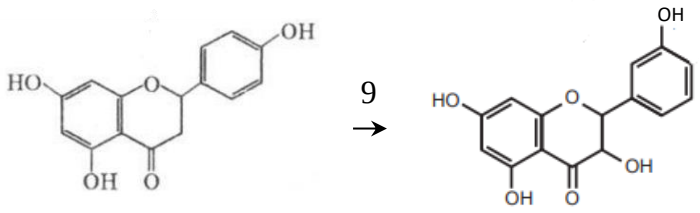
VI. *Isoflavone biosynthesis stage*



flavanone isoflavone

8 − isoflavonesynthase

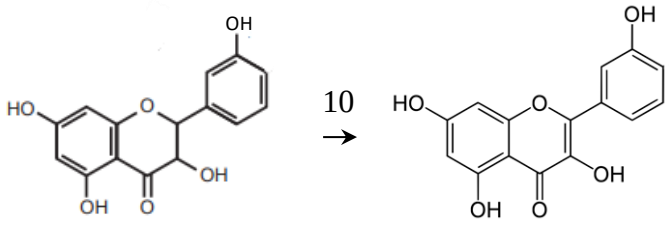
VII. *Stage of biosynthesis of dihydroflavanols*



flavan-one dihydroflavanol

9 – flavanone-3-hydroxylase

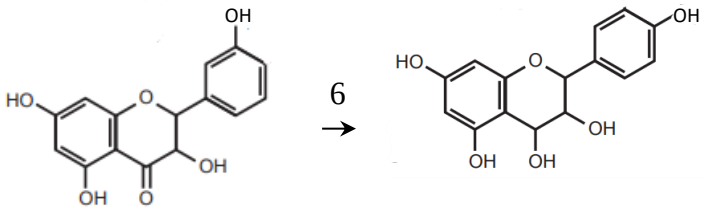
VIII. *Stage of flavonol biosynthesis*



dihydroflavanol flavone-3-ol

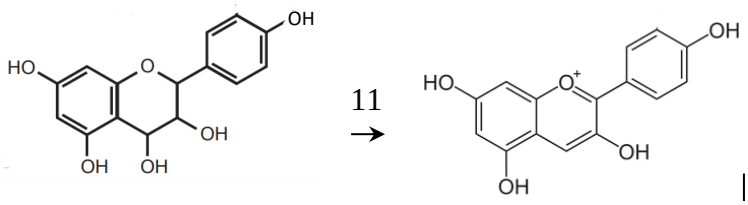
10 − flavonol synthase

IX. *Stage of leucoanthocyanidin biosynthesis*



dihydroflavanol flavan-diol
(leucoanthocyanidin)

X. *Stage of anthocyanidin biosynthesis*



flavan-diol anthocyanidin
(leucoanthocyanidin)

11 – UDP-glucose-flavanoid-3-O-glucosyl-transferase

XI. *Stage of biosynthesis of flavan-lignans*

Flavans and flavones → Flavan-lignans

Figure 2 shows a general diagram of flavanoid biogenesis.

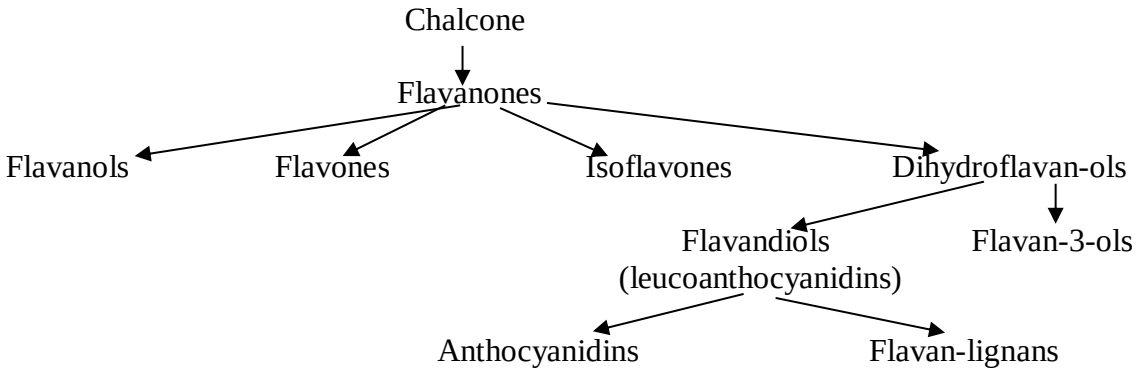
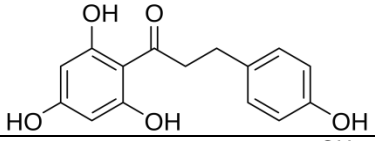
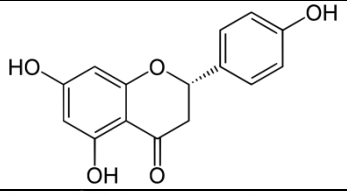
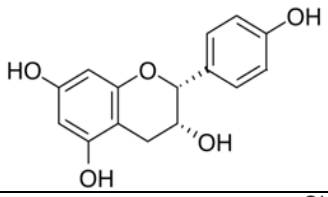
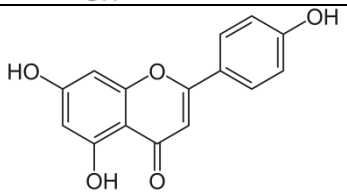
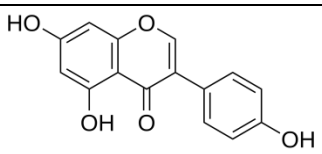
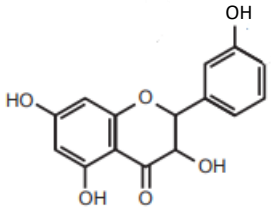
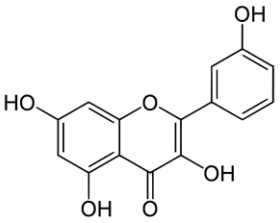
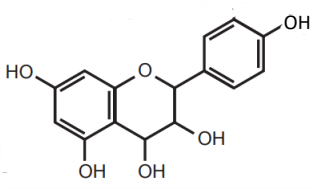
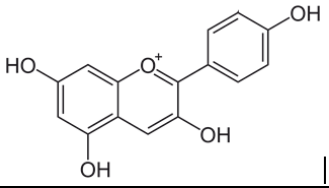
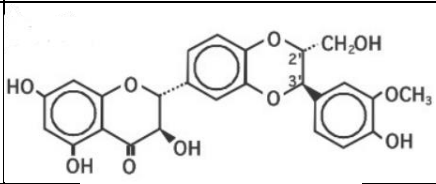
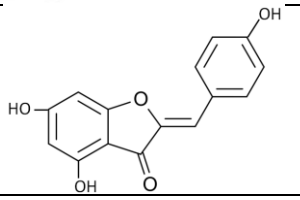


Fig. 2. General scheme of flavanoid biogenesis

Table

Biosynthetic classification of flavanoids (vitamins P)

Class	Class name	Chemical structure	Class representatives	Sources
1	2	3	4	5
I	Chalcones		Naringenin- chalcone, dihydrochalcone (phloretin)	Legume family and all plants
II	Flavan-ones		Hesperidin, hesperitin, naringenin, naringin	Citrus family
III	Flavan-ols		Catechins, epicatechins	Tea leaves, grapes, apples
IV	Flavones		Apigenin, luteolin	Celery
V	Isoflavones		Genistein, daidzein	Soybeans and other legumes

1	2	3	4	5
VI	Dihydroflavanols		Dihydro-flavanol	Actinidia, grapes, sophora
VII	Flavon-3-ol		Quercetin, rutin, kaempferol	Sophora, actinidia, grapes
VIII	Flavandiols (leucoanthocyanidins)		Leucoanthocyanidin	All plants
IX	Anthocyanidins		Cyanidin, delphinidin	Grapes, cherries, black currants, blueberries
X	Flavan-lignans		Silybin, silicristin, silydiamine	Milk thistle, blueberry
XI	Atypical and modified flavanoids		Auron	Almost all plants

Conclusions

1. In plants, all flavanoids exist in glycoside form (more than 90 %) and aglycone form (less than 10 %). The aglycone forms are the most active.

2. To convert glycoside forms into aglycones, it is necessary to carry out acid and enzymatic hydrolysis [19].

3. Our previously proposed structural classification of flavanoids [20] did not take into account the biogenesis of different classes of flavanoids.

4. The current daily intake of vitamin P (50 mg) requires revision, taking into account the characteristics of the chemical structure and biological activity of flavanoids of different classes.

5. We consider it incorrect to call all flavanoids “bioflavonoids”, since flavonoids are only part of the flavanoid family.

Author Contributions

The authors agree to equal distribution of partial participation.

Funding

This study received external funding.

Informed Consent Statement

Informed consent was obtained from all subjects who participated in the study.

Data Availability Statement

All information is in the public domain and specific graphic data can be obtained upon request from the corresponding senior author.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

The study was carried out by the authors themselves without any outside assistance.

References

1. Bentsáth A, Rusznyák St, Szent-Györgyi A. Vitamin nature of flavones. Nature. 1936;138:798.

2. Bentsáth A, Szent-Györgyi A. Vitamin P. Nature. 1937;140:426.

3. Tsao R. Chemistry and biochemistry of dietary polyphenols. Nutrients. 2010;2(12):1231-1246. doi: 10.3390/nu2121231

4. Corradini E, Foglia P, Giansanti P, Gubbiotti R, Samperi R, Laganà A. Flavonoids: chemical properties and analytical methodologies of identification and quantitation in foods and plants. Natural Product Research. 2011;25(5):469-495. https://doi.org/10.1080/14786419.2010.482054

5. García-Calderón M, Pérez-Delgado CM, Palove-Balang P, Betti M, Márquez AJ. Flavonoids and Isoflavonoids Biosynthesis in the Model Legume *Lotus japonicus*; Connections to Nitrogen Metabolism and Photorespiration. Plants (Basel). 2020;9(6):774. doi: 10.3390/plants9060774.

6. Liga S, Paul C, Péter F. Flavonoids: overview of biosynthesis, biological activity, and current extraction techniques. Plants (Basel). 2023;12(14):2732. https://doi: 10.3390/plants12142732

7. Mojbenko AA (editor). Bioflavonoids as organ protectors. Quercetin, corvitin, quertin. Kiev, Naukova dumka, 2012:274. (in Russian)

8. Giamperi L, Fraternale D, Bucchini A, Ricci D. Antioxidant activity of Citrus paradisi seeds glyceric extract. Fitoterapia. 2004;75(2):221-224. doi: 10.1016/j.fitote.2003.12.010.

9. Chervjakovskij EM, Kurchenko VP, Kostjuk EA. The role of flavonoids in biological reactions with electron transfer. Proceedings of the Belarusian State University. 2009;4(I). (in Russian)

10. Umeno A, Horie M, Murotomi K, Nakajima Y, Yoshida Y. Antioxidative and Antidiabetic Effects of Natural Polyphenols and Isoflavones. Molecules.2016;21(6):708. DOI: 10.3390/molecules21060708

11. Rudrapal M, Khan J, Dukhyil AAB, Alarousy RMII, Attah EI, Sharma T, Khairnar SJ, Bendale AR. Chalcone Scaffolds, Bioprecursors of Flavonoids: Chemistry, Bioactivities, and Pharmacokinetics. Molecules. 2021;26(23):7177. doi: 10.3390/molecules26237177

12. Makarenko O, Levitsky A. Biochemical mechanisms of therapeutic and prophylactic effects of bioflavonoids. J Pharm Pharmacol. 2016;4(8):451-456. https://doi: 10.17265/2328-2150/2016.08.013

13. Yahfoufi N, Alsadi N, Jambi M, Matar C. The Immunomodulatory and Anti-Inflammatory Role of Polyphenols. Nutrients. 2018;10(11):1618. doi: 10.3390/nu10111618

14. Abe I, Morita H. Structure and function of the chalcone synthase superfamily of plant type III polyketide synthases. Nat Prod Rep. 2010;27(6):809-838. doi: 10.1039/b909988n

15. Cheng AX, Han XJ, Wu YF, Lou HX. The function and catalysis of 2-oxoglutarate-dependent oxygenases involved in plant flavonoid biosynthesis. Int. J. Mol. Sci. 2014;15:1080-1095. doi: 10.3390/ijms15011080

16. Santos EL, Maia BHLNS, Ferriani AP, Teixeira SD. Flavonoids: Classification, Biosynthesis and Chemical Ecology [Internet]. Flavonoids - From Biosynthesis to Human Health. InTech; 2017. https://doi.org/10.5772/67861

17. Martinez RM, Pinho-Ribeiro FA, Steffen VS, Caviglione CV, Fattori V, Bussmann AJC, Bottura C, Fonseca MJV, Vignoli JA, Baracat MM, Georgetti SR, Verri WA, Casagrande R. Trans-Chalcone, a flavonoid precursor, inhibits UV-induced skin inflammation

and oxidative stress in mice by targeting NADPH oxidase and cytokine production. Photochem. Photobiol. Sci. 2017;16:1162-1173. DOI https://doi.org/10.1039/C6PP00442C

18. Sandoval V, Sanz-Lamora H, Arias G, Marrero PF, Haro D, Relat J. Metabolic Impact of Flavonoids Consumptionin Obesity: From Central to Peripheral. Nutrients. 2020;12:2393. doi:10.3390/nu12082393

19. König A, Sadova N, Dornmayr M, Schwarzinger B, Neuhauser C, Stadlbauer V, Wallner M, Woischitzschläger J, Müller A, Tona R, Kofel D, Weghuber J. Combined acid hydrolysis and fermentation improves bioactivity of citrus flavonoids in vitro and in vivo. Communications Biology. 2023;6:1083. https://doi.org/10.1038/s42003-023-05424-7

20. Levitsky AP, Malinovskii VA. Structural classification of vitamins P. Journal of Education, Health and Sport. 2025;83:64284. https://dx.doi.org/10.12775/JEHS.2025.83.64284