

Review

Separation Sciences in Poland

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Abstract: This paper describes the most significant achievements related to the creation and development of separation methods. Tswiett Nerst's achievements and the role of such centers as Lublin, Warsaw, Gdańsk, Poznań, Łódź, Silesia, Kraków and Toruń are presented, as well as the role of leaders who created theories and methodological studies on chromatography and related techniques. The role of sample preparation methods is emphasized based on the same or similar theoretical foundations. The directions of developing these techniques in Poland today and in the future are presented.

Keywords: history of chromatography and related techniques; interwar period; post-war chromatography development; sample preparation methods; chemometrics; compressed techniques

Everything, in modern separation techniques, began on Polish soils. In the former East Prussia in Wąbrzeźno (from German: Briesen), Walther Nernst was born on the 25 June 1864. He graduated from high school in Grudziądz. After studying and defending his PhD (University of Würzburg), he became a professor at German universities (Leipzig, Heidelberg, Berlin, Göttingen). In 1920, he was awarded the Nobel Prize in chemistry for the third law of thermodynamics. In addition, he introduced to the world scientific literature: the law of partition, the basics of the extraction process in the liquid–liquid system, and the equation for the electrochemical potential of galvanic cells. [1] (Figure 1).

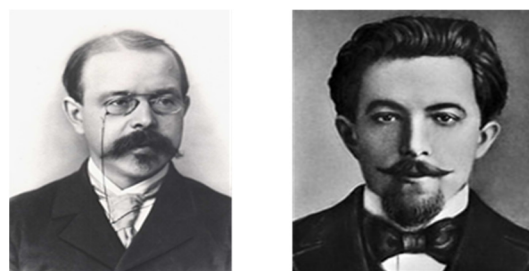


Figure 1. The fathers of physicochemical separation techniques W. Nernst (1864–1941) and M.S. Tswiett (1872–1919).

Another important person who introduced the term and the basics of the chromatography process to the world of science was Mikhail Siemionowicz Tswiett, a botany professor at the Imperial University of Warsaw and the Warsaw University of Technology (Poland was not on the world map, and the Russian tsarist regime occupied this part of the country, including Warsaw) [1] (Figure 2).

On the 21 March 1903, during the Warsaw Scientific Society meeting, he presented the concept and results of systematic research on column liquid chromatography in separating dyes (chlorophylls, chloroplasts, and carotenoids as analytes) (Figure 3). He used ground chalk (calcium carbonate) as the column filling (bed), and the mobile phase consisted of solvents, i.e., benzene, ethyl ether, or ethyl alcohol (mobile phase). The mechanisms responsible for the separation process, according to M.S. Tswiett were adsorption and



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separation. It was not until the 1930s that a detailed study by Kühn et al. [2] and the works of Martin et al. [3] led to a complete description of the process, closer to contemporary interpretation. This resulted in A. Marina and R. Synge being awarded the Nobel Prize in 1952 [4].



Figure 2. The building of the University of Warsaw with the Tswiett's laboratory and a memorial plaque commemorating the discovery of chromatography.

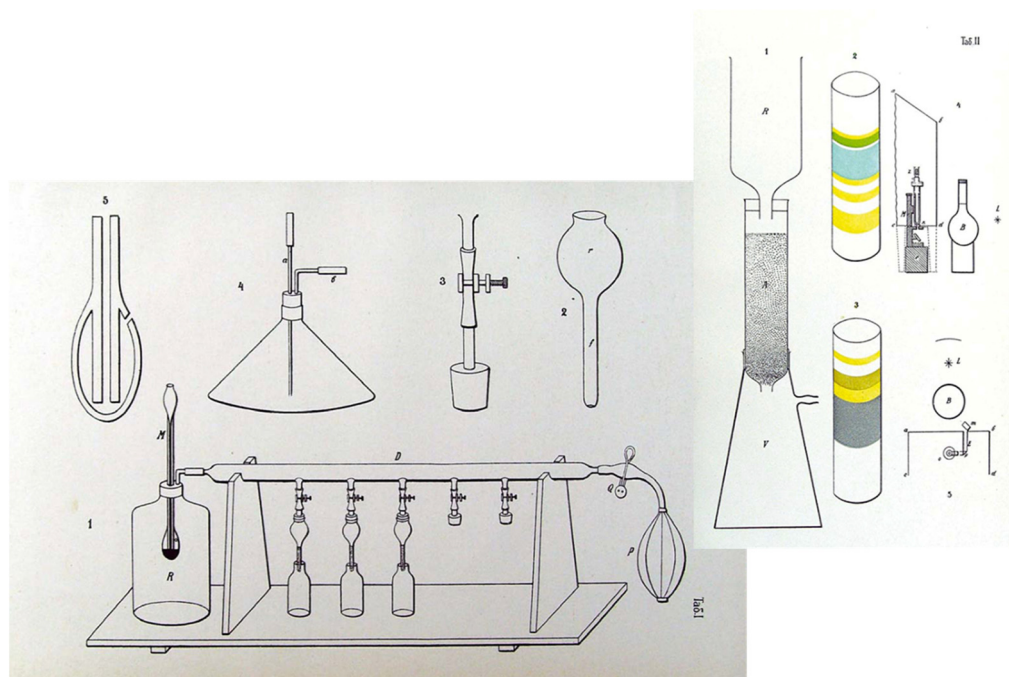


Figure 3. Chromatographic set and the concept of separation of natural dyes according to M.S. Tswiett.

There is no information on the development of this technique in the interwar period in Polish literature. At that time in Poland's leading academic centers (Lviv, Vilnius, Kraków, Poznań, and Warsaw), analytical techniques of physicochemical separation (extraction, flotation, or chromatography) were developed. These studies were mainly carried out by former students (W. Świętosławski, B. Szyszkowski, S. Glixelli, or B. Kamiński) of such masters as: Prof. W. Nernst, Prof. W. Oswald, Prof. S. Arrhenius, pPof. F. Donnan or Prof. J. Hayrovski who obtained a PhD under their supervision or did post-doctoral internships. Unfortunately, there is a lack of details in this matter. Like in many European countries after 1945, scientific life in Poland was rebuilt from scratch. Due to the repatriation movement resulting from the "new territorial order", many Polish scientists from Vilnius, Lviv, Kiev, and Western Europe took the positions of professors/heads of departments

started organizing scientific and academic life. For example, Prof. W. Kemula who came from Lviv to Warsaw, Prof. A. Basiski from Vilnius to Toruń and from Kraków to Lublin, Prof. A. Waksmundzki [5]. As a result, there has been an intensification of research and development, both theoretical and practical, in the field of separation techniques, including chromatographic and related ones, both in quality and purity control of various substances as well as process control in multiple departments and branches of industry and economy. Centers mainly involved in building modern research groups in physicochemical surface phenomena, especially separation processes, were formed and focused around Prof. Andrzej Waksmundzki from the Maria Curie Skłodowska University in Lublin and Prof. Wiktor Kemula from the University of Warsaw [6].

This contribution presents the most significant achievements that have been achieved in the construction of the “Polish chromatography school” in individual academic centers: Lublin, Warsaw, Gdańsk, Poznań, Łódź, Silesia, Kraków and Toruń. Significant influence on it had organized after the war in 1951, first Congress of Polish which resulted in the Chromatographic Colloquium (1954, Krakow). The consequence of this meeting was the publication, edited by professors: J. Opieńska-Blauth, A. Waksmundzki and M. Kański, by PWN of the fundamental book *Chromatografia* [7] In 1955, on the initiative of Prof. W. Kemula, within the Committee of Chemical Sciences of PASci, the Subcommittee of Analytical Chemistry (now the Committee for Analytical Chemistry PASci) was established, where the Chromatographic Section, now the Group of Chromatography and Related Techniques of the Committee, was located [8].

Spectral and electrochemical methods have been successfully developed at the Faculty of Chemistry, the University of Warsaw, by Prof. W. Kemula and his students (Figure 4).

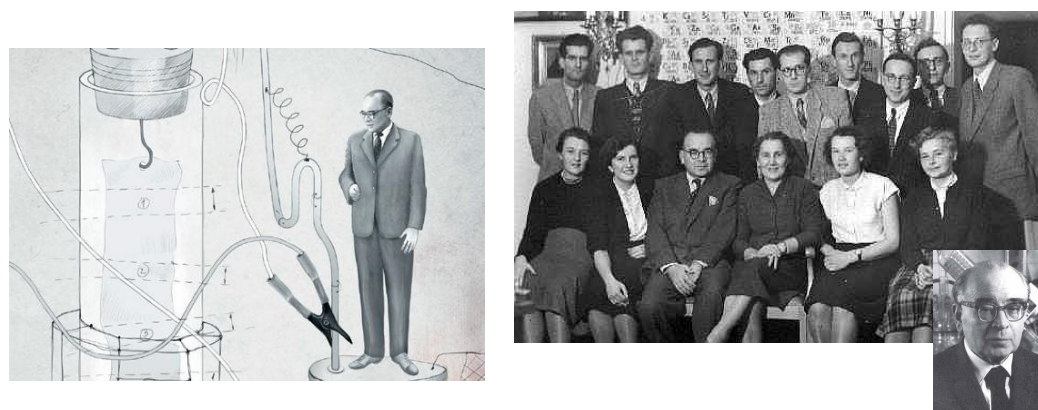


Figure 4. Prof. W. Kemula (1902–1985) together with students of the Faculty of Chemistry, University of Warsaw and the concept of chromatopolarography.

Professor W. Kemula and his co-workers successfully introduced chromatopolarography into the world’s literature in 1952, as a combination of intensively developing polarography and chromatography [9]. The consequence of this scientific and organizational activity was the development by his students and co-workers (D. Sybiliska, J. Jurczak, J. Lipkowski, and others) first works on the separation of chiral analytes using cyclodextrins and studying cyclodextrin systems [10].

Professor M. Trojanowicz (UW and IChTiJ) and his team (Prof. K. Pyrżyńska, E. Dąbek-Złotorzyńska, E. Poboży, and M. Biesad) made a significant contribution to the development of separation methods (flow injection analysis, electromigration techniques, column liquid chromatography, and sample preparation methods). They successfully developed theoretical and practical studies described in numerous monographs, original scientific and research papers, and reviews, including widespread science determination of a range of organic and inorganic compounds [11].

The analytics of inorganic compounds (anions, cations) in theoretical and application studies in ion chromatography have been and are successfully developed by Prof. R.

Dybczyński and his students (IChTiJ Warsaw). As heirs of Prof. J. Minczewski and Z. Marczenka they implemented the concepts of trace analysis. They were also the first in Poland to create a new generation of certified reference materials for chromatographic (IC) and spectral analysis. Combined separation techniques (LC-ICP / MS, CZE-ICP / MS) and miniaturization of these methods and their robotization (*lab on a chip*) have been and are the domain of a team of scientists from the Warsaw University of Technology under the supervision of professors M. Jarosz and Zb. Brzózka. They, too, along with Prof. A. Hulanicki and Z. Witkiewicz, formed the editorial committee of Analytical Chemistry, an international scientific journal of the Committee of Analytical Chemistry PA Sci. Prof. Z. Witkiewicz (Military Technical Academy), author of numerous monographic studies on chromatography and the world's unique five-language chromatographic nomenclature [9]. He successfully described the theoretical foundations of changes and physicochemical and chromatographic properties of liquid crystal stationary phases, especially for classical and capillary gas chromatography. Together with Prof. J. Błądek (Military Technical Academy) and scientists from Russia and Hungary he implemented original pressure thin layer chromatography (OP TLC) sets for production (COBRABiD Warsaw). COBRABiD was a scientific research institution that, thanks to Dr. W. Rytł and Assoc. Prof. Z. Stefaniak, successfully implemented apparatus development (detectors, HPLC kits, OP TLC) and instrumentation for chromatographic analysis. This center also published a scientific and technological journal called *Aparatura Naukowo-Badawcza* [12].

The center, recognized by its position and achievements in Poland and in the world, where physicochemical separation methods were developed (chromatography, flotation, extraction, elutriation, etc.), is Lublin and created in this town by Prof. Andrzej Waksmundzki at UMCS and the Medical Academy (currently the Medical University of Lublin), Lublin School of Chromatography (Figure 5) [12].



Figure 5. Lublin School of Chromatography created by Prof. A. Waksmundzki (first row, central position). In the photo, the top row from the left: M. Jaroniec, J.K. Różyło Z. Supryniewicz, Wł. Rudziński, L. Jusiak, St. Prześlakowski, J. Szczypa, R. Nasuto; bottom row from the left: J. Ościk, A. Barcicka, T. Wawrzynowicz, M. Przyborowska, E. Soczewiński, J. Barcicki.

Here, the first theoretical studies were created to describe the adsorption phenomena at the interface: liquid–solid, liquid–liquid, gas–liquid or gas–solid, and the separation processes. Under the supervision of Prof. A. Waksmundzki, there were over 50 PhD dissertations, the same number of habilitations, and over 30 of his students became professors (including the author of this article). It is here that the first developments of a new generation of adsorbents and fillers for gas chromatography based on native diatomites, carbons and mixed adsorbents, as well as quartz capillary columns, were created. Here, the

original chemically bound phases and high-performance HPLC columns or fillings for *solid phase extraction* techniques were also developed. Additionally here, at the turn of the 1950s and 1960s, the first gas chromatograph in Poland (Prof. Z. Suprynowicz) and an apparatus for electromigration techniques were built. In Lublin, Prof. E. Soczewiński published the foundations of his theory concerning the description of the adsorption mechanism liquid chromatography (the famous Soczewiński-Snyder equation $\log k = \log k_w - S\phi$) [13]. Here, too, based on the phenomenon of adsorption, professors: J. Ościk, M. Jaroniec, W. Rudziński, R. Leboda, J.K. Różyło, A.L. Dawidowicz or M. Waksmundzka-Hajnos, T.H. Dzido and T. Tuzimski and K. Głowniak, developed theoretical studies on the separation mechanism in gas and thin-layer chromatography, column liquid chromatography, and electromigration techniques. The first patent applications and know-how were created in Lublin. Scientists found here an inspiration for the first implementations of consumables and tools for the needs of chromatography and related techniques (Chemical Reagents Factory in Lublin, POCh-Gliwice, Cormay-Poland, AK Nobel, Merck, JT. Baker, Knauer, Camag and COBRABiD in Warsaw). Many monographic studies (including the aforementioned first handbook), recognized scientific publications, and review articles had been written in Lublin. For many years, PhD studies, courses, and training in theory and practice in chromatographic techniques were organized in Lublin (both at the Maria Curie-Skłodowska University and the Medical University). It was also in Lublin where national and international conferences and symposia on separation techniques were organized. Many recognized specialists in adsorption and surface phenomena, including separation methods, were educated in Lublin and successfully developed these skills in their home academic, industrial and research centers in Poland and abroad [6,13,14].

Another important academic center where separation techniques were developed intensively was Gdańsk. Prof. R. Staszewski, who at the Gdańsk University of Technology built a team dealing with developing a new generation of detectors (including selective sulfur detectors) for gas chromatography (W. Janicki, B. Zygmunt, W. Wardencki, A. Przyjazny, and others). At the same time, Prof. J. Kowalczyk was building his scientific team (M. Kamiński, J. Klawiter, B. Makuch, B. Śledzińska, and others). This team studied the theory and practical applications of column liquid chromatography (analytical and preparative) and the construction of liquid chromatographs. At the same time, Prof. A. Stołyhwo showed a high activity in the development of the gas construction and liquid chromatography apparatus (preparative scale) as well as specific and selective detectors for the analysis of oils and fats (LSD detector). These devices have been produced in ELPO Wrocław and Factory of Medical Apparature in Bydgoszcz [15].

The Gdańsk center has made a name for itself in world literature thanks to the studies of Prof. Roman Kaliszan, an ordinary member of PAsci and PAU and his students (T. Bączek, M. Markuszewski, A. Nasal, M. Marszałł, A. Buciński, P. Wiczling, and others) from the Chair and Department of Biopharmacy and Pharmacodynamics at the Faculty of Pharmacy of the Medical University of Gdańsk in the field of mechanism description and prediction of retention data in chromatography based on the quantitative retention-structure relationship (QSRR). Another critical issue was the research carried out in the biological activity of analytes in the area of the so-called *-omic* (metabolomics, proteomics, genomics, lipidomics, etc.) [16,17] (Figure 6).

Another important person who had a significant influence on the development of analytical chemistry in Poland, especially a new approach to methodological developments in separation methods, or rather in new sample preparation methods (passive dosimetry, membrane techniques, extraction techniques, etc.) was Prof. Jacek Namieśnik and created by him the “school” of analytical chemistry [18]. Although there are no purely chromatographic studies of a theoretical nature, work on the so-called artificial nose (W. Wardencki, B. Zygmunt) [19] and methodological studies for the determination of the entire range of organic compounds, taking into account the principles of the so-called “green analytical chemistry” (M. Tobiszewski, A. Galuszka) made a significant contribution to the development and progress in this field [20]. These achievements guarantee this team a

permanent place in the scientific annals. Recent works on toxicology or monitoring of the natural environment, as well as the use of combined techniques in the search for various types of xenobiotics, are a modern direction of methodological solutions (A. Kot-Wasik, B. Zabiegała, Z. Polkowska, M. Biziuk, and others) and development of new solutions in designing tools for trace analysis (A. Wasik, P. Konieczka, and others). Prof. Janusz Pawliszyn was also derived from this University (Waterloo University, Canada), creator of SPME and miniaturized sample preparation systems and new solutions in detecting organic individuals at the molecular level [21]. A student of Prof. J. Namieśnik's is also Prof. Tadeusz Górecki (Waterloo University, Canada) who deals with theoretical and application studies in the field of GC and multivariate GCxGC, LCxLC systems to determine trace amounts of analytes isolated from complex matrices [22]. The Gdańsk University of Technology group, apart from research works, has successfully published and publishes monographs, original creative works, and reviews. They are systematically organizing schools, workshops, and conferences dedicated to determining various analytes in environmental and biological matrices. Various international projects are implemented here, including educational programs.



Figure 6. Gdańsk leaders of separation techniques (top row from the left: J. Kowalczyk, R. Staszewski, R. Kaliszan, P. Stepnowski, bottom row: A. Stołyhwo, J. Namieśnik, J. Pawliszyn, T. Górecki).

An important complementary link of the Gdańsk research center is a team of specialists in separation methods at the University of Gdańsk centered around Prof. Piotr Stepnowski, correspondence member of PASci. Their research interests are focused on studying marine pollutants and chemistry and their effects on the marine ecosystem. Undoubtedly, studies in the analysis of ionic liquids have become a great scientific achievement as the basic research and a new generation of modifiers and solvents for the needs of modern chemical synthesis [23].

The leader in Poznań, who dealt in detail with instrumental techniques in different variants of analytical determinations, and especially chromatographic techniques, both from the point of view of theory and practice, was Prof. Walenty Szczepaniak from the University of Adam Mickiewicz [24]. Similar contributions to building a team of chemists/analysts in the field of disseminating extraction techniques were made by Prof. Jan Szymanowski from the Poznań University of Technology. Prof. W. Szczepaniak has built a strong team of specialists working on surface physicochemistry (Prof. Nawrocki, Prof. Wasiak) and the development of a new generation of phases and columns for gas chromatography. Prof. Nawrocki concentrated his interests on the characteristics of porous adsorbents, especially siliceous and zirconium ones, focusing on chemical activity and their chromatographic properties.

Interesting works with the so-called inversion gas chromatography were the subject of professor's Adam Voelkel research, who continues the work of Prof. J. Szymanowski, an outstanding specialist in extraction techniques. Prof. Henryk Jeleń, a member of PASci with his team (Poznań University of Life Sciences) represented a modern approach to determining various food products using combined LC–MS, GC–MS chromatographic techniques, and especially high-resolution systems. Spectral techniques (high resolution mass spectrometry) in combination with liquid chromatography are developed by Prof. M. Stobecki from the Institute of Bioorganic Chemistry PASci (Figure 7).



Figure 7. Representatives of the Poznań analytical community, top row from the left: J. Szymanowski, M. Stobecki, W. Szczepaniak, bottom row from the left: A. Voelkel, H. Jeleń, J. Nawrocki, W. Wasiak.

Łódź also had its pioneers and promoters of chromatographic techniques. Prof. Dr hab. Tadeusz Paryjczak from the Lodz University of Technology was a leader. He was the first in Poland to publish a compact monographic study on gas chromatography [25]. The group he created consistently researched physicochemical methods of separating a whole range of compounds with a focus on the industrial use of these techniques. Aspects of sustainability and green chemistry dominated these applications. The heir of this activity is one of the students of Prof. T. Paryjczak's, Prof. Jacek Rynkowski and his student—Prof. J. Kałuża-Czaplińska. Together with doctors, she successfully participates in metabolomics research and projects, where chromatographic techniques are used for diagnostic purposes and medical therapy (e.g., autism). Prof. J. Kałużna-Czaplicka strongly popularizes chromatographic techniques in Łódź by organizing symposia and Polish and international conferences [26] (Figure 8).

The significant activity at the University of Lodz in chromatographic and electrochemical techniques showed the team focused around Prof. M. Wroński (University of Lodz) and Prof. J. Maśłowska. Prof. E. Bold's team (Prof. R. Głowacki and Dr. G. Chwatko) continues the tradition and successfully determines a whole range of biologically active compounds using HPLC, CZE, and new derivatization reagents thiols, amino acids and/or proteins in biological samples.

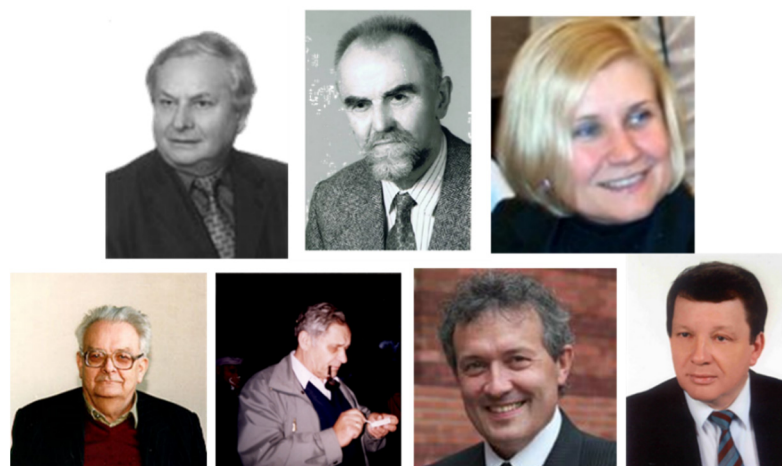


Figure 8. Representation of the Łódź team (top row from the left: T. Paryjczak, E. Bald, J. Kałużna-Czaplicka. Representatives of the Krakow team: bottom row from the left: L. Górski, J. Lasa, A. Grochowalski, P. Kościelniak).

In the field of determinations and physicochemical characteristics of polymers (gel chromatography), intensive research was carried out at the Center for Molecular and Macromolecular Research PASci. The following professors are undoubtedly worth mentioning: M. Kryszewski, J. Michalski, and J. Chojnowski.

Another town on the map of Polish chromatography is Krakow, with its physicochemical academic traditions and the renowned school of professors B. Kamiński, K. Gumiński, and M. Lasoń. The chromatographic methods were developed here by professor Ludwik Górski (Cracow University of Technology) and Prof. Jan Lasa (INPh. PASci and AGH). Prof. Górski dealt with determining a whole range of halogenated volatile organic compounds using GC. Prof. A. Grochowalski continued his work by using high-resolution GC–MS systems to determine dioxins and furans in environmental samples. Interests of Prof. Lasa referred to constructing a new generation of GC detection systems proposed by Dr. J. Lavelock and based on electron capture using Ni^{63} . Prof. J. Lasa's team (I. Śliwka, J. Nęcki, A. Korus) built on Kasprowy Wierch (High Tatras), the first in Poland included in the global monitoring network chromatographic laboratory, to analyze *on-line* greenhouse gases and air composition (smog) (Figure 8). The first determinations of chiral compounds of a therapeutic nature in the 1980s and 1990s using chromatographic techniques with various detection, including MS, were presented by Prof. J. Bojarski from the Medical Academy/Collegium Medicum of the Jagiellonian University. Prof. A. Parczewski from the Jagiellonian University and his students gathered at the Institute of Court Expertise (Prof. W. Piekoszewski, D. Zuba, M. Kała) presented an original approach to the analysis of psychotropic and intoxicating compounds, including drugs, using chromatographic techniques and chemometrics analysis. His work is continued, with a focus on flow analysis (FIA) and electromigration techniques (CZE), by Prof. P. Kościelniak, J. Kochana and J. Kozak. Apart from typical scientific activity, they systematically organize symposia, workshops and publish monographs. Prof. J. Sillbering's (AGH) team successfully develops coupled techniques (combination of chromatography with mass spectrometry) with new methodologies and procedures in determining biologically active substances in the *-omic* area, taking into account the miniaturization of separation techniques. They are the authors of numerous innovative studies that have been successfully used in the laboratory and found practical solutions [27].

The so-called Silesian group of scientists contributed to the significant development, progress, and popularization of separation techniques in Poland, whose undeniable leader is Prof. Józef Śliwiok from the University of Silesia and a team of specialists in the field of liquid chromatography (T. Kowalska, M. Sajewicz), gas chromatography and sample preparation (J. Rzepa, R. Sitek) and chemometrics (B. Walczak, M. Daszykowski). It was

them who in the 1980s organized, first in Katowice and later in Szczyrk, chromatographic seminars, and symposia. Prof. J. Śliwiok founded the first Polish journal, *Acta Chromatographica* (1992), still published by the Kiado Academy (Hungary) [28]. Here, theoretical studies were developed using a chemometrics apparatus to describe the retention mechanisms in chromatography and surface phenomena at the interface, including modeling. The results of these studies are used with great success in *-omics*, especially in metabolomics. At the Medical University of Silesia in Zabrze (currently the Medical University of Silesia) Prof. Danuta Bodzek' team (K. Tyrpień-Golder, B. Janoszka) also developed chromatographic techniques to determine biologically active substances, including alkaloids used for therapeutic purposes. Thanks to Prof. Michał Bodzek from the Silesian University of Technology, membrane systems as selective and specific high-performance separation systems for sample preparation were used. Prof. R. Michalski deals with separation of ionic analytes (anions, cations), including speciation analysis at the Institute of Environmental Engineering PASci in Zabrze. He is the author of numerous Polish and English handbooks and publications in ion chromatography and organizer of multiple conferences devoted to this issue and editor-in-chief of the *Laboratorium* magazine [29]. At the same Institute, chromatographic techniques, especially GC combined with various detection systems, are developed by Prof. M. Czaplińska, previously associated with the Gliwice University of Technology. At this university, also Prof. Irena Staneczko-Baranowska (S. Bajkacz, H. Barchańska, J. Plonka, B. Kowalski) has her school who successfully implemented numerous monographic studies and fundamental scientific research works in the field of developing methodologies for the determination of biologically active substances using liquid chromatography coupled with various detectors including MS. Biological activity, chirality as well as physicochemical dependencies and correlations are issues that allowed to explain many mechanisms at the border between mobile phase–stationary phase–analyte. Her fundamental monographs: *Trace Analysis* and *Bioanalytics* (along with the author of this text) were also published in Springer [30,31] (Figure 9).

An important academic center in which separation techniques have also been developed and popularized with great success is Wrocław and the local University of Technology, represented by the team focused around Prof. B. Kolarz. Professor Kolarz specialized in preparing porous materials, especially adsorbents for liquid and ion exchange chromatography (Prof. A. Trochimczuk). Here also specialists in membrane separation (Prof. T. Bryjak or Prof. W. Walkowiak) were active, focusing on sample preparation methods or their industrial use for environmental protection. Dr. E. Śliwka (the University of Technology), carries out analytics with gas chromatography. Food analysis focusing on its quality and control, including supercritical extraction techniques (laboratory and semi-technical scale) is the domain of researchers associated with Prof. T. Trziszka and Prof. A. Szumny from the University of Life Sciences in Wrocław. Prof. B. Kolarz's student is Prof. Piotr Wiczorek, who carries his professional activity with the University of Opole. Here together with Prof. P. Kafarski and colleagues (J. Lipok, A. Poliwoda, J. Misiak) he developed chromatographic and electromigration techniques, new generation sorbents (MIP) or membrane/liquid membrane systems as selective and specific sample preparation techniques.

Significant activity in modeling mechanisms related to the description of mass transfer using descriptors and thermodynamic relationships in column adsorption liquid chromatography (analytical and preparative scale) shows the team associated with Prof. K. Kaczmarek and Prof. D. Antos from the Rzeszów University of Technology. In Siedlce, at the University of Humanities and Life Sciences, chromatographic and electromigration techniques (isotachopheresis) are developed by Prof. M. Kluska and Dr. B. Głod, who, together with P. Zarzycki from the Koszalin University of Technology, published *Acta Separatoria*, a journal constituting an integral whole of Podlasie Chromatographic Colloquiums. Prof. Elżbieta Skrzydlewska's team from the Medical University of Białystok is also associated with Podlasie. The dominant topics of their activity are related to the description of oxidative stress and the analysis of biologically active compounds in various pharmaceutical preparations. Research using chromatographic techniques coupled with mass

spectrometry in the metabolic analysis regime is developed by Dr. hab. M. Ciborowski's team. However, a pioneer of chromatographic techniques (TLC) popularization at the University of Białystok was Prof. Dr. hab. Helena Puzanowska-Tarasiewicz, whose work is continued by Prof. Joanna Karpińska and Prof. A. Kojło (flow techniques—FIA). Gel chromatography (GPC) was successfully performed at the West Pomeranian University of Technology in Szczecin by Prof. Tadeusz Spychaj. Thanks to his efforts, PWN published a translation of Dusan Berek's monograph entitled *Gel chromatography* [32].



Figure 9. Silesian chromatographers from the top: J. Sliwiok, I. Staneczko-Baranowska, T. Kowalska, B. Walczak, M. Daszykowski, R. Michalski, P. Wieczorek.

In the Kuyavian–Pomeranian region, the development of separation methods is attributed to the scientific activity of Prof. Anna Narębska from the Nicolaus Copernicus University in Toruń, who was Prof. A. Basiński's student. She built a team recognized in Poland and world (R. Wódzki, J. Ceynowa, S. Koter, and W. Kujawski). Its research focused on various theoretical and practical solutions in separation using different membrane techniques. The actual development and progress of theoretical and practical studies in chromatography at the Nicolaus Copernicus University in Toruń are dated from the moment Prof. Bogusław Buszewski, an ordinary member of PASci who moved to Toruń. He created the Center for Separation Methods and Bioanalytic—BioSep at the Nicolaus Copernicus University in Toruń—with a strong representation of student specialists (45 PhDs, 24 habilitations, and 6 professorships). They carry out research on the description of retention mechanisms (R. Gadzała-Kopciuch, T. Ligor, Sz. Bocian, S. Studzińska,

M. Szultka-Młyńska, J. Walczak, M. Skoczylas) in chromatographic elution, preparation of stationary phases and columns or their miniaturization (M. Szumski, M. Kluska, M. Michel, M. Ligor). The latest research is aimed at material chemistry and nanotechnology, especially nanocomposites (protein-metal), as selective and specific systems (M. Sprynskiy, P. Pomastowski, V. Railean-Plugaru). An important topic of Buszewski's team is research using electromigration techniques in the separation of proteins and/or microorganisms (E. Kłodzińska, E. Dziubakiewicz, K. Rafińska, A. Król) or variable field fractionation (FFF) (T. Kowalkowski, V. Reilean-Plugaru). Original methodological and technological solutions in the preparation of samples are other topics that complement the range of interests of the Toruń team. The search for markers for early detection of cancer or civilization diseases in the area of *-omic* is another important issue related to separation techniques in biomedical and pharmaceutical analysis, from the border of chemistry, biology, medicine, or (*life sciences*) [31,33,34]. The group has organized significant scientific conferences and symposia (ISC, ISSS, ExTech, Cancer Diagnosis, Metabolomics, etc.). They have organized postgraduate studies, workshops, and schools recognized in Poland and abroad for many years, where basic courses and the latest achievements in separation techniques, sample preparation, coupled and multidimensional systems, and chemometrics are presented. The team carries out several international and national research projects, publish numerous monographs, patents and works in the best journals worldwide. They have been awarded many prizes and awards for their activity (Figure 10).



Figure 10. Toruń's chromatography school, Prof. Bogusław Buszewski with his students.

Prof. B. Buszewski is the chairman of the Committee of Analytical Chemistry of PAsci [10,35] and the president of the Central European Group for Separation Sciences (CEGSS). He is also the chairman of the Jury of the EuSSS, awarding the European Tswiett and Nerst Award. These organizations are very active in popularizing separation techniques by organizing conferences, symposia, workshops, publishing monographs and publications, and implementing grants and projects. They are awarded the CEGSS medal for their activity and the Tswiett Nernst statuette [36,37] (Figure 11).

In the Kuyavian–Pomeranian region in Bydgoszcz, at the *Colegium Medicum* of the Nicolaus Copernicus University in Toruń, there is also a group significant for separation techniques, the mentors of which were Prof. Roman Kaliszan, Prof. Bogusław Buszewski and Prof. Janusz Pawliszyn. They are related to pharmacy, biochemistry, biomedical analytics and *-omics* (Prof. M. Marszał, B. Bojko, A. Buciński, W. Filipiak, D. Gackowski and R. Oliński) where mass spectrometry or chemometrics dominate the research.



Figure 11. CEGSS medal and Tswiett Nernst statue.

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