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THE LIFE AND SCIENTIFIC WORKS OF MICHAEL TSWETT

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CONTENTS

1. INTRODUCTION

There are many instances in the history of science when fundamental discoveries outstripped their epoch, their contemporaries for one or another reason being unaware of them, and only many years later did they become known and widely put into practice.

This is true of the phenomenon of chromatography, which was discovered at the beginning of this century by the Russian scientist Michael Tswett*. The discovery of this phenomenon made it possible to broaden the use of sorption phenomena. It has influenced the development of the analytical chemistry of complex compounds, including natural substances, put on an absolutely new basis control, regulation and automation in chemical technology, and made it possible to carry out a number of efficient processes of purification and isolation. It served as a basis for the development of a most effective instrumental method of investigation and analysis.

2. BIOGRAPHICAL DATA

Some parts of TSWETT's biography unfortunately remained obscure for a long period[1–12]**. He was born in the small town of Asti, Piedmont, in Northern Italy. Even

* The German transcription of the name, which M. Tswett used in most of his non-Russian papers, is used throughout this article, although Tsvet, of course, would be in line with this journal's rules—*Editor*.

** Of all the material published, the most detailed information was given in the articles by DHÉRÉ[1] and HESSE AND WEIL[3].

After my earlier papers were published[7], I received many letters, and in particular from I. Hais (Czechoslovakia) and K. Lustig (U.S.A.). The latter wrote: "This is the best description of his life I have read and I am only sorry that we know so relatively little about his personality. It would be of interest if one could know more about the man whose method produced so much progress in chemistry and biochemistry in the last 50 years." These letters made me extend, in the present paper, the information based on many years search of materials about M. Tswett and his contribution to science.

Fig. 1. Asti, Alfieri Square.

today there is the three-storey building of the Hotel "Reale" in Alfieri square in the centre of the city. There, in room 14 on May 14, 1872, at 11.30 a.m. Michael Tswett was born. By going along the narrow streets of this ancient city, dating back to the time of the first Roman settlements, one can get to San Secondo square, where there is the municipality. Here in the old register of births one can find the verbose birth-certificate of Michael Tswett. It says that Michael's mother was Maria, née de Dorozza, daughter of Nicholas (presumably an Italian). His father's name was given as Simone de Zevett, son of Nicholas, a Russian subject, who was then already a high-ranking official. They were passing through Asti and Maria de Dorozza had no relatives in this city. The birth-certificate mentions the ailing state of the newborn child.

Semen Tswett was born in 1828 in Chernigov, Malorossia (Ukraine) of a well-off family. It should be noted that the Tswetts have lived in Malorossia from time immemorial to the present day. According to family legend, one of Tswett's ancestors, Kolyadinskii by name, was implicated in the Mazepa insurrection in the time of Peter the Great, after which the name was changed*[13-15].

After graduating from the Tartu (Yur'ev, Dorpat) University, Semen Tswett was offered a position in the Department of Finance[16]. An honest and energetic man, without any patronage he quickly advanced up the ranks. By the time of Michael Tswett's birth, his father was head of the Exchequer of the Podolsk province.

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* The fact that S. Tswett's sons were allowed to bear the double name of Tswett-Kolyadinskii when they joined the army as officers serves as a confirmation of this assertion.

Fig. 2. Hotel "Reale", where M. S. Tswett was born.

Semen Tswett was a man of letters, took a great interest in literature and was well acquainted with many writers. He often went abroad. He was also noted for his independent character and liberal views.

Maria de Dorozza was born in 1846 in Kütahya, Turkey, and it is not known how she came to be in Russia. She was brought up in a family of Russian writers*. Semen Tswett and Maria de Dorozza were married in 1870.

Michael Tswett spent the first half of his short life abroad, in French-speaking Switzerland. He lost his mother very early. From his father's subsequent marriages Michael had two brothers, Alexander and Vladimir, and three sisters, Natalia, Nadezhda and Vera. Michael spent most of his childhood in Lausanne, where his father often came from Russia. In 1882–1885 he studied at the Collège Galliard in Chauderon Square, Lausanne. He lived in the Villa Montbell, at the Rochat-Lagnel boarding house[1,17]. When his father, who resigned in 1882 (when the period of reaction began after the assassination of Alexander II), moved to Switzerland, Michael Tswett went to Geneva. There he studied at the Collège Saint-Antoine and after graduating in 1891 he entered the Physics and Mathematics Department of Geneva University.

After a 4-term course of studies, Michael Tswett in 1893 passed the examina-

* The brothers Zhemchuzhnikov, better known under the joint pseudonym, together with their cousin A. K. Tolstoi, of "Koz'ma Prutkov"—*Editor*.

Fig. 3. Entrance to the Hotel "Reale".

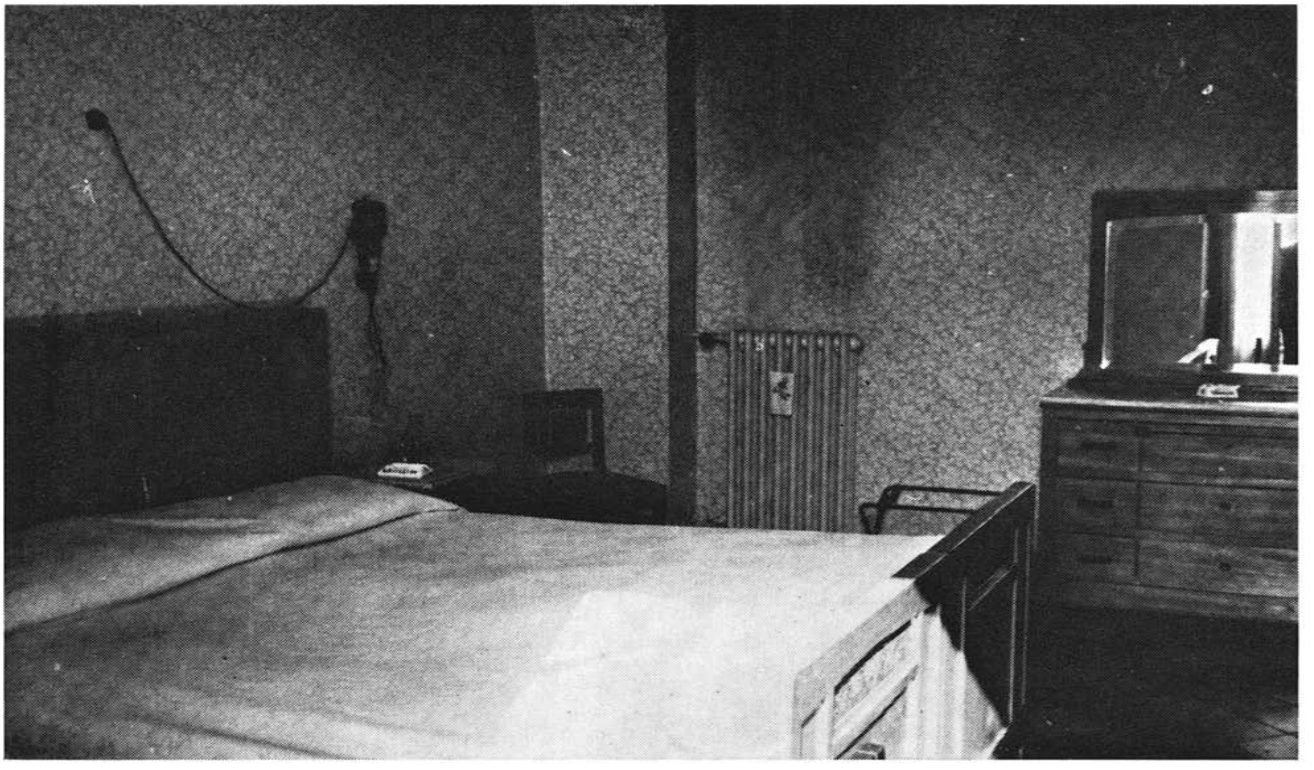

Fig. 4. Room in the Hotel "Reale" where M. S. Tswett was born.

tions and was awarded a bachelor's degree in science. In 1890 his father resumed state service, but still resided in Switzerland together with his family, having an assignment to study the conditions of supplies of Russian agricultural products to France. In 1893 he was appointed Russian trade representative to Genoa.

Meanwhile, M. S. Tswett continued his studies at Geneva University, where the scope of his scientific interests included biology, chemistry and physics. However, most of his time he spent in the laboratory of botany, where under the guidance of Prof. Chodat he carried out his first research on the anatomy of *Solanaceae*, for which he was awarded the H. Davy prize by Geneva University in 1894. Later, he started working in the general botany laboratory of Prof. Thury, where he prepared for his Doctorate thesis. The object of his research was the study of cell physiology. The thesis was completed by February, 1896 and consisted of two parts. The first part dealt with the cell structure and the movement of the protoplasm, and the second with chloroplast structure. In this first extensive study, M. S. Tswett began to outline the problems which later formed the essence of his scientific activity—the study of chlorophylls and the mechanism of assimilation of solar energy by plant tissue. Even then he showed his worth as a versatile scientist, who could make use of methods, approaches and knowledge of related sciences for solving the problems of the branch of science he took up.

By the time of M. S. Tswett's completion of his Doctorate thesis, his father made up his mind to go back to Russia, thinking it wrong to keep his grown-up children far from their motherland. Semen Tswett was given a new assignment; he was appointed President of the Chamber of the Exchequer of Tauria and moved to

Fig. 5. Semen Tswett, father of Michael Tswett, 1862.

Fig. 6. Maria de Dorozza, mother of Michael Tswett, 1870.

Fig. 7. M. S. Tswett in Lausanne, 1875.

Fig. 8. House (Cour de Rive 7) in Geneva where the Tswett family lived in 1883.

Fig. 9. M. S. Tswett with his brother, Alexander, in Geneva, 1891.

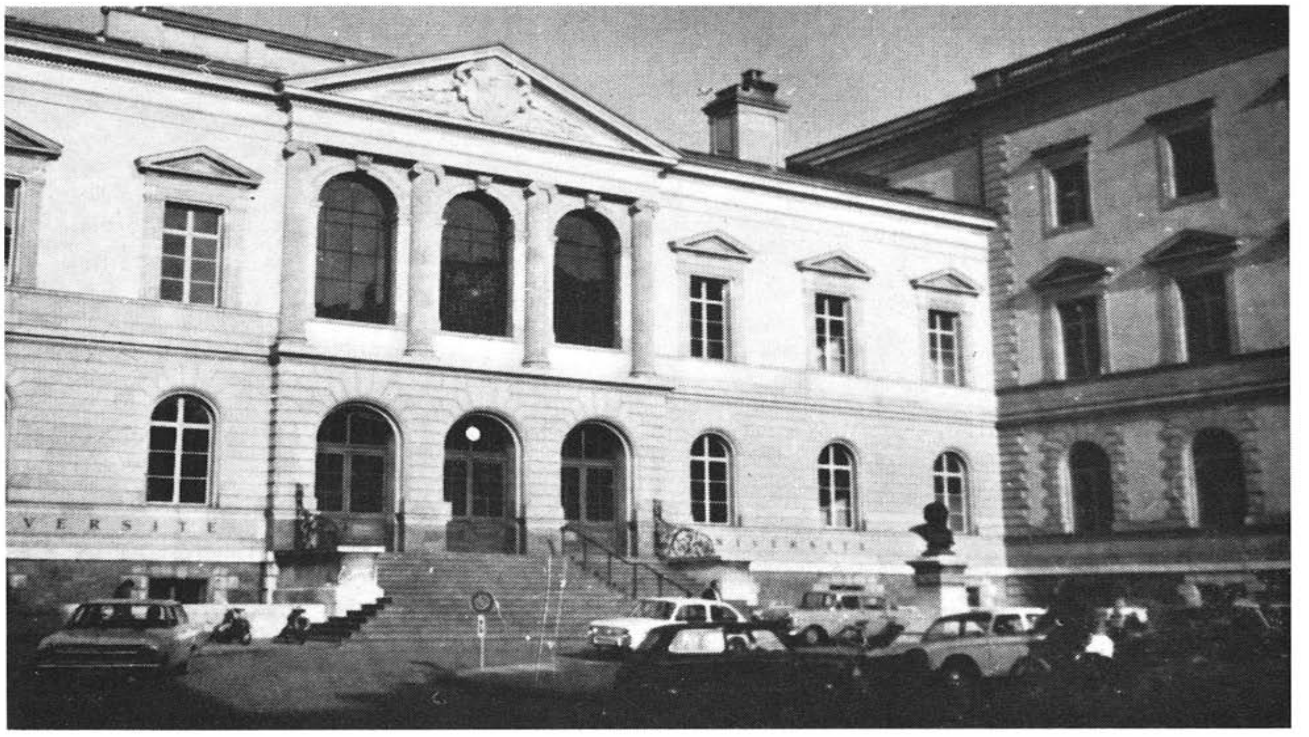

Fig. 10. University of Geneva.

Simferopol. Here, after a tour of Italy (Genoa, Florence, Rome and Naples), M. S. Tswett also came. Having taken up residence in Steven's summer-house, rented for his family by his father in the suburbs of Simferopol, the young scientist completed the manuscript of his Doctorate thesis[17a]. In July, 1896, having dispatched his thesis to Geneva for publication, he started to look for work. First he went to Odessa, where he was promised an appointment at the Botanical Gardens of the University[18].

Unexpectedly, M. S. Tswett did not take up this post in Odessa and in December, 1896, he went to Saint Petersburg, which was recommended to him by the well known scientist I. P. Borodin, who promised him a position at the physics laboratory of the Academy of Sciences[18].

However, circumstances proved to be rather complicated there and the first period of M. S. Tswett's life in Russia was rather difficult. It appeared that the D.Sc. degree of the Geneva University was not valid in Russia and Tswett had to submit new Master's and Doctor's theses[4,19]. In his letters to his friend Briquet in Geneva, Tswett complained of the hardships of life, expressed his disapproval of the then general situation in Russia, and even mentioned his wish to move abroad. One can judge the attitude of mind of the young scientist at that time from the following extracts from his letters[18].

A letter of December 30th, 1896. "... it's already more than 6 months that I have been in Russia, but vainly did I try to feel the beat of a Russian heart in myself! I have passed through nearly all the country, I visited Moscow, the sacred city, trying to see and hear something interesting. But nothing moved my feelings and aroused response in my heart. I feel alien in my motherland. And all this dispirits me...

Fig. 11. Genova Botanical Gardens.

Fig. 12. Library of the Geneva Botanical Gardens where letters of M. S. Tswett are kept.

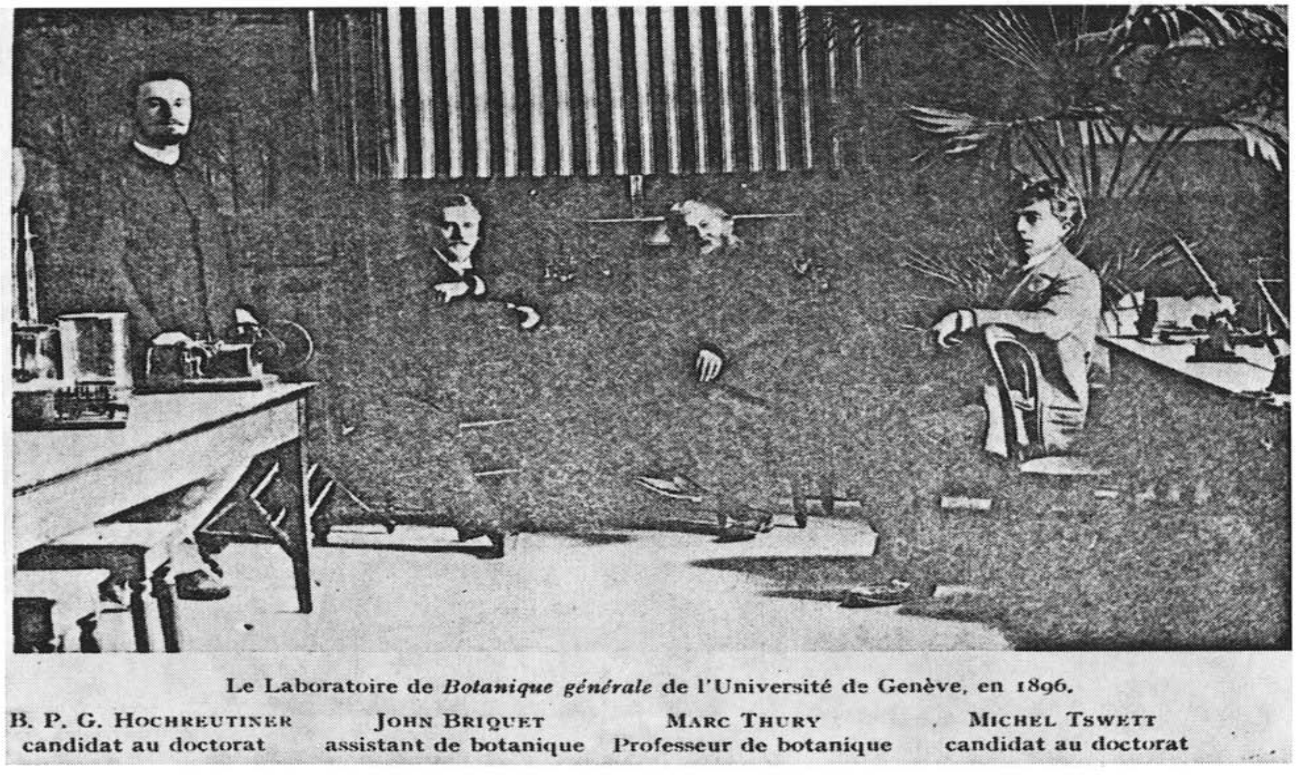

Fig. 13. M. S. Tswett, M. Thury, J. Briquet and B. Hochreutiner (from right to left), Laboratory of General Botany of the University of Geneva, 1896.

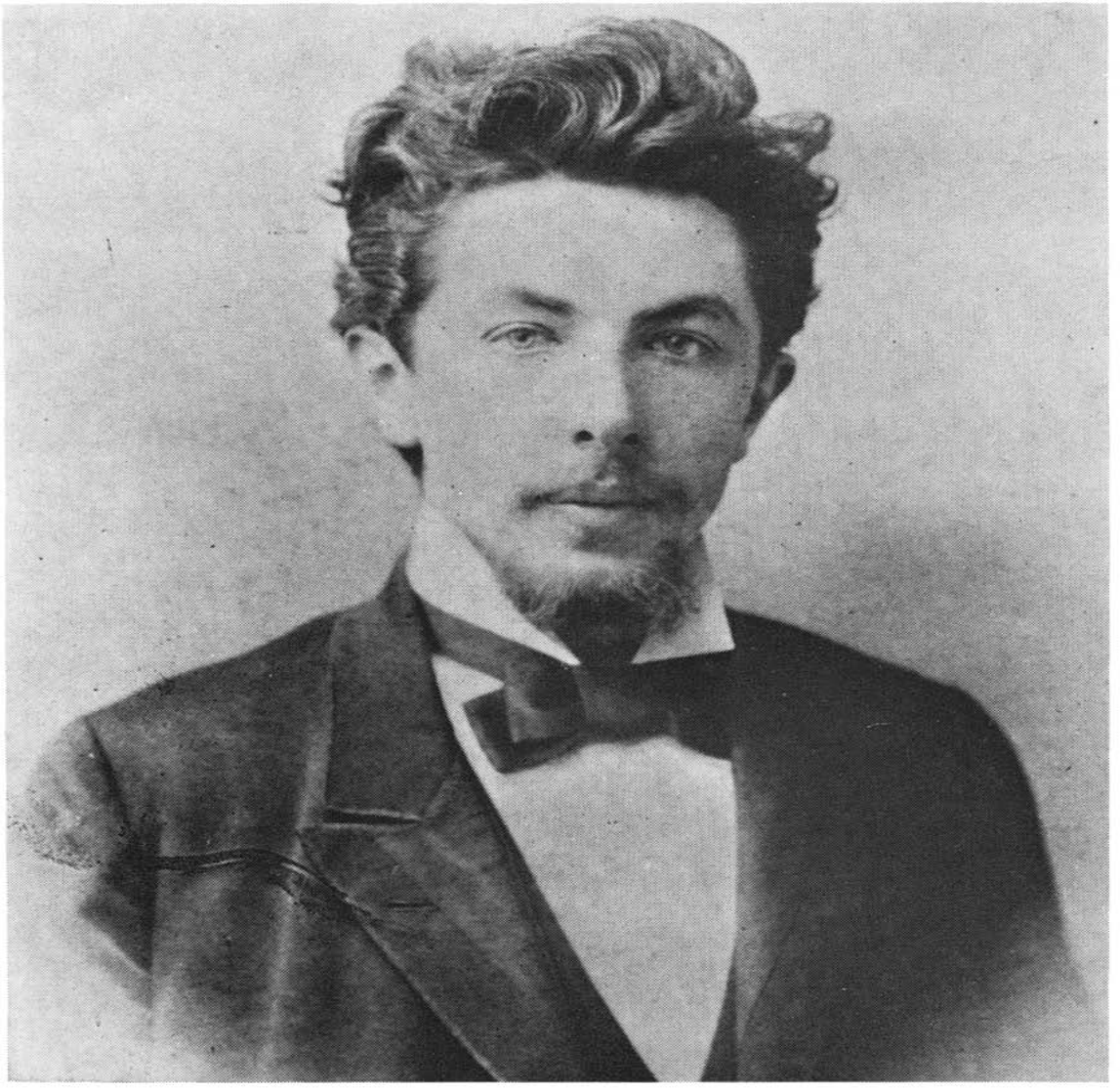

Fig. 14. M. S. Tswett, Geneva, 1896.

Fig. 15a. M. S. Tswett with his sister Natalia in Switzerland.

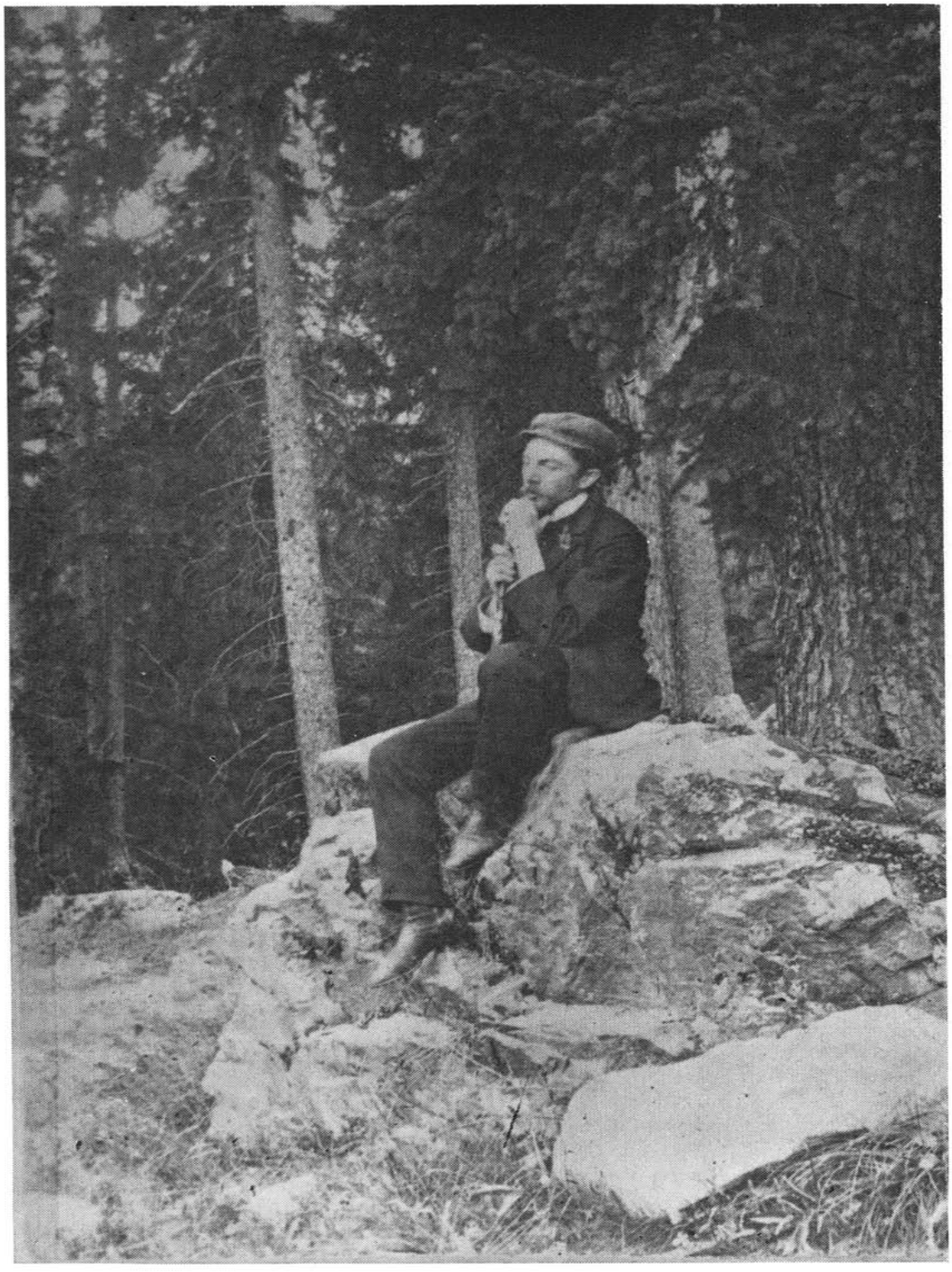

Fig. 15b. M. S. Tswett in Switzerland.

Fig. 16. Laboratory of the Botanical Gardens of Odessa University where Tswett worked for a short time in 1896.

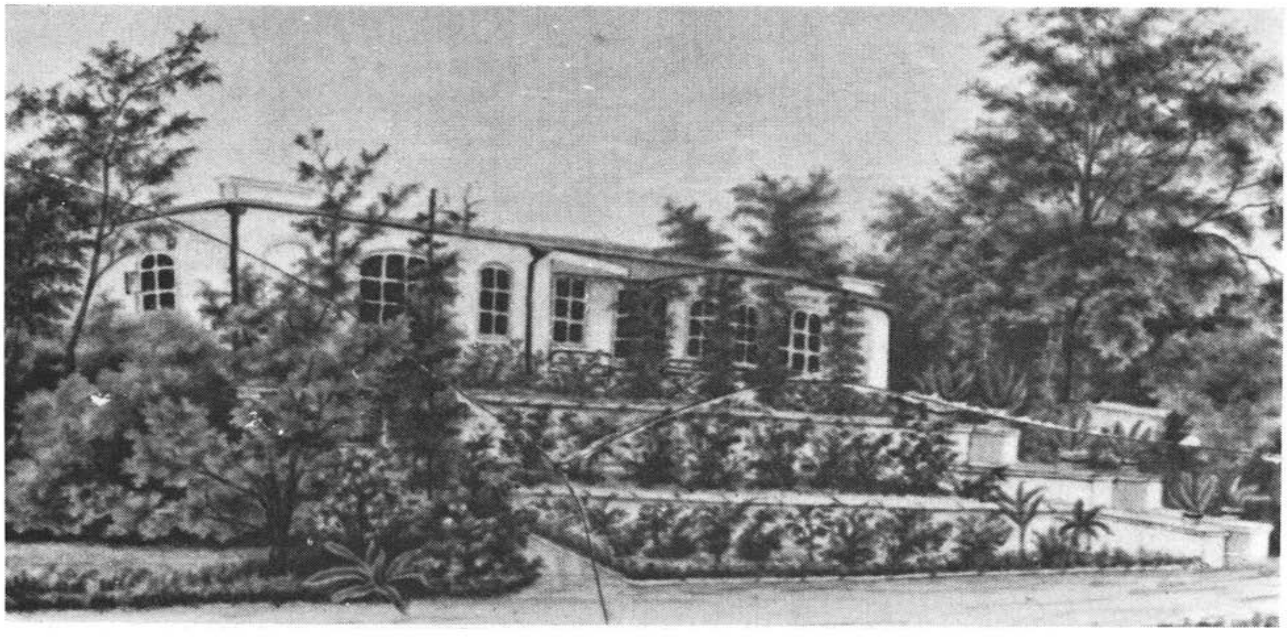

Fig. 17. House of Steven, Simferopol.

(a)

(b)

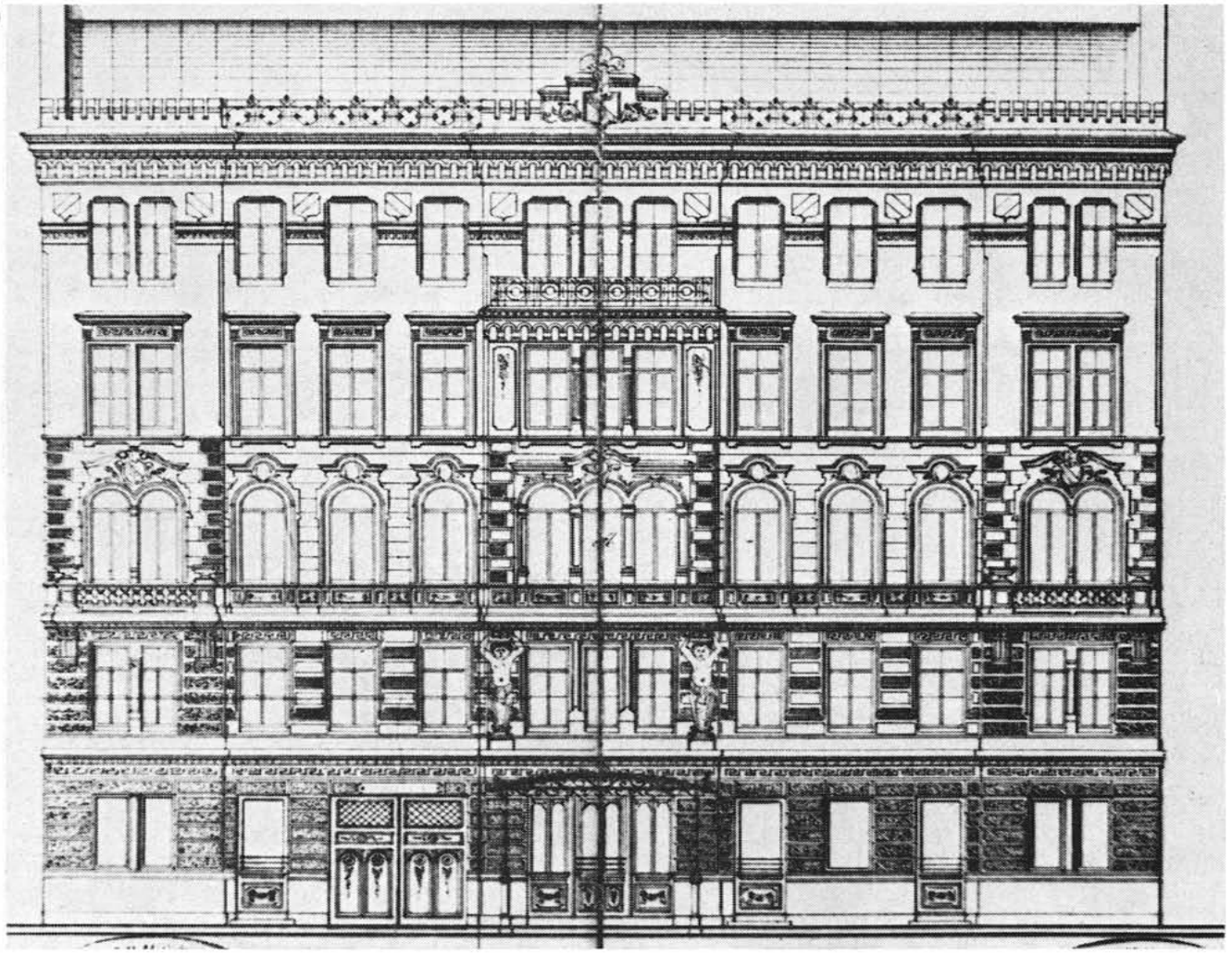

Fig. 18. (a) The place (5 Linee of Vasil'evskii Island) where the house in which M. S. Tswett lived in Saint Petersburg in 1896–1897 was situated. (b) View of this house according to an old plan.

Just think a little of the situation here and you'll see how it constrains and depresses a man in his aspiration for flight. Then you'll understand why our science is developing so slowly and why it's so retarded."

A letter of March 30th, 1897. "No results yet. I'm still awaiting the decision and suffer from bureaucracy. When my thesis is ready, I'll take my examination for a Master's degree, but it will probably take me no less than a year. Having a Master's degree, I may hope to become a lecturer and assistant professor. As you can see, things are not so brilliant. I should say I'm no more lucky in my motherland than if I were abroad."

These sincere and bitter words, said in his hardest times, were interpreted by some publications abroad as being almost a denial of his being Russian. However, all the subsequent life of the scientist conclusively refuted this incorrect assertion[3] (see also the words of Charles Baehni[7,18]).

Gradually, the young scientist's life began to return to normal. He started work at the Laboratory of Biology newly established by Prof. F. Lesgaft and at the same time he taught botany in the instruction courses for women. Above middle height, slightly stooping, always faultlessly dressed, vivacious and witty, M. S. Tswett won the sympathy of everybody. He made the acquaintance of and became intimate with prominent Russian botanists, especially Academician A. S. Famintsyn, in whose botany laboratory he started work on his Master's thesis. And when in 1898 Briquet offered him a position in Germany, he refused: ". . . Thank you for your offer, which I would have accepted without the slightest hesitation a year ago. But now I have here

Fig. 19. The house in Torgovaya Street 25/6, where M. S. Tswett worked and lived in Saint Petersburg in 1897–1901.

Fig. 20. The complex of buildings of the Russian Academy of Sciences where M. S. Tswett worked on his Russian Master's thesis.

Fig. 21. M. S. Tswett, Saint Petersburg, 1901.

a position as stable as the one you offer me and soon it will be still better. Besides, I dare not change my independence for an all-absorbing, perhaps very difficult, occupation".

In 1900, on the recommendation of a number of distinguished scientists, M. S. Tswett was admitted to the Saint Petersburg Naturalists Society.

In 1901, he completed the work on his Master's thesis "Physicochemical structure of the Chlorophyll Grain. Experimental and Critical Study". Shortly before M. S. Tswett completed his thesis, his father died, and M. S. Tswett wrote on the first page of his work "In memory of my father, S. N. Tswett, a thinker and public man"[20,21]. After he had passed the Master's examination on September 23rd, 1901, in the Assembly Hall of Kazan University, he defended his Master's thesis. He was a great success and M. S. Tswett could manifest in full measure his talent as a brilliant speaker who liked and could, in a really captivating style, expound the most complicated phenomena.

M. S. Tswett's thesis for the Master's degree, apart from the results of the study of chloroplasts, chloroglobin* and chlorophyll and careful consideration of the literature, contained many interesting ideas and speculation which characterise Tswett as a scientist with a materialistic viewpoint. In his thesis, giving detailed consideration to different methods of extraction of substances, he touched upon the problems of adsorption. In one of the sections he wrote: ". . . I could vividly see differently coloured rings when filtering petroleum ether extracts of leaves through Swedish paper"[21]. These words are indicative of the young investigator's interest towards adsorption and the results obtained by him represented the first step towards the discovery of chromatography. That is why he had good reasons for writing in the foreword to his major work[22] "The source of my chromatographic method lies in my Russian work of 1901".

After he obtained the Master's degree, Tswett intended to stay in Kazan, but there were no vacancies and there was no hope of obtaining a suitable post at the University or the Academy of Sciences in Saint Petersburg. So, in January, 1902, M. S. Tswett moved to Warsaw, where he first worked as a supernumerary laboratory assistant and later as an assistant at the Plant Anatomy and Physiology Department; in 1902 he became "privat-docent" and was allowed to lecture[23]. Tswett spent 14 years in Warsaw, and it was there that he delivered his first paper on the new field of chromatographic phenomena[24] and numerous works in botany and photosynthesis. In 1907, Tswett was offered a position as Lecturer** in botany and agriculture at the Veterinary Institute in Warsaw, and in 1908 he was elected Senior Lecturer** in botany and microbiology at the Chemistry and Mining Department of the Polytechnic Institute in Warsaw.

At the library of Warsaw University worked Helena A. Trusiewicz, a Czech, who became his wife in 1907.

This first period of the young scientist's life in Warsaw was very happy and successful.

When still in Saint Petersburg, M. S. Tswett worked extensively on the prob-

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* A (hypothetical) complex including chlorophyll and another constituent of the chloroplasts—*Editor*.

** "Prepodavatel' " and "shtatnyi prepodavatel' ": Although even Tswett used to translate these titles as Professor, it should be borne in mind that they were actually inferior to the post of a University Professor—*Editor*.

Fig. 22. House of Ignacy Kraszewski, where M. S. Tswett lived during the first period of his stay in Warsaw.

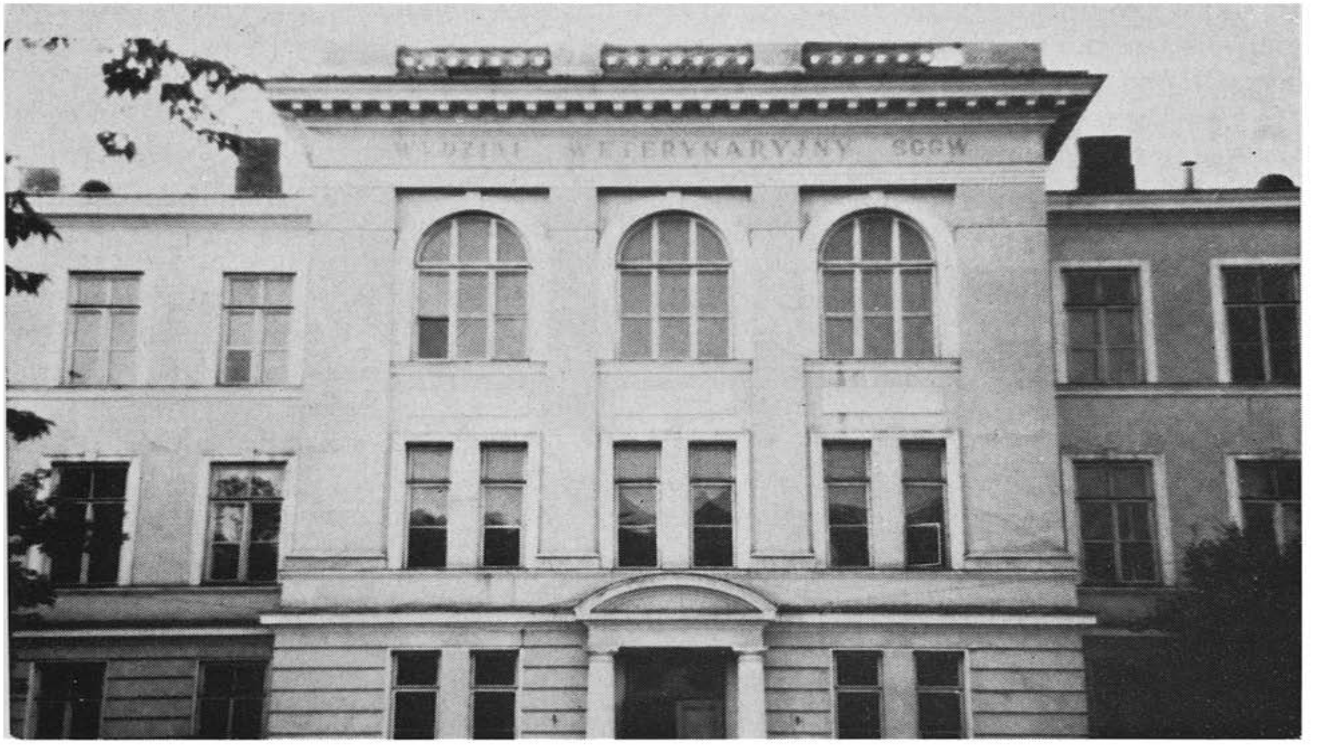


Fig. 23. Veterinary Institute, Warsaw.

Fig. 24. Helena Tswett (née Trusiewicz), wife of Michael Tswett.

lems of chlorophyll, and he searched constantly for a method of separating substances that could be used for the separation of very complex compounds. He was quite convinced that chlorophyll was not an individual substance. After scores of experiments, a simple method was discovered, and in the simplicity of the method lay its great advantage, which, unfortunately, was not appreciated by some of Tswett's contemporaries.

Tswett's experiments on the separation of compounds in a tube filled with chalk not only offered a clue to the mystery of the green leaf, but also laid a foundation of a new method of separation of complex mixtures, *viz.*, chromatography.

M. S. Tswett reported on his discovery (March 8th, 1903) at a meeting of the biology section of the Naturalists Society of Warsaw University[24]. The proceedings stated that in the course of the report, diagrams were shown and D. Ivanovskii, I. Morkovin and the speaker exchanged their opinions on the matter[25].

The young scientist who began his work while still in Saint Petersburg carried out strikingly extensive research work within a short period of time.

Then there were three years of silence when Tswett published only short articles based on his previous research. At the same time, he was working hard on the

Fig. 25. Waldegg: M. S. Tswett with his relations. In the centre M. S. Tswett and Claparède, 1907.

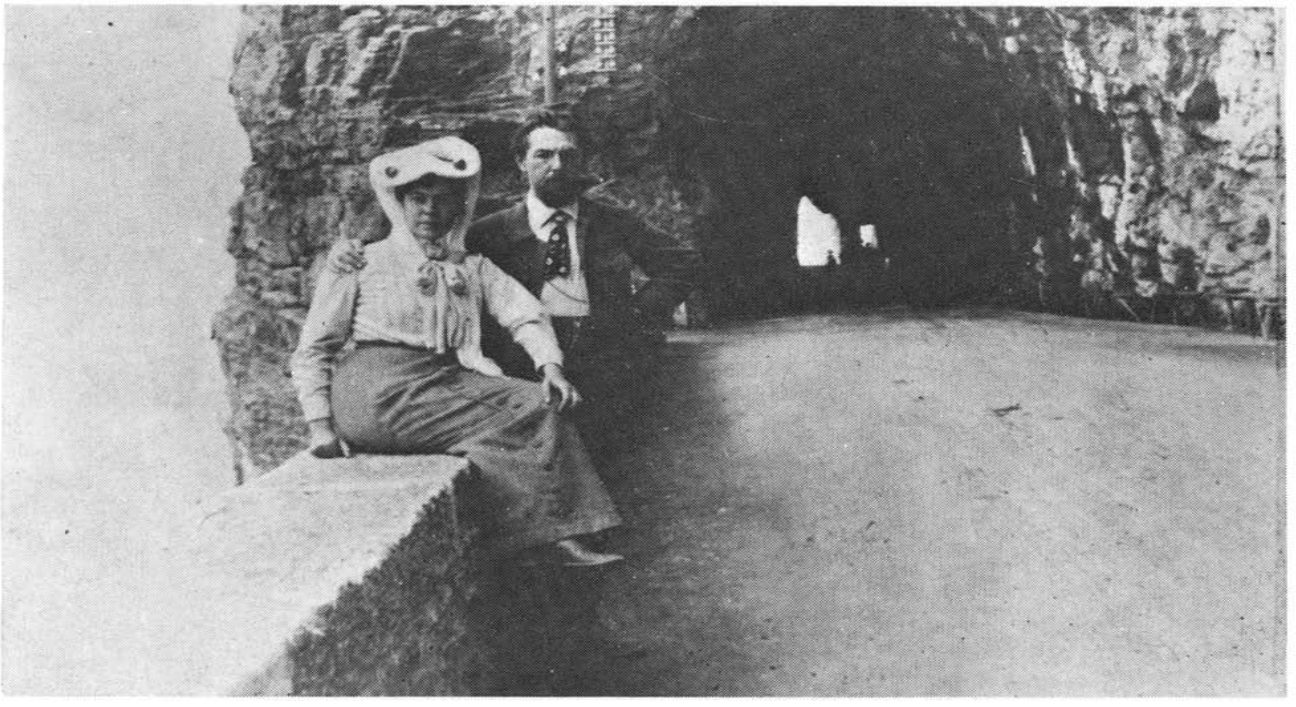


Fig. 26. H. Tswett and M. S. Tswett, Switzerland.

Fig. 27. M. S. Tswett with wife and her relations.

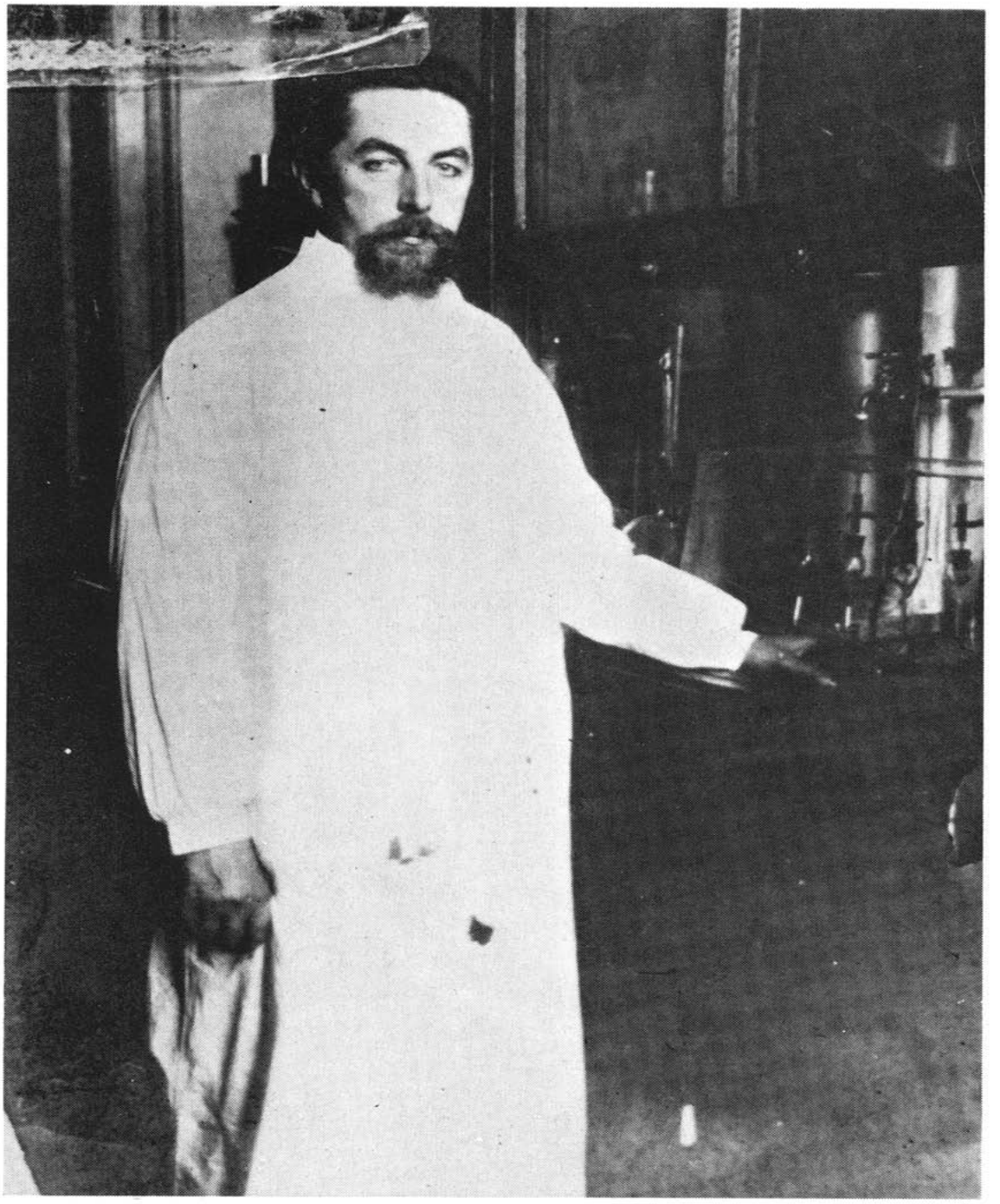
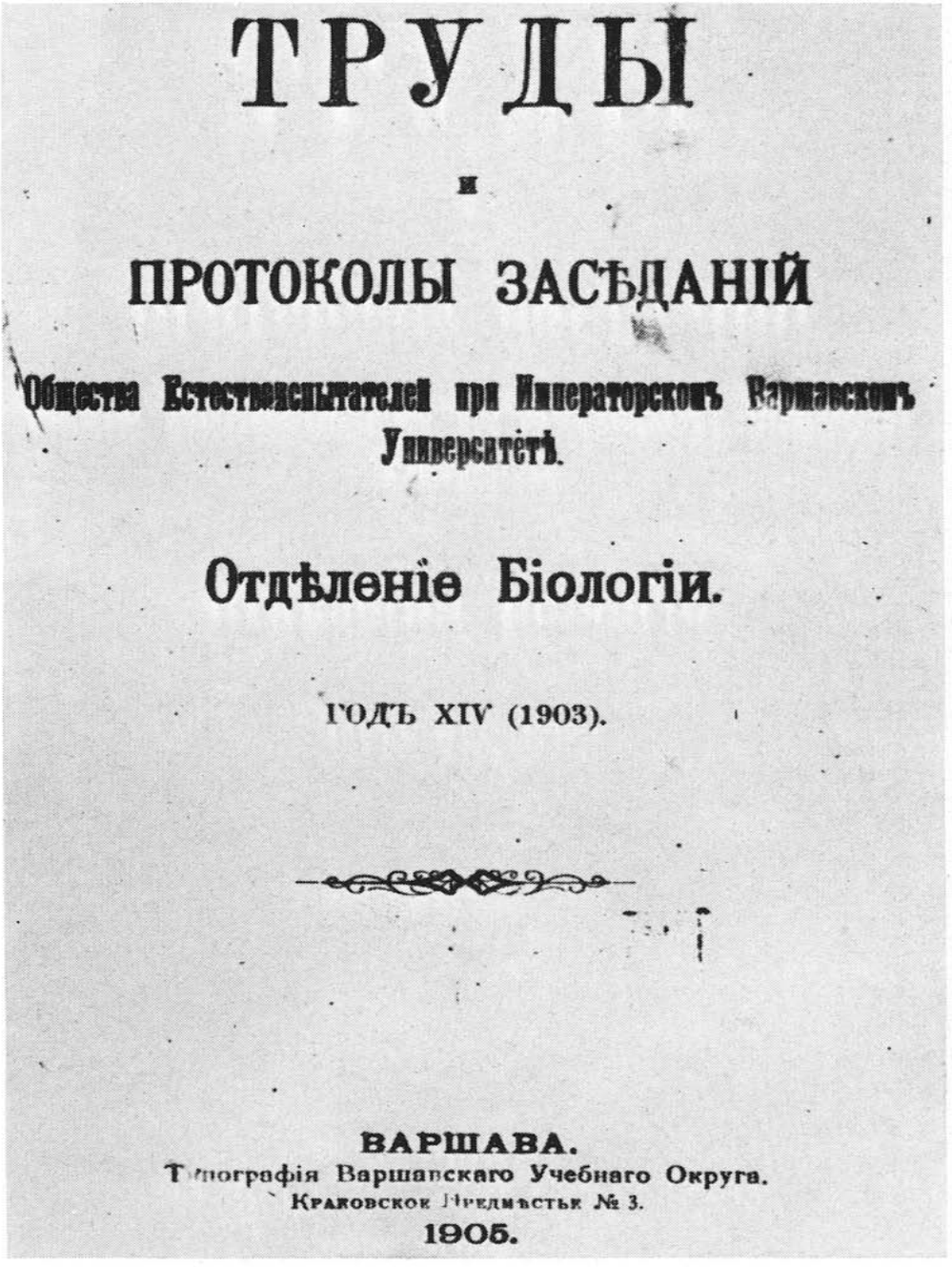


Fig. 28. M. S. Tswett near the first chromatographical unit, Warsaw.



ТРУДЫ

И

ПРОТОКОЛЫ ЗАСѢДАНІЙ

Общества Естествоиспытателей при Императорскомъ Варшавскомъ Университетѣ.

Отдѣленіе Біологіи.

ГОДЪ XIV (1903).

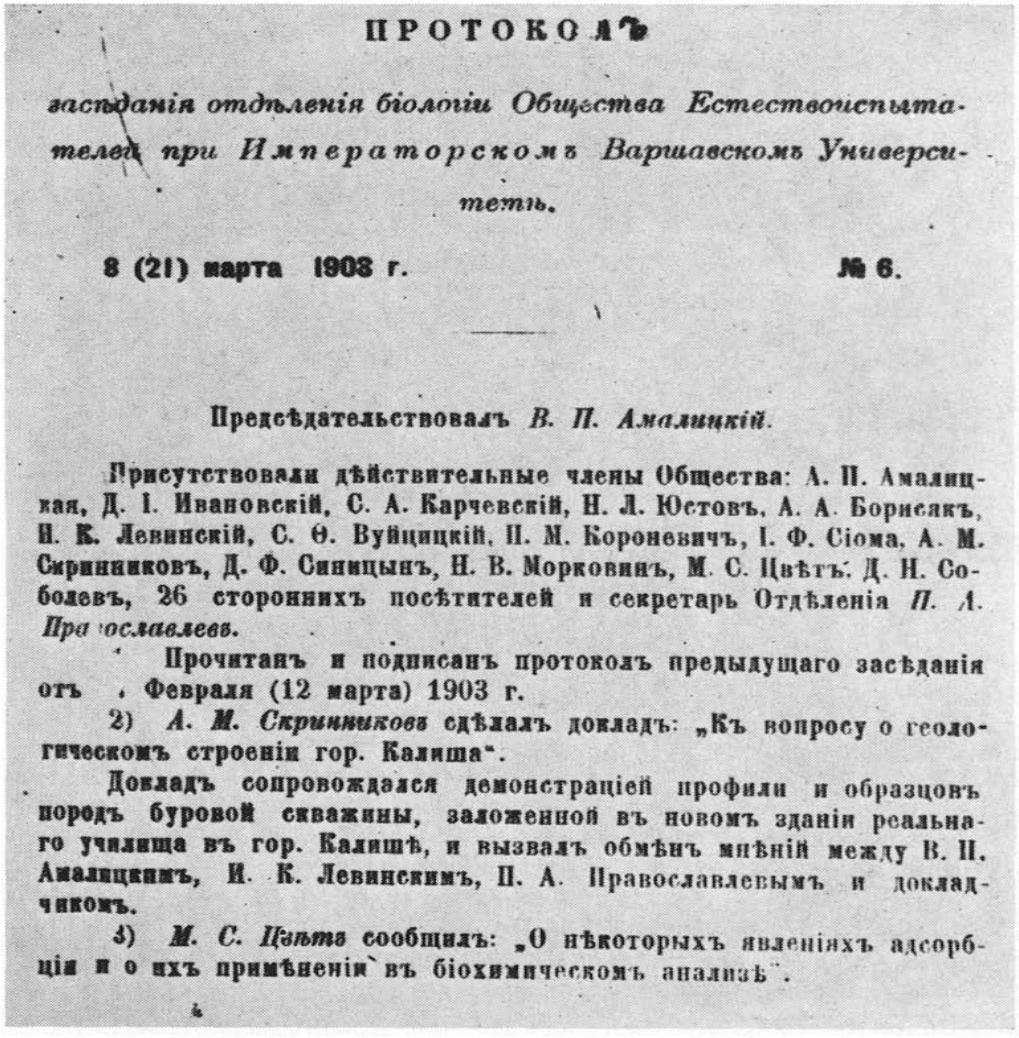
ВАРШАВА.

Типографія Варшавскаго Учебнаго Округа.

Краковское Предмѣстье № 3.

1905.

Fig. 29. The proceedings of the first report and the first paper on chromatography. *(Continued on pp. 330 and 331).*



ПРОТОКОЛЪ

засѣданія отдѣленія біологіи Общества Естествоиспытателей при Императорскомъ Варшавскомъ Университетѣ.

8 (21) марта 1903 г. № 6.

Предсѣдательствовалъ *В. П. Амалицкій.*

Присутствовали дѣйствительные члены Общества: А. П. Амалицкая, Д. І. Ивановскій, С. А. Карчевскій, Н. Л. Юстовъ, А. А. Борисякъ, Н. К. Левинскій, С. Ѳ. Вуйцицкій, П. М. Короневичъ, І. Ф. Сіома, А. М. Сириниковъ, Д. Ф. Синицынъ, Н. В. Морковинъ, М. С. Цвѣтъ, Д. Н. Соболевъ, 26 сторонникъ посѣтителей и секретарь Отдѣленія *П. А. Православлевъ.*

Прочитанъ и подписанъ протоколъ предыдущаго засѣданія отъ . Февраля (12 марта) 1903 г.

2) *А. М. Скрипниковъ* сдѣлалъ докладъ: „Къ вопросу о геологическомъ строеніи гор. Калиша".

Докладъ сопровождался демонстраціей профили и образцовъ породъ буровой скважины, заложенной въ новомъ зданіи реальнаго училища въ гор. Калишѣ, и вызвалъ обмѣнъ мнѣній между В. П. Амалицкимъ, И. К. Левинскимъ, П. А. Православлевымъ и докладчикомъ.

3) *М. С. Цвѣтъ* сообщилъ: „О нѣкоторыхъ явленіяхъ адсорбціи и о ихъ примѣненіи въ біохимическомъ анализѣ".

Fig. 29 *(continued)*.

development of the chromatographic method. In 1906, two articles were published in which Tswett gave detailed descriptions of the results that he had obtained in the course of his research[26,27].

By 1908 he had completed his Doctorate thesis "Chromophylls in the Plant and Animal World", which was published in 1910. On November 28th, 1910, M. S. Tswett brilliantly defended his Russian thesis for a Doctor's degree in botany based on the material of his book. His official opponents were the Professors of Botany D. Ivanovskii and W. Chmielewski, and the chemist, Professor B. Kurilov. M. S. Tswett was awarded N. Akhamatov's Grand Prize by the Russian Academy of Sciences in 1911.

At first, Tswett's discovery drew the attention of his contemporaries, and was discussed not only in scientific publications, but also in popular newspapers.

Some manuals of biochemistry published in 1912 included articles with a detailed description of the adsorption chromatographic method. M. S. Tswett enjoyed universal esteem. As an example, we can refer to the testimonial that was given to him when he was transferred from Warsaw University to the Polytechnic Institute in 1908[7,23].

Труды Варшавскаго Общества Естествоиспытателей.
Годъ XIV. Отдѣленіе Біологіи. — Протоколъ № 6.

М. С. Цвѣтъ.

О новой категоріи адсорбціонныхъ явленій и о примѣненіи ихъ къ біохимическому анализу.

Предварительное сообщеніе.

(Сообщено въ біологическомъ отдѣленіи Варшавскаго Общ. Естествоиспытателей 8/21 Марта 1903 г.).

Введеніе.

Подъ названіемъ *адсорбціи* соединяются въ настоящее время явленія отчасти въ своей сущности, можетъ быть, разнородныя, но отвѣчающія слѣдующему общему опредѣленію: сгущеніе на поверхности тѣлъ окружающихъ ихъ газовъ, паровъ, жидкостей или растворенныхъ въ послѣднихъ веществъ.

Поглощеніе животнымъ и древеснымъ углемъ не только красящихъ веществъ, по общераспространенному мнѣнію, но и вообще всевозможныхъ растворенныхъ веществъ, а также газовъ; поглотительная способность почвы, огромная поглотительная способность для газовъ палладіевой и платиновой черни; сгущеніе водяныхъ паровъ и газовъ на стеклянныхъ и металлическихъ поверхностяхъ (образованіе такъ называемыхъ „Wasserhaut" или „Lufthaut"); поглощеніе водяныхъ паровъ мелко-порошкообразными и коллоидальными металлическими окислами; поглощеніе воды гидрогелемъ кремнистаго ангидрида; поглощеніе солей целлюлезой и животными перепонками; имбибиціонныя свойства целлюлезы, крахмала и пр.:

1

Fig. 29 *(continued)*.

During the years of his work in Warsaw, M. S. Tswett went abroad several times to acquaint himself with the state of research work and training, particularly to the Botanical Gardens in Berlin, and to the universities of Kiel, Amsterdam, Leiden, Delft, Brussels and Paris. He repeatedly participated in scientific congresses in Moscow and Saint Petersburg, where he presented his papers; *e.g.*, in 1911 at the 2nd Mendeleev Congress he presented a paper "The Present State of the Chemistry of Chlorophyll". M. S. Tswett was accepted as a member of the Naturalist's Society of Warsaw and the German Botanical Society.

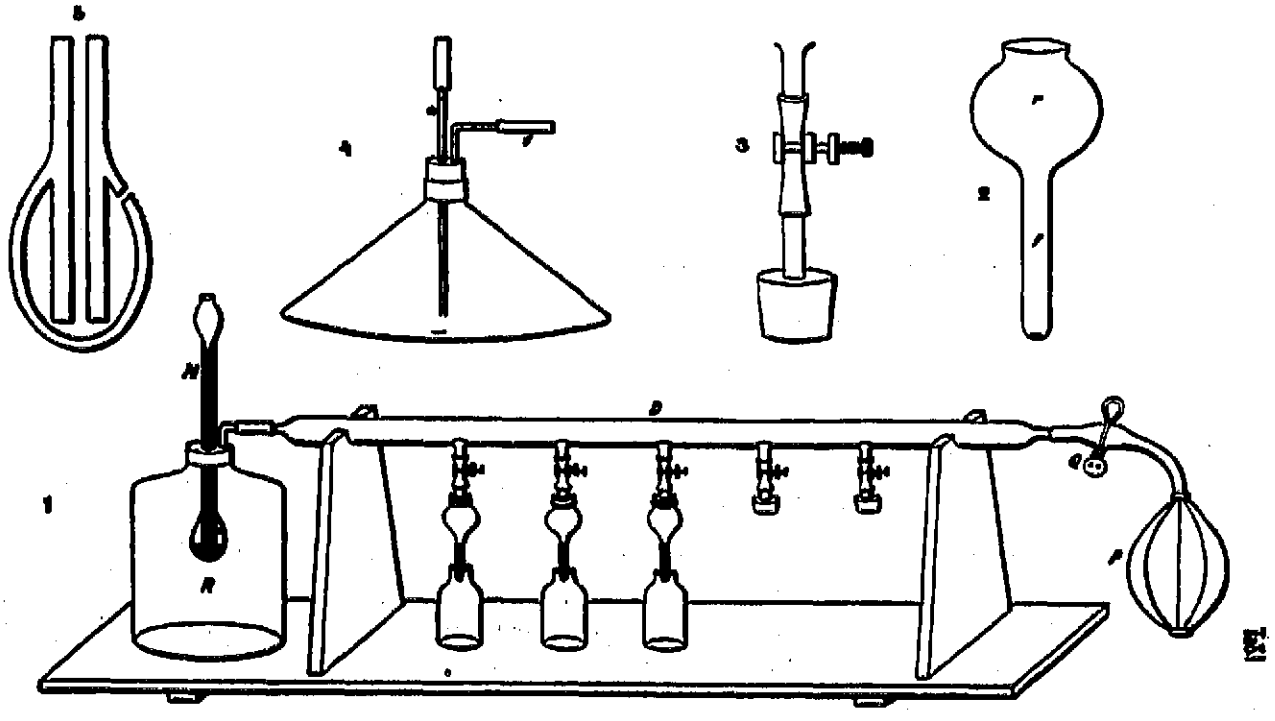


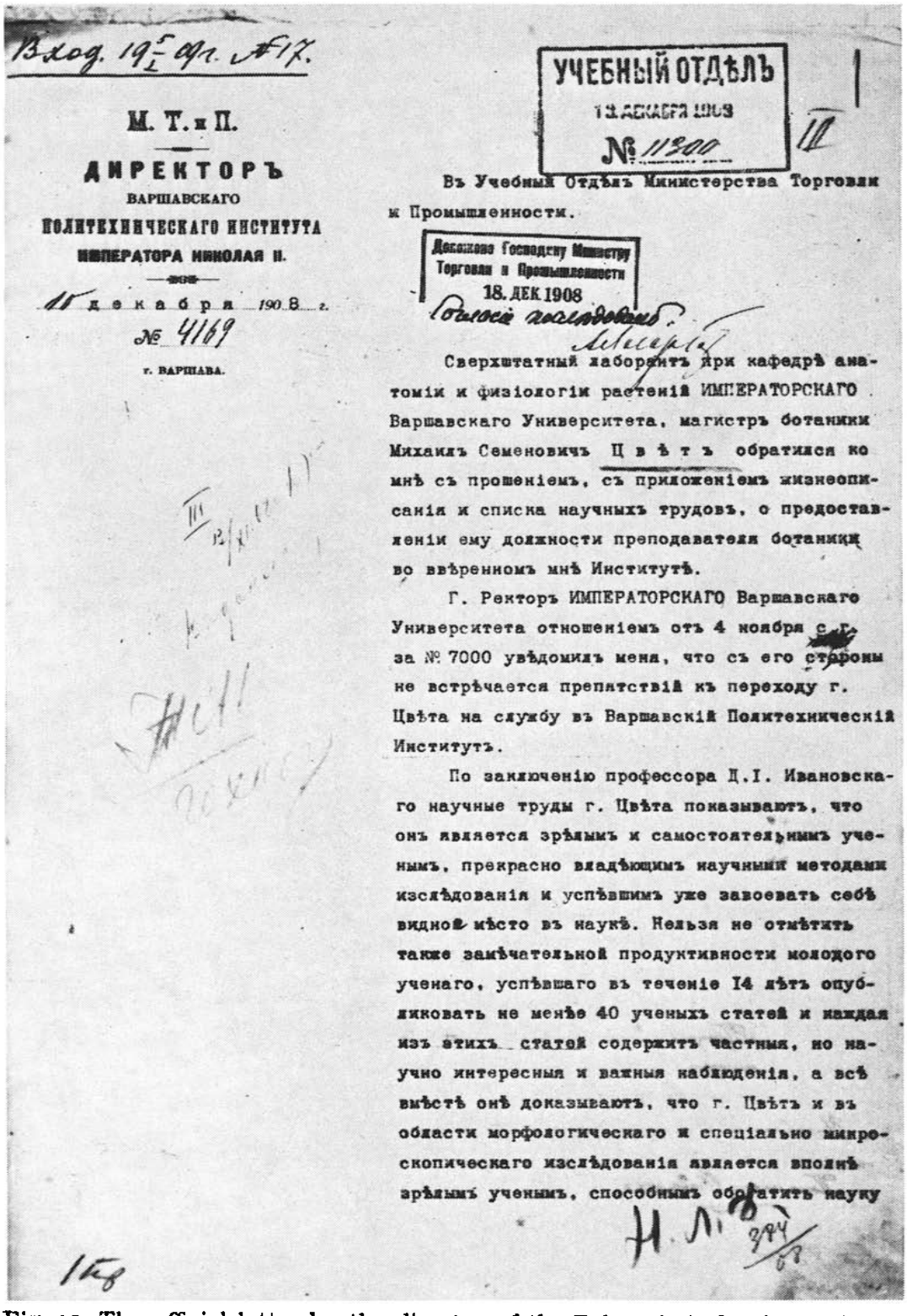
Fig. 30. First chromatographic unit.

However, many of the ideas and the chromatographic method of M. S. Tswett were not recognized during his lifetime. This may be partly due to unfavourable references by some well known scientists with whom Tswett had a scientific controversy.

According to an apt remark of L. ZECHMEISTER, many people met M. S. Tswett's work "with silent distrust"[8,33], which is why some time later Tswett's discovery was not acknowledged and served as the basis of the distrust towards him as a scientist.

During this period, lecturing in botany and microbiology to the first-year students became a burden for Tswett. He had to perform more and more experiments to develop his ideas in order to prove them right, and he was therefore constantly looking for an opportunity to obtain a position in the special Botany Department in the Samara or Novoalekseevsk Institute, or in Moscow or Lvov University. In one of his applications to the Ministry of Education, he wrote: "My nomination to the chair would give me an opportunity to find a broader field of application for my knowledge and to place my scientific work on a broad footing".

But the officials at the Ministry considered the opinion of influential but not



Вход. 19/I 09 г. № 17.

М. Т. и П.

ДИРЕКТОРЪ
ВАРШАВСКАГО
ПОЛИТЕХНИЧЕСКАГО ИНСТИТУТА
ИМПЕРАТОРА НИКОЛАЯ II.

15 декабря 1908 г.
№ 4169
г. ВАРШАВА.

УЧЕБНЫЙ ОТДѢЛЪ
13 ДЕКАБРЯ 1908
№ 11300

Въ Учебный Отдѣлъ Министерства Торговли и Промышленности.

Докладова Господину Министру Торговли и Промышленности
18. ДЕК 1908

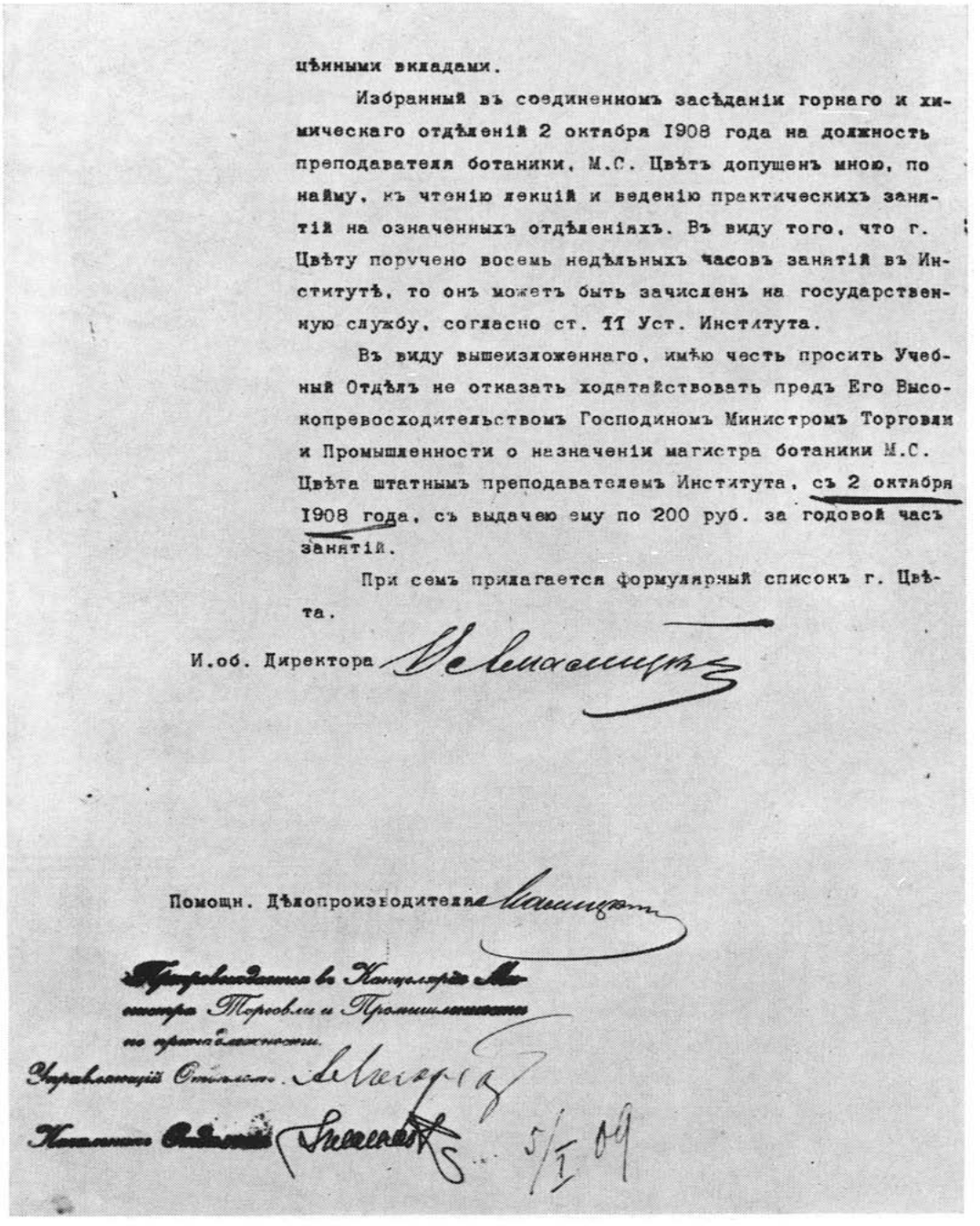
Сверхштатный лаборантъ при кафедрѣ анатоміи и физіологіи растеній ИМПЕРАТОРСКАГО Варшавскаго Университета, магистръ ботаники Михаилъ Семеновичъ Цвѣтъ обратился ко мнѣ съ прошеніемъ, съ приложеніемъ жизнеописанія и списка научныхъ трудовъ, о предоставленіи ему должности преподавателя ботаники во ввѣренномъ мнѣ Институтѣ.

Г. Ректоръ ИМПЕРАТОРСКАГО Варшавскаго Университета отношеніемъ отъ 4 ноября с. г. за № 7000 увѣдомилъ меня, что съ его стороны не встрѣчается препятствій къ переходу г. Цвѣта на службу въ Варшавскій Политехническій Институтъ.

По заключенію профессора Д.І. Ивановскаго научные труды г. Цвѣта показываютъ, что онъ является зрѣлымъ и самостоятельнымъ ученымъ, прекрасно владѣющимъ научными методами изслѣдованія и успѣвшимъ уже завоевать себѣ видное мѣсто въ наукѣ. Нельзя не отмѣтить также замѣчательной продуктивности молодого ученаго, успѣвшаго въ теченіе 14 лѣтъ опубликовать не менѣе 40 ученыхъ статей и каждая изъ этихъ статей содержитъ частныя, но научно интересныя и важныя наблюденія, а всѣ вмѣстѣ онѣ доказываютъ, что г. Цвѣтъ и въ области морфологическаго и спеціально микроскопическаго изслѣдованія является вполнѣ зрѣлымъ ученымъ, способнымъ обогатить науку

Fig. 31. The official letter by the director of the Polytechnic Institute about Tswett.

(Continued on p. 334)



цѣнными вкладами.

Избранный въ соединенномъ засѣданіи горнаго и химическаго отдѣленій 2 октября 1908 года на должность преподавателя ботаники, М.С. Цвѣтъ допущенъ мною, по найму, къ чтенію лекцій и веденію практическихъ занятій на означенныхъ отдѣленіяхъ. Въ виду того, что г. Цвѣту поручено восемь недѣльныхъ часовъ занятій въ Институтѣ, то онъ можетъ быть зачисленъ на государственную службу, согласно ст. 11 Уст. Института.

Въ виду вышеизложеннаго, имѣю честь просить Учебный Отдѣлъ не отказать ходатайствовать предъ Его Высокопревосходительствомъ Господиномъ Министромъ Торговли и Промышленности о назначеніи магистра ботаники М.С. Цвѣта штатнымъ преподавателемъ Института, съ 2 октября 1908 года, съ выдачею ему по 200 руб. за годовой часъ занятій.

При семъ прилагается формулярный списокъ г. Цвѣта.

И.об. Директора

Помощн. Дѣлопроизводителя

Препровождается въ Канцелярію Министра Торговли и Промышленности по принадлежности.

Управляющій Отдѣломъ.

Начальникъ

5/I 09

Fig. 31 *(continued)*.

Fig. 32a. H. Tswett and M. S. Tswett, Warsaw.

very competent people rather than the opinions of people who were familiar with Tswett and could characterize him in the best possible way[7].

A contrary opinion of one of the experts of the Ministry of Education of the Tzarist government, Professor V. Zalesskii, was also published earlier[7].

The difference between the point of view of Zalesskii and that of some other people can be illustrated by the letter of the scientists's wife, Helena Tswett, to the Deputy Minister of Education, found in the State Archives[7,23]. This letter is characteristic of the atmosphere that surrounded Tswett. For this double Doctor of Botany, widely known in Russia and abroad, there was no chair or laboratory available in the Russian Empire, which could only have a negative effect on his life. An outstanding scientist, daring in his scientific works, always a man of principle in his disputes with his opponents, Tswett at the same time was a very gentle and sympathetic man, but quite unpractical. He could not learn to compromise his beliefs amongst the corridors of the Departments and he suffered deeply from the distrust of his associates and his failure to devote himself to science solely.

When German troops approached Warsaw in 1915, Tswett moved to Moscow. He left all his books and archives in Warsaw; later they all disappeared, never to return. He hoped to have favourable changes in his life in Moscow. In his letter to his friend Briquet, dated November 28th, 1915, he wrote[18]: "I hope to obtain a post of a chair at one of the University cities and not to grow too old by this time to go on with my research".

In 1916, together with the Warsaw Polytechnic Institute, M. S. Tswett moved to Nizhnii Novgorod. Here, under the difficult conditions of war, he organized lectures

Fig. 32b. M. S. Tswett, 1911, Warsaw.

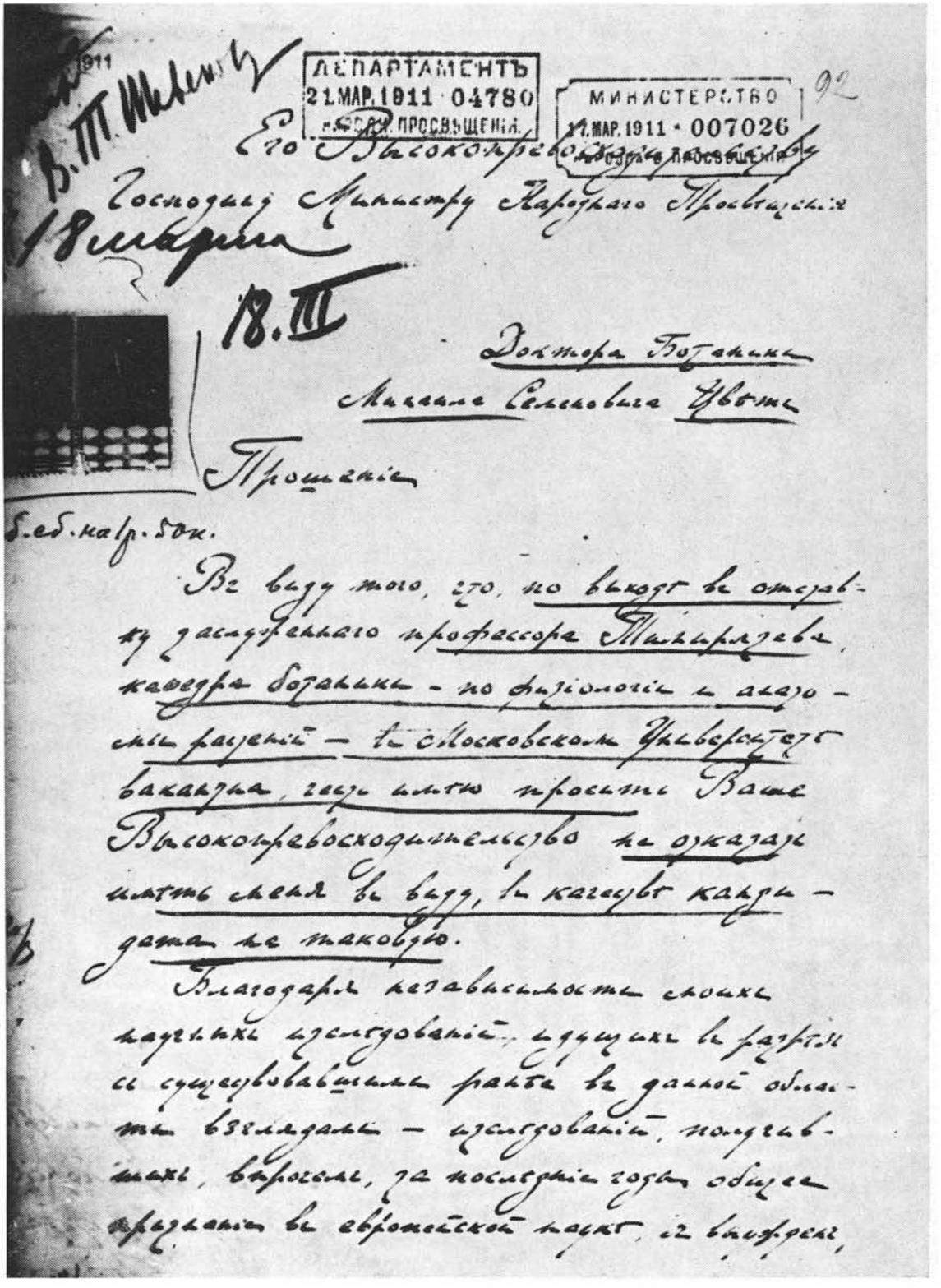


Fig. 33. Letter from M. S. Tswett to the Ministry of Education, 1911. *(Continued on p. 338)*

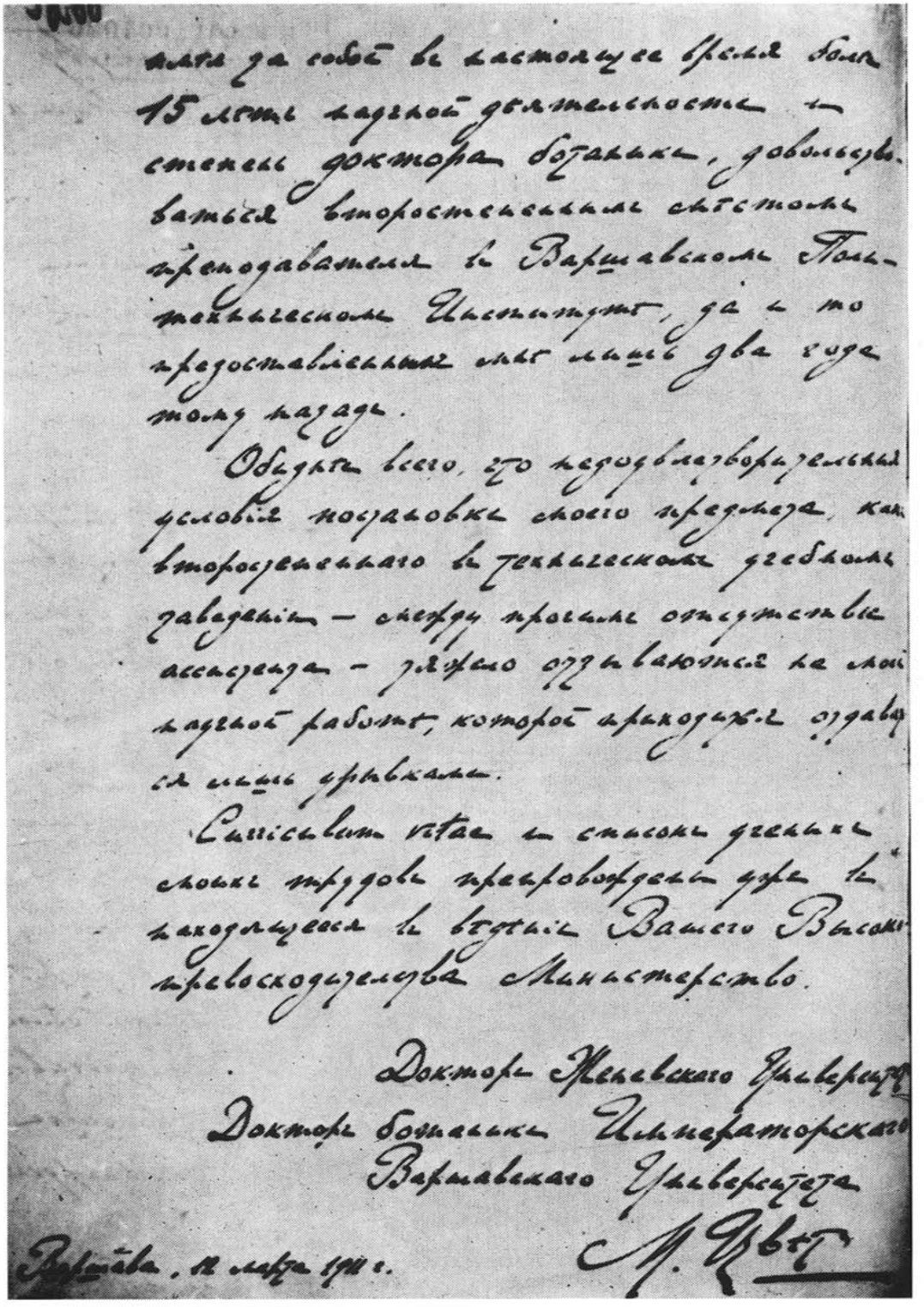


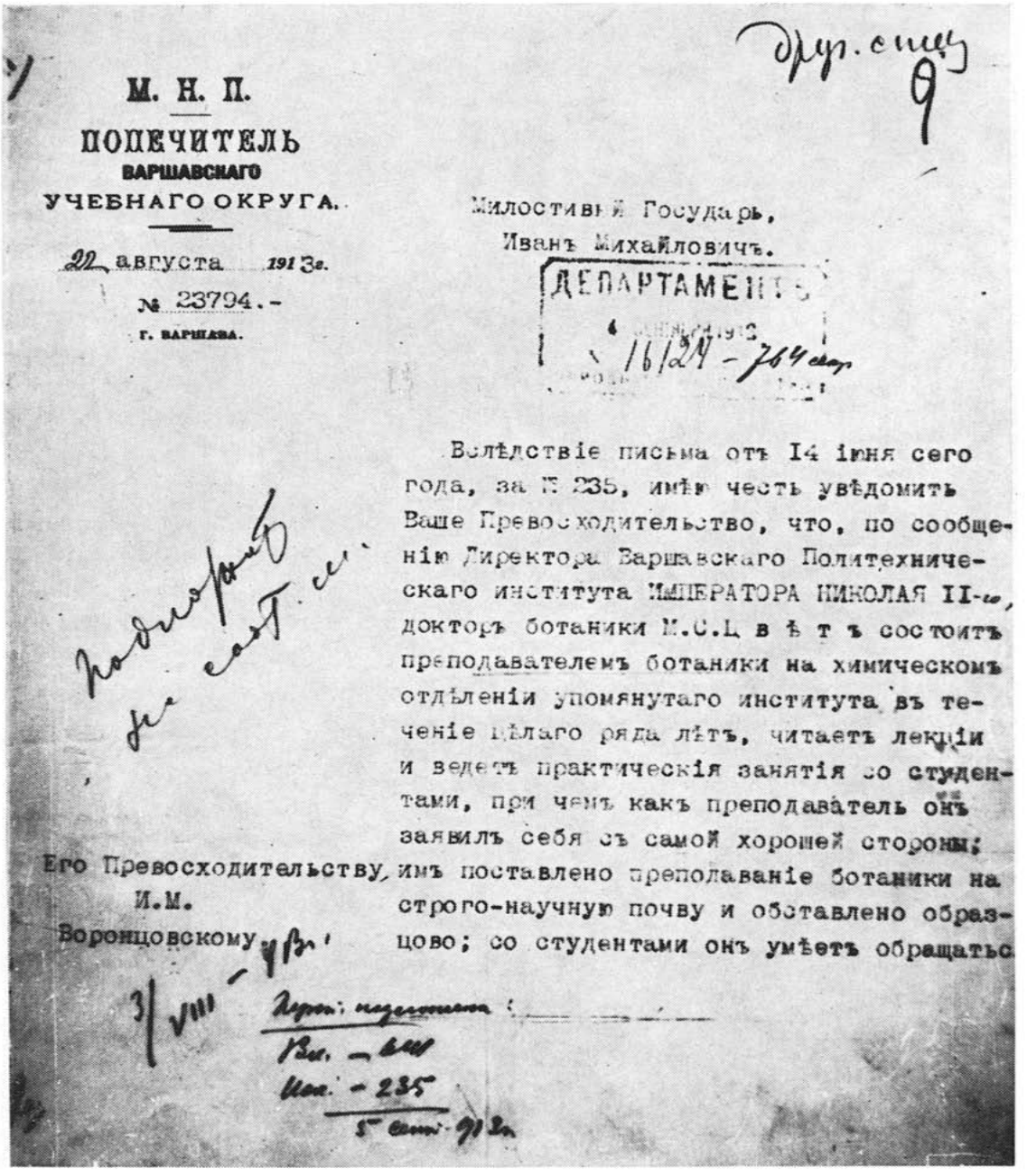
Fig. 33 *(continued)*.

Fig. 34. M. S. Tswett with his step-mother Ella Wilhelmina Tswett (Ebner).

Fig. 35. M. S. Tswett, 1911, Kiel.

Fig. 36. House in Skaternii Street, Moscow, where relations (see Fig. 37) of M. S. Tswett lived.

Fig. 37. M. S. Tswett with his relations (from left to right): Vladimir Tswett-Kolyadinskii, Michael Tswett, Nadezhda Tswett, (then Lyashchenko), Ella W. Tswett (Ebner), Vera Tswett (then Brand), Alexander Tswett-Kolyadinskii.



М. Н. П.

ПОПЕЧИТЕЛЬ
ВАРШАВСКАГО
УЧЕБНАГО ОКРУГА.

22 августа 1913 г.
№ 23794.-
г. ВАРШАВА.

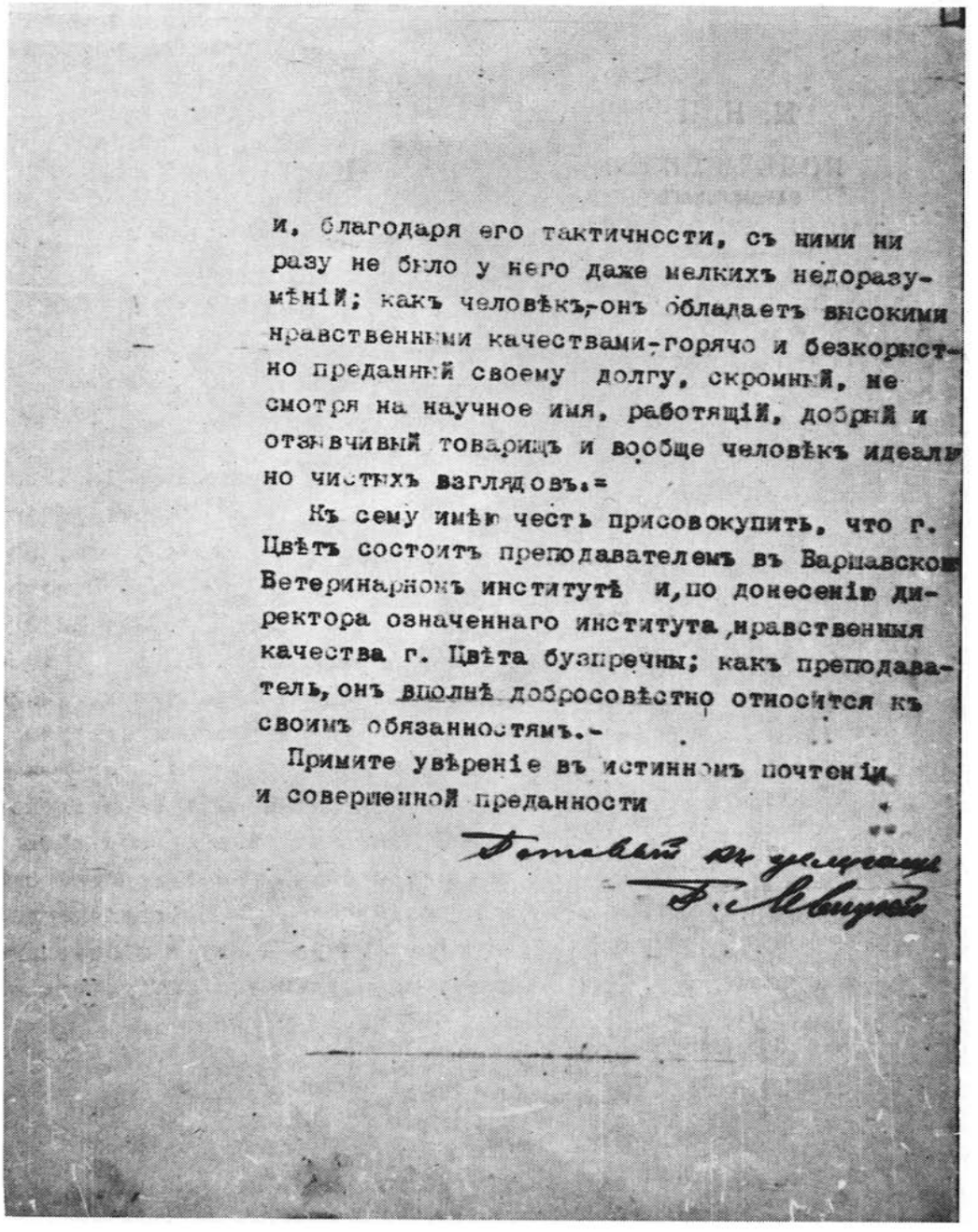
Милостивый Государь,
Иванъ Михайловичъ.

ДЕПАРТАМЕНТ
16/24 - 764

Вслѣдствіе письма отъ 14 іюня сего года, за № 235, имѣю честь увѣдомить Ваше Превосходительство, что, по сообщенію Директора Варшавскаго Политехническаго института ИМПЕРАТОРА НИКОЛАЯ II-го, докторъ ботаники М.С.Ц в ѣ т ъ состоитъ преподавателемъ ботаники на химическомъ отдѣленіи упомянутаго института въ теченіе цѣлаго ряда лѣтъ, читаетъ лекціи и ведетъ практическія занятія со студентами, при чемъ какъ преподаватель онъ заявилъ себя съ самой хорошей стороны; имъ поставлено преподаваніе ботаники на строго-научную почву и обставлено образцово; со студентами онъ умѣетъ обращаться

Его Превосходительству,
И.М.
Воронцовскому

Fig. 38. Letter about M. S. Tswett to the Ministry of Education.



и, благодаря его тактичности, съ ними ни разу не было у него даже мелкихъ недоразумѣній; какъ человѣкъ,-онъ обладаетъ высокими нравственными качествами-горячо и безкорыстно преданный своему долгу, скромный, несмотря на научное имя, работящій, добрый и отзывчивый товарищъ и вообще человѣкъ идеально чистыхъ взглядовъ.=

Къ сему имѣю честь присовокупить, что г. Цвѣтъ состоитъ преподавателемъ въ Варшавскомъ Ветеринарномъ институтѣ и,по донесенію директора означеннаго института,нравственныя качества г. Цвѣта безупречны; какъ преподаватель,онъ вполнѣ добросовѣстно относится къ своимъ обязанностямъ.-

Примите увѣреніе въ истинномъ почтеніи и совершенной преданности

Fig. 38 *(continued)*.

Fig. 39. M. S. Tswett, Warsaw, 1913.

in botany and laboratory work and participated in developing programmes for agricultural courses, which later were reorganized into the Agricultural Institute of Gorkii, Tswett being one of the founders[20].

During this period, M. S. Tswett's health became very poor. On doctor's recommendations he went to Vladikavkaz (now Ordzhonikidze), where his sister and her family lived at that time. He wrote to Geneva from this city on July 18th, 1917: "I obtained a full professorship in Yur'ev (Derpt, Tartu), where I am also in charge of the Botanical Gardens. This could have been very happy news for me if my state of health had not become so poor within the last two years and if there had not been the menace of a new occupation because the Germans are in the vicinity of Yur'ev.

Here the political situation is rather strained and the revolution acquires an increasingly social nature. "Death to the bourgeois" can be read on many slogans carried by the demonstrating Bolsheviks, the supporters of Lenin.

Claparède told me in his letter that you suffer greatly from war there in Geneva. If only this war would finish. Both opponents in the war resemble to me two infuriated lions ready to gorge one another till the end of their tails"[18].

This noteworthy letter shows the understanding by M. S. Tswett of the social

Fig. 40. House of Nadezhda Tswett-Lyashchenko, near Kiev, with whom M. S. Tswett stayed in 1915.

Fig. 41. Building of the Technical School of Nizhnii Novgorod, where the Polytechnic Institute was installed in 1916.

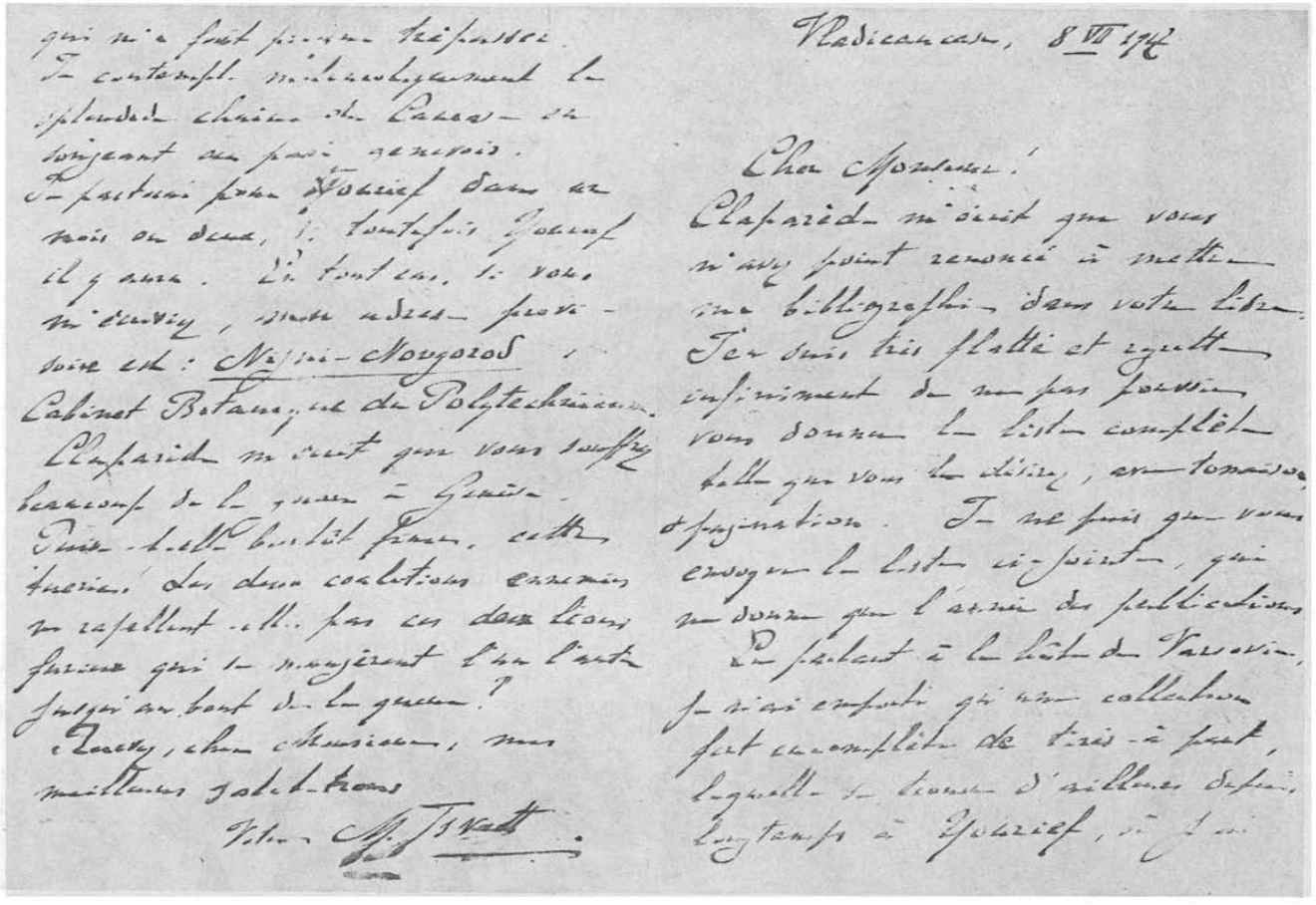


Fig. 42. Letter from M. S. Tswett to J. Briquet from Vladikavkaz.

forces behind the revolutionary processes in Russia and of the unjust nature of World War I*.

In the autumn of 1917, Tswett moved to Tartu (Estonia), where he started lecturing in general botany, but he hardly had time to give lectures on the first part of the programme for the first term when German troops marched into Tartu in February 1918. In spite of the persuasion of German friends, Tswett left that quiet city which he loved. Together with other Professors of the Russian Department of the University, he moved to Moscow and then to Voronezh[30].

In Russia the revolution triumphed, but counter-revolution unleashed the Civil War and nobody cared for the sick Professor. A tender-hearted man, I. V. Verevkin, a veterinary surgeon, offered Tswett a small room in his house at the end of his court-yard in Khalutinskaya (Baturinskaya) street. Here in the garden it was quiet and comfortable. Quite near was the high bank of the river, where the ailing scientist, deserted by nearly everybody, often went for a walk. In Voronezh he became one of the first Professors of Voronezh University. Both in Tartu and Voronezh, Tswett's

* M. S. Tswett's sisters and brothers, like himself, after the Great October Revolution belonged to the representatives of the Russian intelligentia who were not hostile to the Soviet power. His brother, V. Tswett-Kolyadinskii, holder of four St. George Crosses for courage, became one of the first pilots in the Red Army[13,14].

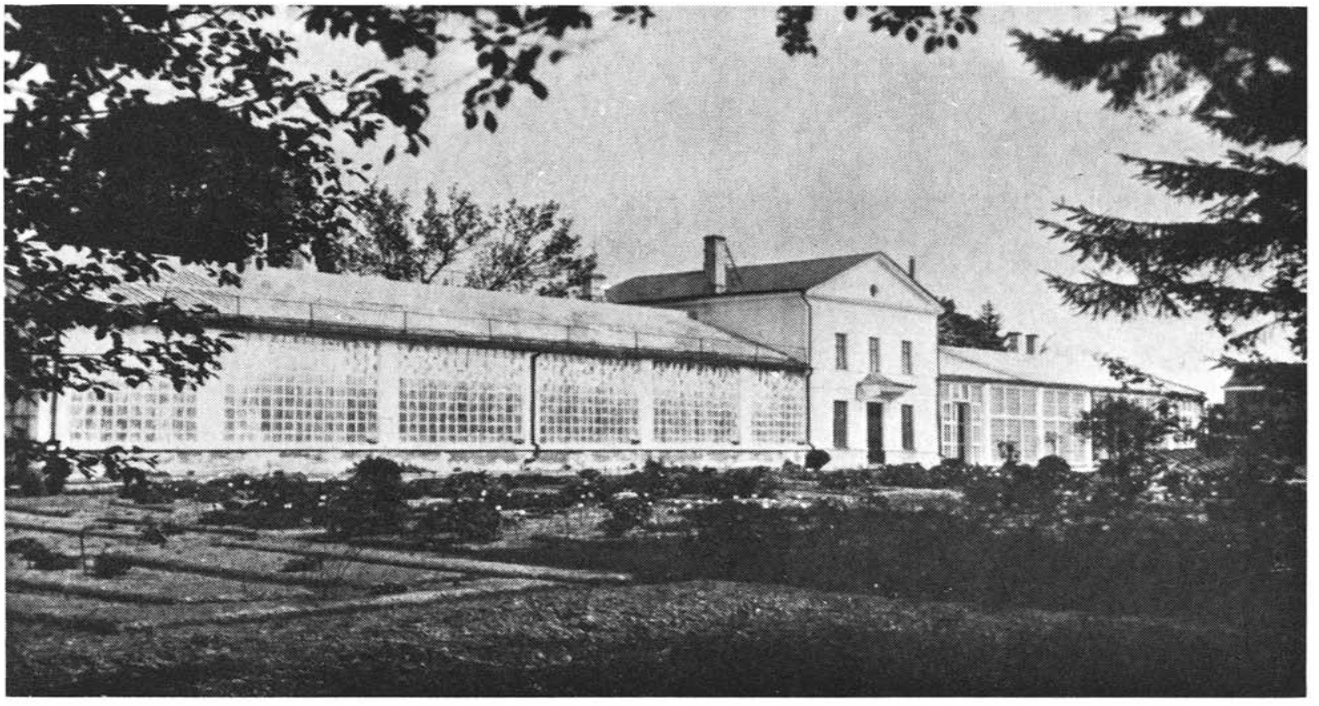


Fig. 43. Botanical Gardens of the Yur'ev University (Tartu).

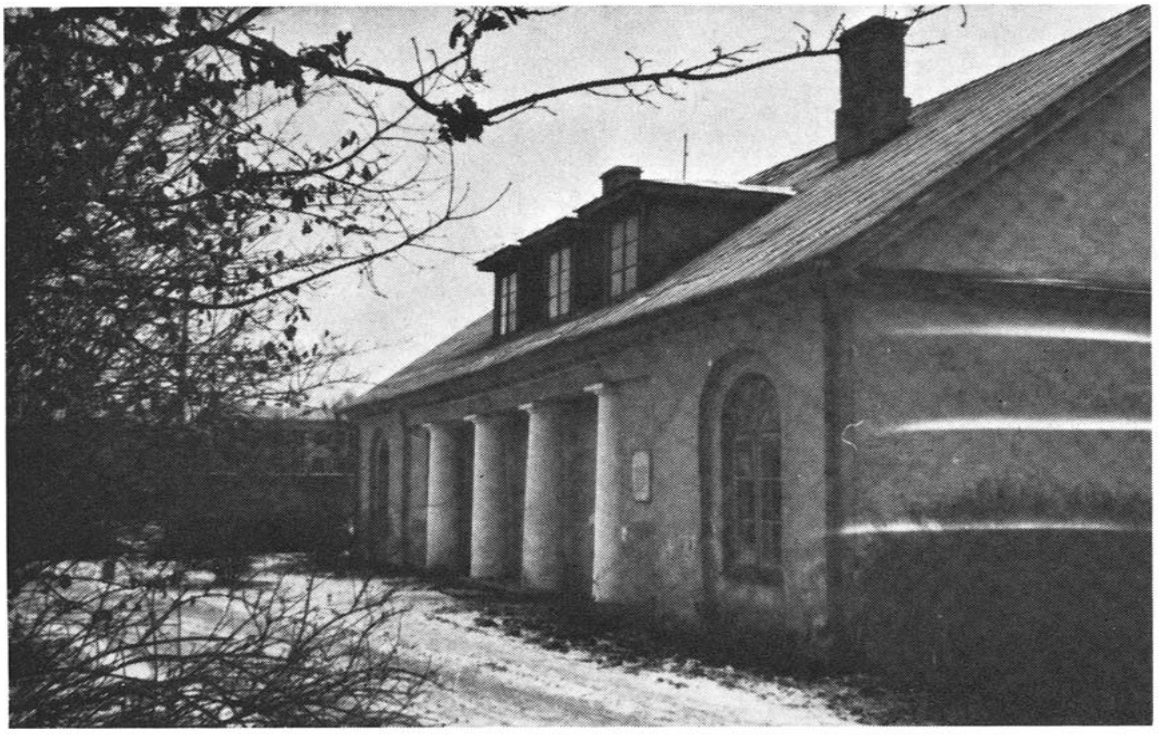


Fig. 44. The house in the Yur'ev Botanical Gardens where M. S. Tswett gave lectures.

Fig. 45. The old house of Voronezh University.

Fig. 46. The window of Tswett's room.

Fig. 47. M. S. Tswett on his deathbed.

СПИСОК

ОФЕССОРОВ, ПРЕПОДАВАТЕЛЕЙ И НАУЧНЫХ СОТРУДНИКОВ
ОРОНЕЖСКОГО УНИВЕРСИТЕТА, УМЕРШИХ С 1919—1924 Г.Г.

1919 г.

1. Гумовский, Емельян Андреевич—ординатор акушерско-гинекологической клиники. 22 апреля.
2. Шошков, Николай Александрович—ординатор клиники нервных и душевных болезней 10 мая.
[illegible]екштрем, Альберт Густавович—преподаватель [illegible]сической филологии. июнь
[illegible]ржеевский, Виктор Викторович—ординатор [illegible]рвных и душевных болезней. июнь.
[illegible]ка, Август Янович—хранитель музея древно[illegible]зящных исскуств. 7 июня
Цвет, Михаил Семенович—профессор ботаники. 26 июня
Лебе[illegible]в, Николай Александрович—ординатор пропе[illegible]ической терапевтической клиники. 10 августа
Андерсен, Эйнгард Эрнестович—лектор английского [illegible]ыка 23 августа.
9. [illegible], Платон Платонович—профессор математики. [illegible] ноября.
10. Конаржевский, Франц Францевич—помощник [illegible]блиотекаря 19 ноября.
11. Шалланд, Лев Адамирович—профессор истории [illegible]рава и государства. 13 декабря.

Fig. 48. Information about the death of M. S. Tswett.

Fig. 49. Alekseev Monastery where M. S. Tswett was buried.

Fig. 50. The opening address of Prof. A. Kiselev during the installation of a memorial tablet to M. S. Tswett, Voronezh, in June, 1969.

health was poor. He could lecture only when sitting at a desk. His thoughts were clear, the ideas were profound and consistent, but it was clear that it took a great effort to lecture. The University doctors stated that he had suffered from heart disease[5]. He died on June 26, 1919 in the hospital and was buried not far from his last refuge in the cemetery of the Alekseev monastery[31]. During World War II the cemetery was destroyed and it is now impossible to find M. S. Tswett's grave. The modest memorial tablet placed on the house at 20, Baturinskaya street, in June, 1969, reads "Here lived the outstanding Russian scientist Mikhail Semenovich Tswett, 1872–1919". In May 1972 memorial tablets were unveiled in Asti and Leningrad.

3. CHROMATOGRAPHIC WORKS BY M. S. TSWETT

During the three different periods of his work (in Geneva, Saint Petersburg and Warsaw), M. S. Tswett worked not only in different cities, but partly also on different problems. The number of his published works totalled 62, three of them being books[17a,21,22], the rest being mostly short papers. The publications dealt with the problems of cell physiology, chlorophyll chemistry, photosynthesis and chromatography.

M. S. Tswett's distinguishing features as a scientist were exceptional erudition, thoroughness in the lay-out and execution of experiments which he did himself, his power to generalize, his respect for the work of other scientists, coupled with his being a man of principle in sticking to his views, his ability to present his thoughts in a clear and accurate form and, when necessary, in a telling metaphorical way.

An indication of M. S. Tswett's emphasis on the search for purely physical methods of separation can be found in his work of 1899 but especially in his Master's

thesis. He there states: "Different coloured bands were observed by me when filtering a petroleum ether extract of leaves through Swedish paper", and he added that "instead of paper, linen or starch powder can be used". This enabled him to say in the foreword to his main book[22] that the embryo of the analytical method had been described in his Russian work of 1901.

First chromatographic paper (1903)

Only two years later the above method was outlined more clearly. In his paper "A New Category of Adsorption Phenomena and its Application to Biochemical Analysis" Tswett remarked: "Especially instructive is the observation of adsorption phenomena during filtration through powder. First a colourless then yellow (carotene) liquid flows out of the lower end of the funnel, and in the upper layers of an inulin column there is formed a green ring, below which there appears a yellow border. During the subsequent flow through the inulin column of pure ligroin, both rings, green and yellow, considerably broaden and spread downwards ...

... On the basis of the foregoing, there appears the possibility of developing a new method of physical separation of different substances dissolved in organic liquids. The method is based on the ability of the solutes to form physical adsorption compounds with different mineral and organic solids"[3,24].

In this first chromatographic work, M. S. Tswett for the first time used the developing variant of chromatography in addition to the frontal version; he described the use of more than 100 different substances as adsorbents, for the first time used the methods of stepwise changes of the properties of the solvent, and determined that purely physical adsorption of substances takes place. The only missing aspect in this work was the term "chromatography", which, naturally, does not prevent us from considering it to be the first work on chromatography*.

The 1906 papers

In the next works[26,27], published three years after the 1903 report, M. S. Tswett introduced the term "chromatography". He wrote: "If a petroleum ether solution of chlorophyll is filtered through a column of adsorbent (for this purpose I use mainly calcium carbonate, tightly packed into narrow glass tubes), the pigments, according to their position in the adsorption sequence, are deposited in separate coloured zones along the column from the top down, due to the fact that the pigments with stronger adsorption displace those which are more weakly retained. This separation becomes practically perfect if, after the extract of pigments has passed through the column of adsorbent, the latter is washed with pure solvent". He then vividly and metaphorically described[26] his discovery: "Like rays of light in the spectrum, different components of the pigment mixture are naturally arranged in the column of calcium carbonate, which allows their qualitative and quantitative determination. The preparation thus obtained I name a chromatogram, and the method proposed—chromatography" (*cf.* ref. 31).

In the same paper, M. S. Tswett gave in advance an answer to those who would

* Unfortunately, some authors dated the discovery of chromatography as 1906, when M. S. Tswett's first article was published in German[26,27].

consider the method suitable only for the separation of coloured substances, judging by its name: "It is obvious that the adsorption phenomena described are characteristic not only of chlorophyll pigments; it is evident that different coloured and colourless compounds follow the same regularities".

In his next paper[27], M. S. Tswett described a manifold with a number of chromatographic columns, 2–3 mm in diameter and 30–40 mm in length, the pressure head at the inlet being 0.5 atm; he described a detailed method of preparation of highly efficient columns and pointed out the necessity of using small and homogeneous particles of adsorbent: "Fineness of the adsorption powder is very important: when roughly ground material is used the chromatograms are blurred, as diffusion in too wide capillaries interferes with the adsorption".

In the same work, Tswett first described the use of columns 20 mm in diameter for preparative purposes and mentioned the necessity of using, in some cases, adsorbents that would provide for hydrolytic or oxidation–reduction reactions on their surface.

In these two papers there is an inaccurate description of the nature of the processes that occur in capillary analysis (predecessor of paper chromatography in the frontal version). At this time, M. S. Tswett ruled out adsorption as the basis of this method and he thus suggested: "In order not to mix up different matters, the term "adsorption analysis" should be reserved for the method developed by me. But this, undoubtedly does not lessen the significance of capillary analysis". Subsequently, Tswett modified his opinion, admitting that adsorption might also be involved. In his major work[22] he wrote: "The band of filter-paper, used for capillarization of solutions, is analogous to the column of calcium carbonate powder or other adsorbent used in chromatographic analysis".

A study of his first works on chromatography conveys a vivid idea of the major stages of the discovery of chromatography. First Tswett carried out static experiments on the adsorption of pigments by filter-paper. By using different solvents and displacing adsorption equilibrium, he successively solubilized different pigments. Then, instead of filter-paper, he used adsorbent powder. As adsorbent powder had to be filtered off, Tswett placed it in a funnel and this suggested the use of dynamic conditions, combining filtration and adsorption operations, *i.e.*, carrying out separation by the frontal version. Similarly, as in the static experiments he had used a solvent wash on the coloured filter-paper to solubilize carotene, so after the partial separation of the coloured zones he then proceeded to wash with solvent under dynamic conditions and thus discovered the elution development version of liquid chromatography. He noted the advantage of this method over the frontal version, making it possible to achieve complete resolution.

It is worth mentioning some of the principal qualities of M. S. Tswett that were conducive to his discovery of chromatography. In the first place, he was an excellent chemist, physicist and botanist, a man of great erudition, a subtle observer and a brilliant experimentalist. His experiments with chlorophyll gave him a splendid opportunity for observation as it was possible to follow the movement of the coloured zones visually. He proceeded from his previous experience, but he did not stop there as he constantly searched for a new and more powerful physical separation method until he succeeded.

When evaluating M. S. Tswett's role in the discovery of chromatography, *i.e.*, a continuous multi-stage sorption process, one can compare this discovery with such a

great step forward as the development of methods of separation and analysis, which represented a transition from single evaporation to multi-stage distillation. It should be borne in mind that these two stages are separated by centuries of research.

Chromophylls in the Plant and Animal World (1910)

M. S. Tswett's major monograph, which represents his Russian thesis for a Doctor's degree, shows the further development of his chromatographic method[22]. The work comprises three parts and is striking in its thoroughness. The first part is devoted to methodology. Four chapters of the eleven discuss adsorption from solvents presented in the literature and describe methods of adsorption chromatographic separation. The second part describes the results of the study of chromophylls of seminal plants and archegoniates, algae and bacteria, flagellates and animals (twenty chapters altogether). The third part, comprising three chapters, is dedicated to the energetics of chromophylls and presents the author's ideas of the mechanism of photosynthesis.

In this book, Tswett's new ideas and results, obtained by the chromatographic method, are of major interest. Naturally, a substantial proportion of the material on this matter in the book overlaps with the above-mentioned results of the first three publications on adsorption chromatographic analysis[24,26,27], but here the theory of the method is essentially developed.

Data on the study of the adsorption properties of 126 different adsorbents are of interest. Tswett carried out a thorough study of the phenomenon of adsorption substitution of some substances by other substances, thus defining an adsorption series. In some of his experiments he used displacement chromatography for separation. He gave a very detailed description of the mechanism first of the frontal separation of mixture components, and then of the process of the migration of sorbed substances under the stream of solvent, which results in "the mass of adsorbate moving slowly in the direction of the current of pure solvent", during which process the zone broadens. Tswett wrote "When passing an appropriate solvent through the column of adsorbent, saturated at its top with some substances, the latter, besides displacement phenomena, will move with different speeds and then gradually separate as independent adsorption zones".

Tswett realized the necessity of studying the aggregation states of the pigments when they become adsorbed, by exploiting their spectroscopic properties and examining, for instance, the reflection spectra of adsorbates. He emphasized that all the phenomena studied confirm the purely physical nature of adsorption which can take place only if there is no complication arising from chemical interactions or the formation of molecular complexes between the solutes. At the same time, he noted the inadequacy of the thermodynamic theory of adsorption and thought it necessary to supplement it with the molecular-kinetic approach. Tswett observed the distortion of the front of zones in columns of large diameter (up to 30 mm) owing to uneven movement of the stream through different parts of the column cross-section. He gave detailed recommendations on the selection of adsorbents and solvents.

It should be noted that M. S. Tswett gave thorough consideration to the processes of capillary analysis, which before his work were carried out by using the frontal method. He did not use the developing chromatographic technique, developed by him, although he was the first to point out this method, having compared a strip of

paper with a chromatographic column, as already mentioned. In spite of the shortcomings of capillary analysis demonstrated by direct experimental evidence ("partial separation, crude, incomplete"), Tswett wrote, quite unbiased: "However, further development of capillary analysis is highly desirable".

A number of chapters of the book can be considered as being a detailed manual on chromatography, which is of interest even now, 70 years after the discovery of the chromatographic method.

In some short papers, M. S. Tswett gave a description of the practical application of the chromatographic method.

Tswett's main methodical contributions

While alive, M. S. Tswett did not earn honours, neither did he win full recognition. He died in obscurity, but he was deeply convinced of the importance of his discovery. Unfortunately, in Tzarist Russia, conditions were such that part of his merit could not be realized in full measure.

In evaluating the part played by M. S. Tswett in creating chromatography, it should be noted that his discovery of chromatography was based on the results of the study of adsorption available in his time, due to the efforts, in particular, of Lowitz, Ostwald and Freundlich. The ability of M. S. Tswett to make a profound analysis of the works of other scientists by no means detracts from the importance of the very fact of discovery. A study of M. S. Tswett's works reveals that his merit is first of all in defining the basic principle of the process as a multi-stage separation of complex mixtures by sorption, discovering the elution development version of chromatography, substantially developing the frontal version, establishing the possibility of carrying out the processes according to the displacement version, and unifying all the versions of the chromatographic method by a general approach. Of exceptional interest are M. S. Tswett's ideas concerning the physical nature of adsorption in chromatographic separations, the conditions that lead to rapid establishment of adsorption equilibrium, the distribution of substances in adsorption series, and, accordingly, the regular order of their distribution along the column or at the column outlet. He pointed out the possibility of adsorption on a surface previously saturated with another adsorbed substance, and was the first to show distinctly the complex nature of interactions in a sorbate–sorbent–solvent system. He suggested what is now known as reaction chromatography. He was the first to carry out modification of adsorbents by heating them. By discussing the sorptive properties of water, he showed to a certain extent, the way to partition chromatography (ref. 22, p. 87). M. S. Tswett also made a gas (air or methane) pass through the column, although this was done only to eliminate the solvent.

Tswett used the chromatographic method widely, not only to separate a mixture and to establish the fact that it consists of different components, but also for quantitative analysis; he contemplated the possibility of introducing reference (marker) components into the mixture to facilitate identification. He was the first to use chromatography as a preparative method to produce individual compounds and to change deliberately the properties of the mobile phase in the course of the chromatographic process. He also pointed out the need for a spectral study of compounds in the adsorbed state.

M. S. Tswett carried out for the first time chromatographic processes under reduced or increased pressure, gave recommendations for the preparation of effective columns and used both micro-scale and preparative columns and the inverse flow of the mobile phase in the column. He drew attention to the necessity of accounting for the simultaneous occurrence in the column of adsorption processes and of diffusion phenomena. He carried out the separation of substances both by the method of elution of sectional zones and by the effluent method.

M. S. Tswett proposed that all pigments (and all substances) should be subjected to chromatographic analysis in order to elucidate their composition and to check their purity[32]. Apart from evolving the fundamentals of the method and using it extensively to solve many problems that are complicated even at the modern level of development, he introduced many basic concepts and terms of the novel method, including the name of the method—"chromatography", "development", "displacement", "chromatogram", etc.

The present extensive development of paper chromatography is to a considerable extent the result of extending the general relationships discovered by M. S. Tswett on columns to paper strips. He paved the way to thin-layer chromatography by showing the analogy between the properties of a paper strip and those of a calcium carbonate layer used for chromatographing solutions in columns.

This detailed examination of all that has been introduced by M. S. Tswett into chromatography confirms the view of Zechmeister, who wrote: "M. S. Tswett is the true inventor of chromatography in all of its fundamental aspects"[28,33].

M. S. Tswett envisaged chromatography merely as a method with which he would be able to solve other problems in which he was deeply interested, such as the structure of the subcellular components of plants and animals and the mechanism of photosynthesis, and in these fields he has launched many novel ideas and established many new relationships. Some of these have been highly appreciated. However, he entered the history of science in the first place as the founder of chromatography.

As is well known, in the early days chromatography remained unnoticed. Zechmeister was correct in stating[28] that the importance of many an outstanding discovery is not always appreciated at first and that further development often begins only after a considerable period of time has elapsed. The duration of such a latent period is a measure of the extent to which the discoverer has advanced ahead of his contemporaries. The latent period of chromatography lasted about 25 years, only a small number of various applications of the method being reported, *e.g.*, the Czech biochemist STOKLASA in 1909 and DHÉRÉ in Switzerland from 1911 used chromatography systematically[34]. In the U.S.A., this method was used by PALMER[35]. The works of COWARD (1929)[36] and LIPMAA (1926)[37] who were concerned with a study of extracts from flowers and the separation of rhodoxanthin and xantophyll, also fall within this period. BERL AND WACHENDORF[38] were then drawing near to the use of gas chromatography. However, chromatography did not develop extensively during that period. In part this may be due to the warning voiced by WILLSTÄTTER, who was afraid of chemical reactions of pigments with adsorbents. But the main reason was the absence of a genuine need for the method. The latent period lasted until about 1931 when the work of LEDERER, KUHN and WINTERSTEIN[39–41] opened up the new and still developing epoch of the flourishing of chromatography in its more advanced versions in new fields of application.

Forerunners of Tswett

From time to time there have appeared the results of interesting searches into the old literature for work carried out in the pre-Tswett period of chromatography[42–49].

It seems that the earliest works in this field were those of RUNGE, who had used since 1834 a radial method for separating salts and organic substances[50,51]. Then in 1851 SCHOENBEIN and GOPPELSRÖDER started a series of investigations on the so-called capillary analysis, which consists in the separation of zones by capillary ascent of sample solutions on strips of paper[52–54]. Tswett was well acquainted with this work and wrote: "Goppelsröder devoted himself from 1861 to the practical development of Schoenbein's idea with astounding patience and accumulated an enormous number of observations" (ref. 22, p. 106). Tswett noted the work carried out in 1851 by COHN who obtained a radial chromatogram with three rings when evaporating drops of a solution of "phycocyan"[55].

Another group of studies was devoted to separations on a bed of sorbent. It seems that in this case it is best to begin with the words of M. S. Tswett, who, citing Sachsse, (ref. 22, p. 24) wrote: "The absorptive properties of soil with respect to salts were known already to Aristotle, since he pointed out the conversion of sea water to potable water by passing it through a layer of earth". WILLIAMS[47] referred to the work of THOMPSON AND WILLIAMS, who developed a separation method on a column with an adsorbent long before 1850. Later, the work of READ (1893)[56], who observed some changes in the composition of a solution of salts when filtered through powdered kaolin, is mentioned. The work of DAY (1897)[57], who observed the clarification of oil upon being filtered through a limestone bed, was described. In 1900, S. K. KVITKA received a patent for a method of fractionating petroleum by filtration through porous media[48]. Similar results were obtained by ENGLER AND ALBRECHT[58]. This list of publications could be extended further.

In both cases, adsorption separations were carried out by the simplest versions of frontal analysis. In spite of their unquestionable value, usefulness and interest, none of these proposed methods was able to evolve into the chromatography that is used so extensively today.

The name of chromatography

Instead of the name "chromatography", it has been suggested that the method should be named after Tswett in his honour, that is, "Tswettanalysis" or "Tswett-sorboanalysis"[59–61,66], while other workers have proposed the term "sorption analysis"[62–64] or the unusual term "likmisis"[64]. M. S. Tswett used two terms almost equally: "chromatographic analysis" and "adsorption analysis", and also sometimes "adsorption chromatographic analysis". A reply to all these suggestions has been given by ETTRE[65]. By keeping the name of chromatography, which is familiar and customary to everyone, then M. S. Tswett will receive the measure of respect that he deserves as the founder of the method. It is necessary to remember also the words of PURNELL about the similarity between the surname of Tswett in Russian and the Russian word for colour[67].

4. CONCLUSION

As a scientist, M. S. Tswett was not only the founder of chromatography. He considered chromatography first of all as a method that he could use to solve other problems in which he was interested, such as the structure of plant plasma and the mechanism of photosynthesis. In these fields he put forward many new ideas that were given credit in his time, but he went down in the history of science in the first place as the founder of chromatography. Undoubtedly, Tswett was an investigator of remarkable personality, who outstripped his epoch and belonged to the group of outstanding scientists of the beginning of the 20th century who enriched science with discoveries of paramount importance.

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