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Two international achievements by Lithuanians in the science of experimental botany during the 20th century

(1) The foundation for twentieth century experimental botany in Lithuania

Lithuania has had a long history and old traditions in the formation and development of different sciences, including the natural sciences as well. Natural philosophy has been discoursed at Vilnius University since its founding in 1579. Experimental botany started with the founding of the Chair of Natural Sciences at Vilnius University in 1781, after reforms in the educational system of the Great Duchy of Lithuania. Significant contributors to the organization of studies in experimental botany were made by Stanislaw Jundziłł, Head of the Chair, Jędrzej Sniadecky, Professor of the Chair of Medicine and Pharmacy, and others. However, further development in the science was interrupted due to political activity when the Russian Czar's government closed Vilnius University in 1832.

Only under the favorable circumstances in 1918 did Lithuania regain its independence. In 1922, the University of Lithuania was founded in the city of Kaunas, which at that time was the temporary capital of the Republic of Lithuania. The Chair of Botany with its sections of Plant Systematic and Plant Physiology was established along with the faculty of Mathematics and Natural Sciences at the University of Lithuania in 1922. At this point, the study of botany was restored in Lithuania. During the twentieth century, different branches of botany in Lithuania were founded and developed, but most international recognition was won in studies of experimental botany — in the field of plant growth physiology — performed by Jonas Dagys and Alfonsas Merkys.

Research in plant growth physiology started in Europe and Russia at the turn of the twentieth century, and later in the United States of America. During the twentieth century, the most famous centers for these studies were located in Holland, Denmark, Austria, Germany, Russia, the United States and the Soviet Union. A lot of review papers regarding investigations into plant growth substances were performed at scientific institutions in Europe, the United States and the Soviet Union and have been published. However, the value of Lithuanian studies has vanished among the studies of the Europeans, Russians and Americans. This was mostly due to the fact that Lithuania belonged to the USSR after World War II, and her science and cultural identity was violated. So, I would like to direct attention and make a few points about the place of Dagys's and Merkys's achievements in the general field of plant growth knowledge. From the historical viewpoint of science, Dagys's studies were investigated by some Lithuanians[1], whereas Merkys's studies still request comprehensive studies. Such a narrow attention to Merkys's works from a historical viewpoint may be reasoned by the opinion that the science of the period after World War II has been too young for historical studies.

To reach this goal, I investigated some review papers from the field of plant growth physiology that appeared during 1920–1970, and turned my attention towards how Dagys's and Merkys's studies have been integrated into the general context of the field.

(2) Some words about the birth of plant growth physiology at the turn of the 20th century

Growth and development is an essential state of living organisms. Plant growth substances such as hormones and vitamins perform fundamental roles in plant growth and development. Primary knowledge about such substances has been connected with studies in the field of plant responses to environmental

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[1] J. Klimavičiūtė, "Botanikos mokslas Lietuvoje 1919–1943 m." (2002); A. Merkys, "Prof. S. Jundzilo ir Prof. J. Dagio gyvenimas ir veikla“ (1995).

factors. Nowadays, scholars have no doubt about a living organism's responses to environmental factors and the decisive role played by hormones in these processes. However, at the end of the nineteenth century, research into plant responses to physical factors such as light and gravity had just started. In 1881, two well-known Englishmen, a father and son named Darwin, indicated that some signal must exist, which tells a plant to respond to light by bending.[2] They called the phenomenon heliotropism. Later, P. Boysen Yensen from Copenhagen University talked about the occurrence of some substance that regulated the curvature of the axial organ during heliotropism.[3] At the turn of the twentieth century, interest in plant movement and the causes of this process grew in European scientific laboratories. It was observable that plant movement is related with growth, and that growth contains two distinct processes: cell-enlargement and cell-division. Therefore, it was possible to suppose about the existence of two types of materials for these processes.

In 1926, F. Went from Utrecht University successfully extracted and tested the activity of a growth material with name auxin from the tips of an oat seedling's first leaf.[4] In the twenties and thirties, materials similar to those indicated by Went were extracted from different plants' growing organs.

It was 1901 when E. Wildier announced that a new substance was necessary for the multiplying of yeasts.[5] Wildier suggested a name for this unknown substance — 'bios'. In the first twenty years of the twentieth century, the nature of growth substances was not understood, hence such terms as 'vitamin', 'auximones', 'bios', 'growth substance', and 'growth hormones' are found in literature with reference to the unknown factor of stimulation.[6]

(3) First steps and great achievement of Lithuanian in plant growth substances research

Though a Chair of Botany was founded at the University of Lithuania in 1922, there were no scientists of experimental botany therein. The head of the Chair, Constantine Regel, was a well-known plant sociologist, while plant physiology was attended to by Liudas Vailionis, who was a graduate of Jagiellonian University, but didn't have a scientific degree. In my view, experimental botany in Lithuania was really rebuilt in the middle of the thirties, when a graduate of the University of Lithuania, Jonas Dagys, published scientific work in an international scientific periodical. The story of the article was as follows. In 1933, with a grant from the Education Ministry of Lithuania, Dagys went to Graz University in Austria to enter doctoral studies. At that time, the head of the Chair of Plant Physiology and Anatomy at Graz University was K. Linsbauer — specialist of plant anatomy, morphology and physiology. The staff at the Linsbauer Laboratory investigated questions regarding plant anatomy and physiology, and among them — plant growth substances. At the time that Dagys started his studies, growth substances and their chemical features had been divided into two groups by the Copenhagen plant biochemists N. Nielsen and V. Hartelius.[7] Substances of one group had similar characteristics to auxin chemicals. They were mostly characterized as materials that promoted elongation growth. The second group was named substances B — similar to "bios". They were mostly characterized as being responsible for plant cell division. As far back as in the first decade of the twentieth century, the existence of substances that promote cell division in wound tissues was demonstrated by the well-

[2] C. Darwin and F. Darwin, "The Power of Movement in Plants" (1881).

[3] P. Boysen-Jensen, "Über die Leitung des Phototropischen Reizes in der Avenkoleoptile", *Ber. Deut. Bot. Ges.* (1913), Vol. 31, p. 559–566.

[4] F. W. Went, "Wuchsstoff und Wachstum", *Rec. Trav. Bot. Neerland.* (1928), Vol. 24, p. 1–116.

[5] E. Wildiers, "Nouvelle substance indispensable au developpment de la levure", *La Cellule* (1901), Vol. 18, p. 313–332.

[6] J. Sanborn, "Essential Food Substances in Soil", *J. Bacteriol.* (1927), Vol. 13(2), p. 113–121.

[7] N. Nielsen and V. Hartelius, "The separation of growth promoting substances", *C.R.Lab.Carlsberg* 1, p. 20; N. Nielsen und V. Hartelius, "Über die Bildung eines Wuchstoffes (Gruppe B) auf chemischem Wege", *Bioch. Zeitschr.* 256. See J. Dagys, "Wuchsstoffe der Microorganizmen in Embryonalen Geweben und Blutungssafte", *Protoplazma* (1935), Vol. 1, p. 16.

known German botanist, G. Haberlandt.[8] He called these substances cell division hormones, and suggested that they must be accumulated in the embryonic tissues. Until the middle of the thirties, the existence of cell division hormones was explained hypothetically. It was unknown whether 'bios' had some similarities with cell division hormone, or whether it was simply attributable to the yeast cells' multiplying factor. In 1933, Hollander V. Hartelius demonstrated that a 'bios' substance existed in plants.[9] It was thought that the 'bios' substance was composed of a few different substances however, and at that time nobody had separated or identified them. The physiological action of 'bios' itself was mysterious in general. However, some hypothesis existed. A German, H. von Guttenberg, proposed that the 'bios' group only indirectly influenced the growth process, by observing yeasts' cells absorption of "bios" without any growth.[10] An Austrian, E. Almoslechner, contradicted Guttenberg and suggested that 'bios' had a special role in cell division, and that this group was similar to Haberland's plant division hormone.[11] In 1935, Dagys wrote:

> Almoslechner's hypothesis that 'bios' substance is responsible for cell division intrigued me, and I decided to examine it. If this hypothesis is right, 'bios' substance must be accumulated in the embryonic tissues of higher plants.[12] The amount of this substance must be large in the meristema tissues[13] of germinate buds and law — in the beginning of the dormancy period.[14]

The aim of Dagys' studies was to estimate the existence of 'bios' in different plants' embryonic tissues and sap. He applied Almoslechner's method in the experiment. He made different concentrations of extracts of embryonic tissues (from buds, young leafs etc.) of plants and observed the effect for the duration of yeast generation. The extract with largest amount of bios caused the shortest duration of the yeast generation period. Thus, Dagys ascertained that embryonic tissues had more 'bios' than other tissues, and decided that 'bios' had to play some role in the embryonic growth, which basically led him to conceptualize a thesis *that 'bios' acts as a hormone of meristema growth*.[15] That meant that 'bios" not only motivated plant cell division, but also growth. This concept was different from the most accepted viewpoint of those times, that 'bios' was just a substance for cell division. Considering the level of the science of those days, Dagys's conclusions were of high quality. His point was accepted by most known plant growth investigators of the twentieth century. In the well-known review periodical "Annual Review of Biochemistry", researcher Boysen Jensen wrote:

> As these substances which influence the growth of yeast are very widely distributed in higher plants it was postulated that they were also important to the embryonic growth of the latter (Dagys).[16]

Boysen Jensen's citation was a great recognition of Dagys in scientific society. However, how did Dagys's thesis influence the development of 'bios' research? In the end of the thirties it was ascertained that 'bios' is composed of B group vitamins. The role of vitamins is to regulate living organism metabolism and breathing. In fact, Dagys's preposition was substantiated.

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[8] G. Haberlandt, "Zur Physiologie der Zellteilung." *Mitt. Sitzungsber. K. Preuß. Akad.Wiss.* (1913, 1914, 1919). See J. Dagys, "Wuchsstoffe der Microorganizmen in Embryonalen Geweben und Blutungssafte", *Protoplazma* (1935), Vol. 1, p. 17.

[9] V. Hartelius, "Über da Vorkommen von Wuchstoff B im Harn", *Bioch Zeitschr.* 261 (1933). See J. Dagys, "Wuchsstoffe der Microorganizmen in Embryonalen Geweben und Blutungssafte", *Protoplazma* (1935), Vol. 1, p. 17.

[10] H. von Guttenberg, "Wachstum und Bewegung", *Fortschritte der Botanik* 2. See J. Dagys, "Wuchsstoffe der Microorganizmen in Embryonalen Geweben und Blutungssafte", *Protoplazma* (1935), Vol. 1, p. 17.

[11] E. Almoslechner, "Die Hefe als Indikator für Wuchsstoffe", *Planta* (1934), Vol. 22. 4, p. 515–542.

[12] This is similar to what Haberland had suggested about the cell division hormones. My note –A.R.

[13] Plant meristema tissue is constituted from divided cells and is initial for different tissues of plant.

[14] J. Dagys, "Wuchsstoffe der Microorganizmen in Embryonalen Geweben und Blutungssafte", *Protoplazma* (1935), Vol. 1, pp. 17-18. (My translation – A.R.).

[15] *Ibid*.

[16] P. Boysen Jensen, "Growth Regulators in the Higher Plants", *Annual Review of Biochemistry* (1938), Vol. 7, p. 525.

After returning from Austria, Dagys continued plant growth studies in Lithuania at Vytautas Magnus University, then later at Vilnius University. From 1938–1939 he received traineeship at the laboratories of famous plant growth researchers such as F. Kögl in Holland and N. Nielsen in Denmark[17]. In 1940, he started to head the Chair of Plant Anatomy and Physiology at Vilnius University, and the laboratory of Plant Physiology was founded in 1957 under his guidance at the Institute of Biology of the Lithuanian Academy of Sciences.

However, the political situation in Lithuania changed after World War II. It was incorporated into the Soviet Union. That caused changes in all spheres of human life. The scientific institutions were reorganized according to Soviet principles. During the early post-war period, biological science in the Soviet Union was based on Trofim's Lysenko's 'theory'. After the VASKhNIL session during July–August of 1948, Dagys was removed from the post of the Head of the Chair of Plant Anatomy and Physiology for five years, as he had been educated in the period of the independent Republic of Lithuania and supported the accepted theories of western scientists. Even though Lithuania had experience in plant growth research at the highest levels, the first ten years after the World War II were especially difficult for the development of science in Lithuania.[18] Still, new and very talented investigators appeared in the field of plant growth physiology.

Jonas Dagys (in the right) and Alfonsas Merkys (in the left) in 1988. Photo was provided by dr. J. Jurevičius, Laboratory of Plant Physiology of Institute of Botany in Lithuania.

[17] A. Merkys, "Prof. S. Jundzilo ir Prof. J. Dagio gyvenimas ir veikla" (1995).

[18] I wrote about the development of Botany in Lithuania after World War II in my dissertation work "Botany science in Lithuania in 1944-1965" (unpublished) and in the article A. Ričkienė "Botanikos studijų ypatybės Lietuvoje 1944-1950 m.", *Botanika Lithuanica* (2001), Vol. 7(1), p. 27-41. (in Lithuanian with English summary). Dagys's political problems were discused there.

Alfonsas Merkys studied under the supervision of Dagys at the Faculty of Natural Sciences at Vilnius University in the beginning of the fifties. After his graduation from Vilnius University, Dagys recommended that he continue studies in the field of plant growth, and also suggested entering doctoral studies at Moscow State University. Thus, Merkys started his studies at the laboratory of Plant Physiology in Moscow State University under the guidance of the Russian scientist, Nina Turkova. He analyzed questions concerning plant responses to gravity. In 1956, Merkys wrote his first work about the physiological causes of plant space orientations and defended it as a thesis for his scientific degree at Moscow State University. Then he returned to Vilnius and started to work at the Laboratory of Plant Physiology, which was founded by Dagys in 1957 at the Institute of Biology of the Lithuanian Academy of Sciences. In 1961, he exchanged with Dagys and started to head the Laboratory of Plant Physiology of the Institute of Botany of Lithuanian Academy of Sciences.[19] In 1965, Merkys wrote and defended a doctoral thesis [20] in which he extended the material of his investigations on the physiological causes of plant growth and space orientation. Since then, he has continued to initiate new research of plant growth physiology in Lithuania. During the acting period, Merkys formed three research trends: plant reaction to gravity, plant hormone auxin action, and plant growth and development in Space. This paper discusses the story of one very interesting achievement of Merkys, along with fellow colleagues in the field of the mechanism of auxin action.

(4) Birth of a new approach to biological processes in the middle of the 20th century; the mechanism of action of plant hormones, and Lithuanian achievements in this field

Previously, it was mentioned that Fritz Went was the first who separated a plant growth substance called auxin from the tip of an oat seedling's first leaf. [21] Since then, everything about auxin: its formula [22], transport in plant, and localization and physiological role during plant growth by elongation has interested scientists. Until the middle of the twentieth century, the elongation growth of a plant cell was mostly explained as an increasing of cell wall plasticity after reaction to a growth substance — auxin.[23]

Then, in the middle of the twentieth century, a model of DNA and the mechanism for its replication was suggested, and a new approach in the studies of a living organism's development was initiated. Consequently, a short while later a gene activation hypothesis related with plant hormones action made an exhibition.

During the middle of the twentieth century, two hypotheses about the mechanism of auxin action were developed: in the sixties — gene activation, and in the seventies — acid growth.[24] The view that auxin regulates the synthesis of ribonucleic acid, whose coding information is necessary for the growth proteins was suggested by F. Skoog and developed by J. Key, L. Nooden, K. Thiman and others.[25] In 1966, an American, D. J. Armstrong, summarizing their results in the article "Hypothesis concerning the Mechanism of Auxin Action" [26] wrote "…auxin functions as signal for polypeptide

[19] Institute of Biology of Lithuanian Academy of Sciences was divided to the Institute of Botany and Institute of Zoology in 1959.

[20] A. Merkys, *Geotropizm rastenij i jego znachenye dlia orientacii pobegov*. Doctoral thesis (1966), (unpublished). Archive of the Laboratory of Plant Physiology, Institute of Botany, Vilnius.

[21] Botanical term of monocotyledonous plant seedling first leave is coleoptile.

[22] In the early thirties, a few materials with auxin features were isolated, but during 1934-1935 auxin was identified as indole-3-acetic acid. Throughout the paper I use the term auxin in β-indole-3-acetic acid instead. A frequently used abbreviation for β-indole-3-acetic is IAA.

[23] J. Bonner, "The Action of the Plant Growth Hormone", *The Journal of General Physiology* (1933), Vol. 17 (1), p. 63-76.

[24] A. Theologis, "Rapid Gene Regulation by Auxin", *Annual Review of Plant Physiology* (1986), Vol. 37, p. 407-308.

[25] Joe L. Key, "Hormones and Nucleic Acid Methabolism", *Annual Review of Plant Physiology* (1969), Vol. 20, p. 449-474.

[26] D. J. Armstrong, "Hypothesis Concerning the Mechanism of Auxin Action", *Proceedings of National Academy of Sciences of the United States of America* (1966), Vol. 56, p. 64-66.

chain initiation in higher plant cell".[27] From Armstrong's report, we can see that a conception about the mechanism of auxin action at gene level existed in the sixties. The plant hormone, genes, and initiation of synthesis of new protein hold a significant place in it. Nevertheless, the problem of the mechanism of plant hormones action was very puzzling. The fact that auxin acts at low concentrations suggested the view that it stimulated growth acting as a group of enzymes.[28] That meant that it might be bound with the protein in the plant cell. As far back as 1954, some information about the form of a bond with the protein auxin, which was impossible to separate by standard methods, appeared in the scientific press.[29] Then, the question of whether auxin forms bonds or is physiologically active free aroused. Investigations in the field of bound auxin were developed in different scientific laboratories. In 1960, A. Galston and K. Purves disputed these studies in the review article "The Mechanism of Action of Auxin" and wrote that:

> Some auxin-protein complexes have been reported, though their significance remains obscure… This evidence, although suggestive, will remain no more than an attractive possibility until an unambiguous auxin-protein is isolated, and its possible relation to growth phenomena carefully examined.[30]

From this citation we see that there was no evidence that auxin forms bound with certain proteins were significant for plant growth by elongation in 1960. In 1965, A. Winter and K. Thiman performed experiments, but didn't find that auxin bound with protein accelerated cell growth by elongation.[31] One very interesting suggestion about primary plant hormones action that connected three things, plant hormone, protein, and gene activation was made by an American, James Bonner.[32] J. Bonner and his student R. C. Huang studied plant histons.[33] Most plant chromatin[34] is bound by them with nucleus proteins, and surely they have some role in the plant. In the book *The Molecular Biology of Development*,[35] Bonner talks about the hormones as materials-effectors. An effector, according to him, is a material that can activate genes. But how are histons associated with gene activation? Some explanations in this field were done by E. Stedman from Edinburg University in the beginning of the fifties. According to him, histons act as inhibitors of genes in the chromatin.[36] Logically, something must draw histons from DNA for the genes' derepression. How did Bonner use Stedman's speculation? Some examples given by Bonner demonstrate that after treatment of a plant with a special hormone, derepression of genes follows with the decline of histons in the chromatin. It indirectly shows that hormones regulate plant growth by acting with chromosomal proteins-histons.[37] Bonner's suggestion was one of the possible ways for solution to the mechanism of hormone action in 1965.

As mentioned, Merkys started studies in the field of plant growth and space orientation in the middle of the fifties. As far back as 1965, Merkys, along with other colleagues studying the geotropic

[27] D. J. Armstrong, " Hypothesis Concerning the Mechanism of Auxin Action", *Proceedings of National Academy of Sciences of the United States of America* (1966), Vol. 56, p. 66.

[28] Enzymes are accelerants of protein origin.

[29] S. A. Gordon, Occurrence, "Formation and Inactivation of Auxins", *Annual Review of Plant Physiology* (1954), Vol. 5, p. 366.

[30] A. W. Galston and K. W. Purves, "The Mechanism of Action of Auxin", *Annual Review of Plant Physiology* (1960), Vol. 11, p. 263.

[31] A. Winter, K. Thiman, "Bound Indoleacetic Acid in Avena Coleoptiles", *Plant Physiology* (1966), Vol. 41, p. 335.

[32] I recite about Bonner's suggestion of plant hormones action wider than the others because his views were of high cited in Lithuania.

[33] Histons are chromosomal proteins

[34] Chromatin is a material of cell nucleus.

[35] The book *The Molecular Biology of Development* was published in 1965. It was translated into Russian in 1967 with the name *Molekuljarnaja biologija razvitija* (1967).

[36] See D. Bonner *Molekuljarnaja biologija razvitija* (1967), p. 97.

[37] *Ibid*., p. 155.

curve [38] got results that showed stimulation of plant cell growth by elongation is accompanied by the intensification of amino acid incorporation into the proteins.[39] In my view, it is possible to say that these results showed relations among cell enlargement, protein synthesis, and gene activation as well. In 1966, Merkys defended his doctoral thesis. In the thesis conclusions he wrote:

> The physiological action of auxin during gravitropic reaction is related with protein metabolism in a plant cell. The stimulation of cells by elongation is attended by acceleration of auxin binding with protein and incorporation of amino acids into the protein.[40]

Hence, in this thesis he noted three things, stimulation of plant cells' elongation by means of auxin, auxin binding with protein, and acceleration of protein synthesis. In 1966, at the International Symposium on Plant Stimulation, Merkys talked for the first time about possible auxin action at the gene level,[41] and after a few years started a new experiment with colleagues. It was aimed at studying the correlation between the binding process of auxin with proteins and growth acceleration. "We also want to study the fraction of proteins with which auxin came in to the binding" he wrote in a scientific article in the Journal "Flora".[42] The experiment was performed using an autoradiograph method. After the experiment they drew the notion that there were correlations between the acceleration of cell growth by elongation, auxin binding with proteinous DNA and RNA, and amino acid incorporation into the proteins.[43] The conclusions made by him were such:

> It is possible that the essence of the physiological action of IAA[44] consist in the opening of the possibility for the formation of a certain kind of RNA.[45]
>
> [T]he primary step of the induction of growth acceleration by IAA is most likely connected with the interaction of IAA by binding with DNA or probably with RNA. This interaction can lead to results in protein (probably enzymes) synthesis, and cell enlargement.[46]

We can see from this thesis that in 1969, Merkys and his co-workers' suggestion had already associated four things, *auxin, its' binding with nucleoproteid, appearance of new protein and cell growth by elongation,* and in my opinion he defined that *auxin starts the primary action by interacting with a certain protein and acts at the gene level.* Merkys continued these studies for many years, as well as their continuance in different laboratories, and little by little it was explained that the plant hormone auxin starts the primary action by interacting with a protein-receptor and acts at the gene level. It means that Merkys's preposition was reasonable.

[38] During gravitropic reaction (when an axial organ is placed horizontal) different sides of the axial organ grow under different intensities, and the axial plant organ bends. The plant hormone auxin plays an essential role during the establishment of the geotropic curve.

[39] A. Merkys, A.Putrimas, A.,Marčiukaitis, "Izmeneniya napravlennosti vklyucheniya β-indoliluksusnoj kisloty i amino kislot v belki rasteniy vsledstviye geotropicheskogo razdrazheniya", *Tezisy Dokladov Fiziko-khimicheskiye osnovy avtoregulyacii v kletkakh* (1965), p. 33-34.

[40] A. Merkys, *Geotropizm rasteniy i yego znacheniye dlya orentacii pobegov.* Unpublished Doctoral thesis (1966), *Archyve of the Laboratory of Plant Physiology*, Institute of Botany, Vilnius, p. 446. (My translation A.R.).

[41] A. Merkys, "Role of β-indoleacetic acidin geotropical reaction and its connection with the energetic and protein cell metabolism*". Symposium on Plant Stimulations. Abstracts*. Sofia (1966), p. 26.

[42] A. Merkys, A. Putrimas, A. Marčiukaitis, "Binding of β-indoleacetic acid with proteins of plants and possible physiological significance of this process", *Flora* (1969), Vol. 160, p. 517.

[43] *Ibid*.

[44] IAA is abreviation of indoleacetic acid , which I refer to as auxin.

[45] A. Merkys, A. Putrimas, A. Marčiukaitis, "Binding of β-indoleacetic acid with proteins of plants and possible physiological significance of this process", *Flora* (1969), Vol. 160, p. 529.

[46] *Ibid*., p. 530.

(5) Conclusions

At the end of the nineteenth, and the beginning of the twentieth century, natural phenomena like the growth and development of plants started to be perceived as the result of the action of growth substances. During the twentieth century, plant growth studies spread across Europe, Russia, the Soviet Union and the United States of America. Little by little, unclear questions regarding their nature, composition, chemical and physical characteristics, actions, and the significance of these were studied. When Dagys started studies, knowledge about the growth substance 'bios' in plants was narrow. The action, purpose, formula and many other things about this material were unknown. Many scientists from different countries worked in this field. Dagys ascertained two things: the wide presence of 'bios' in plants, and the possible purpose of them as materials of embryonic growth. His preposition was reasonable.

The huge impulse towards studies and the development of plant hormones and plant growth substances made the discovery of DNA code and its replication mechanism possible. New hypotheses regarding gene activation and hormones as gene activators arose in the sixties.

When Merkys started to study gravitropic reaction and the mechanism of auxin action during plant growth by elongation, some views in this field were already formed. His studies were influenced by the general view of hormones as gene activators. In such a context he proposed a scheme for the mechanism of the primary action of the plant hormone auxin. He thought that auxin starts primary action by interacting with certain protein and acts at the gene level. Similarly, Merkys influenced the development of investigations related to plant hormones' physiological actions in plants.

In general view Dagys and Merkys studies extended knowledge of plant growth and development.