Archivum Immunologiae et Therapiae Experimentalis (2018) 66:1–9
https://doi.org/10.1007/s00005-017-0502-6

LETTER TO THE EDITOR

# Biomedical Research in Wrocław: A Combined Density-Equalizing Mapping and Scientometric Analysis

**David A. Groneberg**[1]

Received: 10 July 2017 / Accepted: 4 September 2017 / Published online: 3 January 2018
© L. Hirszfeld Institute of Immunology and Experimental Therapy, Wroclaw, Poland 2018

## Abstract

The aim of this study was to assess the evolution of biomedical scientific activities of Wrocław scientists in the post-war time when this field of academics was rebuilt by the works of Ludwik Hirszfeld and colleagues. Using the NewQIS platform and the Web of Science database, novel procedures such as density-equalizing mapping were combined to bibliometric tools to visualize scientific progression. In total, 10,366 biomedical research articles originating from Wrocław were identified. Since 1972, there is a steady increase in research activity with the year 2015 holding the largest number of published items (895). A total of 2934 published research cooperations with 104 different countries is present. This is a percentage of 28.3% of all publications. In total, 101 research areas are present in Wrocław biomedical research with the highest number of articles being published in the area of biochemistry/molecular biology (2140). Research in this field was cited 27,360 times. The field of immunology has 1186 articles with 9247 citations. Density-equalizing mapping and network techniques revealed a distinct global pattern of research collaborations with German, US and UK affiliations as the primary cooperating partners of Wrocław. In summary, the present study supplies the first density-equalizing mapping approach that visualizes research activity in Wrocław over the past decades.

**Keywords** Wrocław · Biomedical sciences · Scientometrics · Density-equalizing maps

## Introduction

Representing one of Central Europeans' oldest universities, the University of Wrocław was originally founded in 1702. Since over three centuries, it constitutes the centre of academic research in Wrocław and Silesia. Being a multinational university in the nineteenth century with German, Polish and Jewish students forming different student organizations such as the Polish Concordia and Polonia fraternities, the German Teutonia or the Jewish Viadrina or the Student Union, the university later faced a dark period of time during the Nazi period. In this time, more than 250 doctorate degrees were stripped from Jewish and other scholars, Polish students were discriminated, and German scholars from Wrocław university even participated in the fascist historical justification for a "plan of mass deportation in Eastern territories".

After this dark period and the deleterious destructions of the Second World War, the old university deceased. Directly after the war, a new Polish University of Wrocław was funded with the help of scientists of the University of Lwow (Ogorzalek 2008). The first dean of the medical faculty was the renowned scientist Professor Ludwik Hirszfeld (Balinska 2002; Kierzek et al. 2013; Lonc and Gosciniak 2012; Milgrom 1998). Together with a number of sister universities such as the Wrocław University of Science and Technology, the Wrocław Medical University or the Wrocław University of Environmental and Life Sciences, the University of Wrocław and other scientific institutions including the Ludwik Hirszfeld Institute of Immunology and Experimental Therapy, Polish Academy of Sciences, today symbolize the great success of Polish scientists in biomedical and life sciences in the past 70 years. There are numerous excellent reviews and historical articles that address the achievements made by Polish scientists in different disciplines of the biomedical and life science areas in Wrocław (Dobryszycka et al. 2003; Ostrowski 2003). The aim of the present study

✉ David A. Groneberg
occup-med@uni-frankfurt.de

[1] Institute of Occupational Medicine, Social Medicine and Environmental Medicine, Goethe-University, Frankfurt, Germany

was to illustrate scientific success by the use of novel visualization techniques and advanced scientometric tools using the established NewQIS (New Quantity and Quality indices in Science) study protocols (Groneberg-Kloft et al. 2009a, b). This is important because citations in the literature can be found that claim that "Bright light of learning snuffed out in Breslau" after the Second World War (Wong 2001).

## Materials and Methods

### NewQIS Protocol

As previously described, the presently used NewQIS methodology is a well-established project that has so far been used to study more than 50 different biomedical and life science areas (Al-Mutawakel et al. 2010; Glynn et al. 2010; Groneberg et al. 2011; Groneberg-Kloft et al. 2009c; Kusma et al. 2009; Schoffel et al. 2009; Vitzthum et al. 2009). The NewQIS platform approach consists of modern visualization algorithms such as the density equalizing calculations published by Gastner and Newman (2004), country-specific indices using the Hirsch-index (H-index) (Hirsch 2005) and other scientometric tools.

### Data Source and Time Span

Data were retrieved from the database Web of Science Core Collection database from Thomson Reuters as carried out in former studies (Bruggmann et al. 2016c; Groneberg et al. 2016a, b; Koster et al. 2016; Schoffel et al. 2016). The search term *Wrocław* was entered in the address field. Next, the search was restricted to articles so that it comprises only the bibliometric information of the original research articles. Afterwards, the data set was scanned for the WoS categories that are linked only to biomedical research fields. These items were filtered. Due to the exclusion of other topics, the database can be referred solely to the subject area of Biomedicine in Wrocław. Since the address field search in the Web of Science data base is only established for articles from the years 1972 onwards, the current analysis is restricted to the period 1972 to the end of 2016.

### Density-Equalizing Mapping

Density-equalizing mapping was used as described previously (Bruggmann et al. 2016a, b; Groneberg et al. 2016a, b). In brief, the territories were re-distributed according to the chosen variable, i.e. the number of published items or citations, respectively (Bruggmann et al. 2015a, b; Groneberg et al. 2015). The calculations are based on Gastner and Newman's algorithm (Gastner and Newman 2004).

### Analysis of Research of International Collaborations

To analyze international Wrocław biomedical research collaborations from the viewpoint of a global research network, all affiliations that published research publications together with scientists from Wrocław were analyzed as previously described for other medical entities (Carl et al. 2014). A bilateral cooperation between two countries was defined when at least one author originated from Wrocław and at least one other author from a non-Polish affiliation. A matrix with all networking countries was constructed using vector techniques. The thickness of the vector quantified the number of cooperation articles (Scutaru et al. 2010).

## Results

### Total Research Activity in Biomedical Sciences

In total, a number of 10,366 articles were identified in the Web of Science database being published by Wrocław scientists in the period from 1972 to the end of 2016. As illustrated in Fig. 1, there is a steady number of articles per year until 1994 with a maximum of 148 articles from Wrocław. From 1995 onwards, there is a steady increase in research activity with the year 2016 holding the largest number of published items (895) (Fig. 1B).

Density-equalizing mapping was used to illustrate the research output by Wrocław scientists and their collaborating partner scientists all over the world by territorial resizing. In a first step with the inclusion of the Wrocław institutions, the resulting density equalizing map is dominated by Poland (Fig. 1a).

### Country Research Network Analysis of Wrocław Research

A total of 2934 published research cooperations with 104 different countries is present. This is a percentage of 28.3% of all publications. 1814 collaborations were bilateral between when density-equalizing mapping was calculated to illustrate the global proportions of Wrocław research partner countries, the resulting world map was distorted to Germany (908), the US (784), the UK (558). Also, Italy (449) and France (361) were dominant research partners (Fig. 2a). From 1995 onwards, there was a steady increase in international collaborations (Fig. 2b). Chart techniques were used (Fig. 3a) to illustrate the collaborations between Wrocław and its foreign partners and the collaborations between the foreign partners, indicating that there are numerous articles between EU partners of Wrocław scientists. Sixty-two

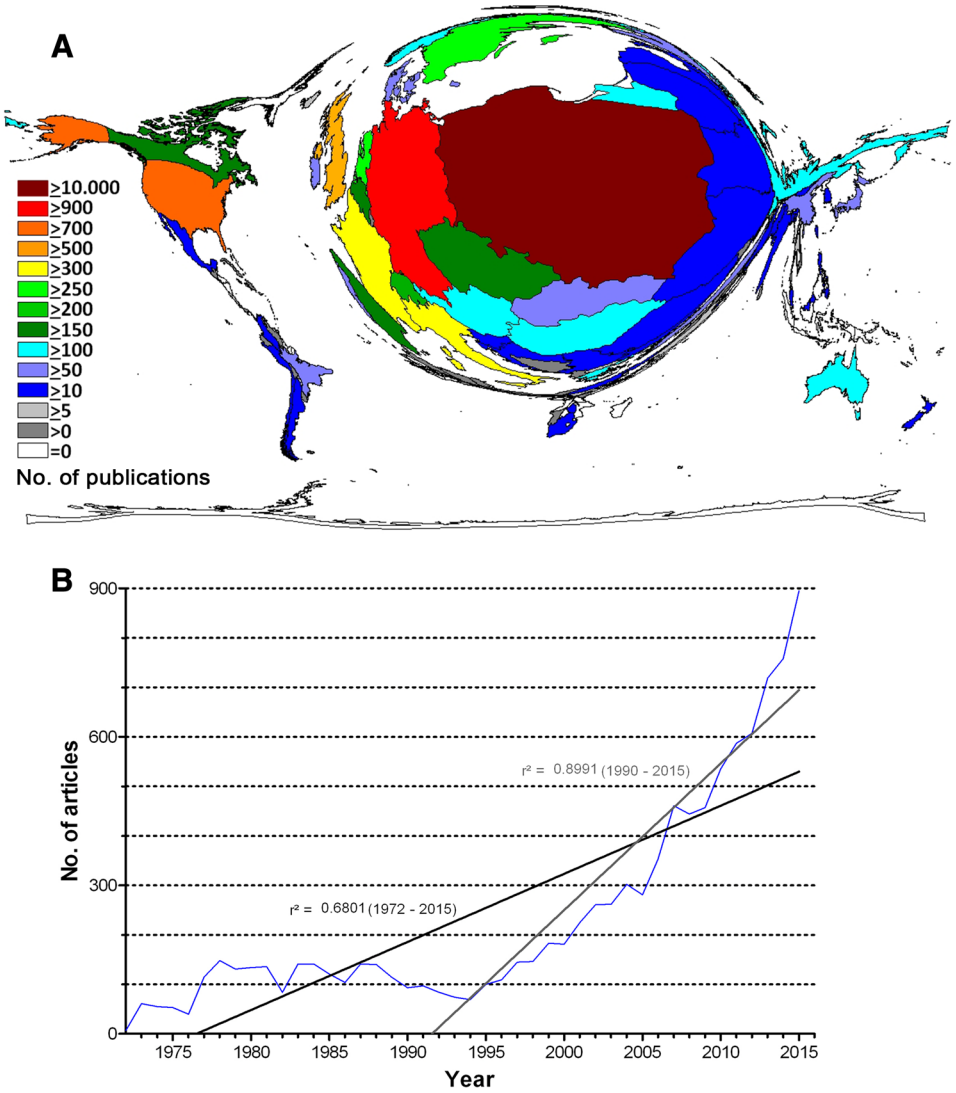


**Fig. 1** Publication performance. **a** Density equalizing map of the number of publications per country. **b** Number of publications per year, $r^2$ = correlation coefficient

percent of all collaborations were established between Wrocław scientists and scientists from a single other country. There were 506 tripartite collaborations (17%). The maximum number of countries was 25 in a single cooperation. Over the time, there an overall increase in international research collaborations by Wrocław scientists since 1972 with the year 2015 exhibiting a record number of 298 collaborations (Fig. 3b).

## Semi-Qualitative Indicators: Citations and H-Index

Analysis of research quality is difficult. Here, semi-qualitative citation indicators such as total citations and H-index were calculated and visualized by density-equalizing mapping. In total, Wrocław articles received citations. Maxima were present for articles from 2006 with 7575 citations and for articles from 2001 with 5191 citations.

Density-equalizing mapping for the H-index illustrated a world map distorted to Poland, followed by Germany, the US and the UK (Fig. 4a). Figure 4b depicts the modified H-index for the partner countries.

## Research Areas

In total, 102 research areas are present in Wrocław biomedical research from 1972 onwards. In total, the highest number of articles was published in the area of biochemistry/molecular biology (2140). This research was cited $c = 27{,}360$ times. The second most proliferative field was immunology (1186 articles/9247 citations), followed by pharmacology/pharmaceutics (1040/8944), chemistry (829/9952). The highest citation rate was found for the area of cardiovascular research (22.51 citations per article) (Fig. 5a). The time evolution analysis demonstrates that the research focuses were relatively dynamic from

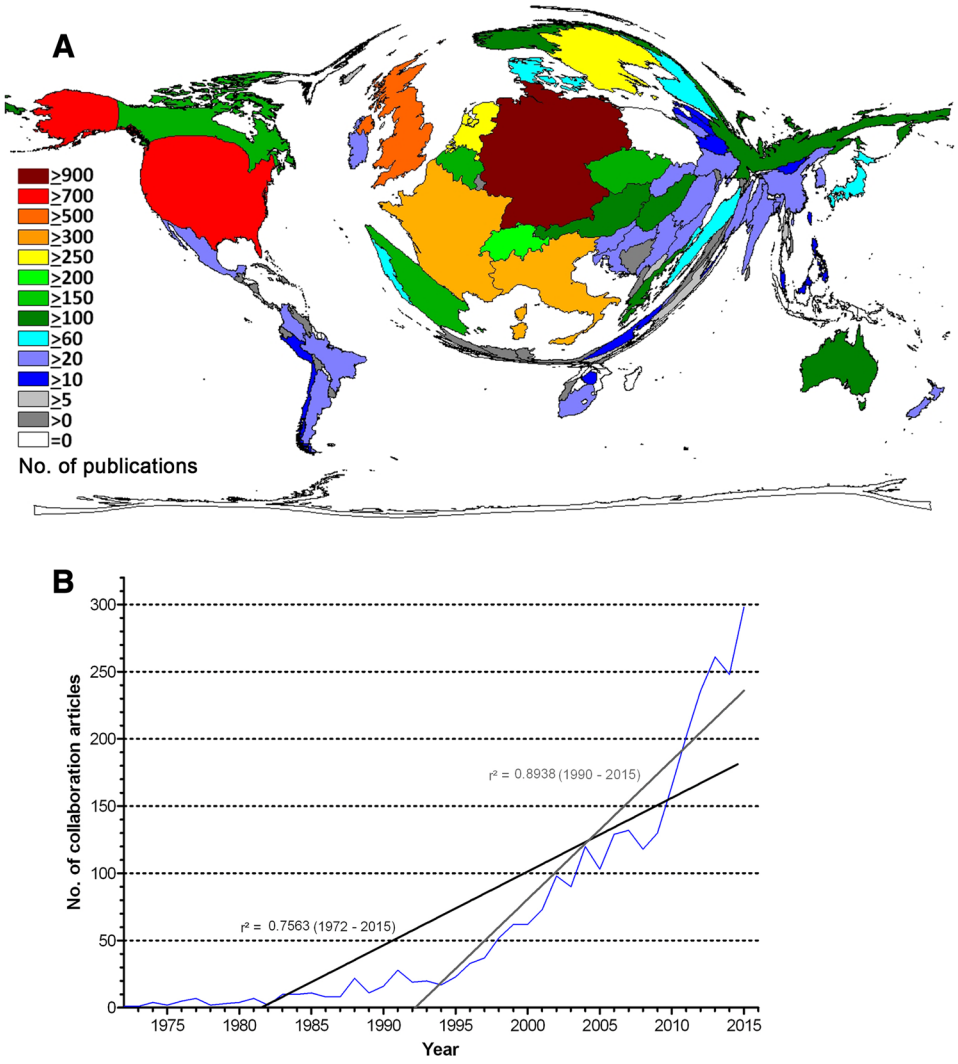


**Fig. 2** International collaborations. **a** Density-equalizing map of the number of publication per collaboration country. **b** Number of collaboration articles per year, $r^2$ = correlation coefficient

1972 to 2007. Since one decade, the proportions are relatively stable with the fields of experimental medicine, biochemistry and molecular biology, pharmacology and cardiovascular research playing major roles. While the total dominance of immunology in the 1970s–1980s has decreased—there are still numerous immunologic research publications present today days but other biomedical fields have also increased scientific activities (Fig. 5b).

When the cooperations with scientists from other countries were analyzed on a country-specific level, it becomes apparent that cardiovascular research is often in the focus of international research collaborations with various countries. Also, biochemistry and molecular biology play a prominent part (Fig. 6).

## Discussion

The development of medicine in Wrocław from the fourteenth century onwards has been elegantly summarized recently by Zajaczkowski (2014) and there are numerous excellent publications that focus on specific aspects and scientists who drove the scientific progress in Wrocław in the past centuries (Kacala et al. 2015; Kustrzycki et al. 2013; Zarsky 2012; Undas and Wiesner-Spyrczynska 2016). The present study puts its focus on the quantitative development of the biomedical field after 1945 when the academic research was restored primarily by scientists from the Jan Kazimierz University of Lvov (Kacala et al. 2015; Wojtkiewicz-Rok 2002). It uses scientometric

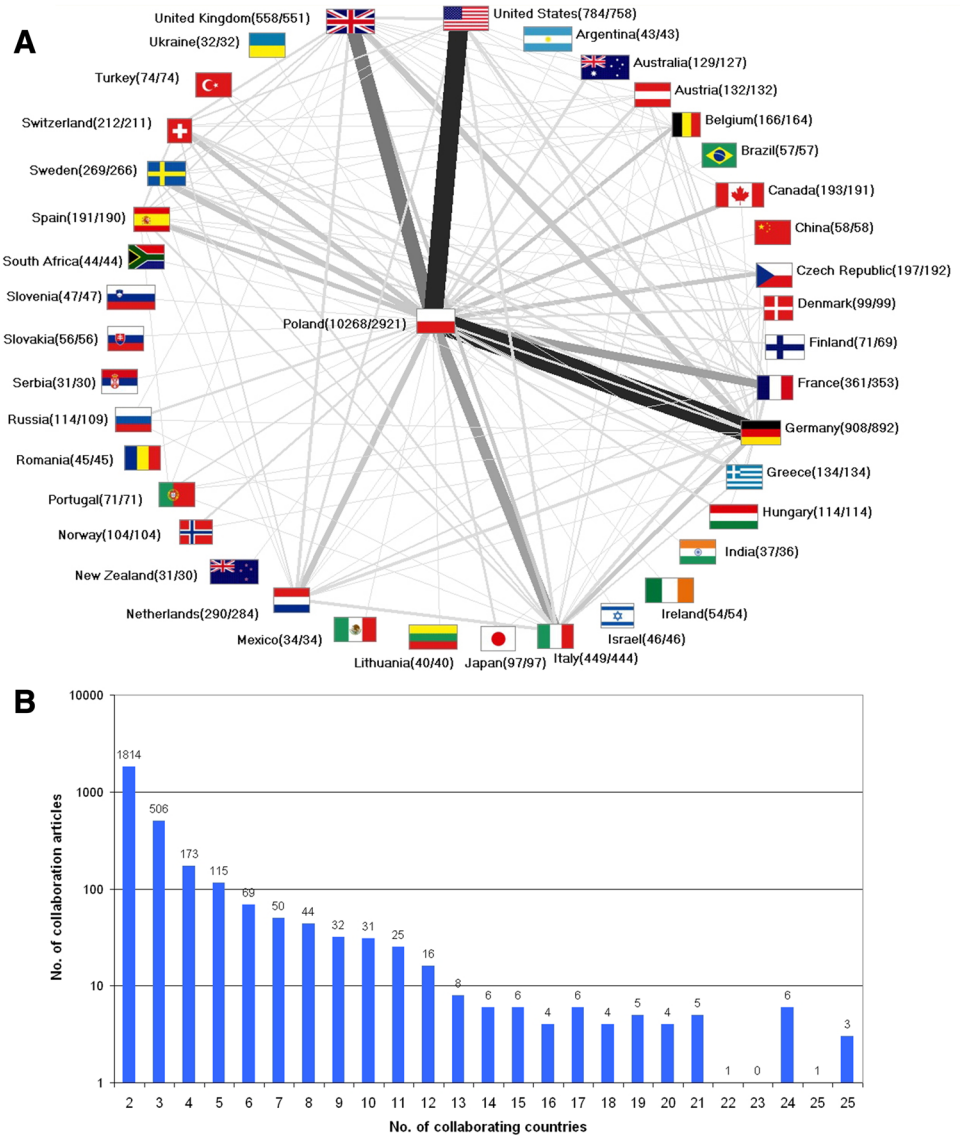


**Fig. 3** International network. **a** Network diagram of the international collaboration partners, numbers in brackets (publications/collaboration articles). **b** Number of articles and their associated collaborating countries

approaches which have so far been employed and discussed in various areas of science: defined as the use of mathematical techniques to investigate scientific publishing and communication patterns in the distribution of information—scientometrics have been an established approach for decades (Sawada et al. 2007; Scutaru et al. 2010; Smith et al. 2008) and indeed, the *Archivum* has published numerous articles focusing on scientometric aspects (Glanzel et al. 2008; Moed 2009; Pilc 2008).

Presently, density-equalizing mapping calculations were used to extend simple scientometrics to advanced visualization techniques to depict a sketch of the global research network that has been established by Wrocław scientists. The density-equalizing maps visualize the capacity that has been build within a total of 2934 international Wrocław research cooperations with a total of 104 different countries. Since the international collaborations constitute nearly a third of all Wrocław biomedical publications, it can be stated that Wrocław scientists exhibit a high degree of internationality and serve as active ambassadors of Polish sciences in this field since many decades. The present findings clearly contradict the previous statement that the "Bright light of learning snuffed out in Breslau" after the Second World War (Wong 2001). It is noteworthy that a clarifying comment on this statement that pointed to the achievements of Hirszfeld and colleagues was unfortunately rejected by Nature (Gorski 2017).

Undoubtedly, the openness towards external, foreign scientific collaborations had been started after the war by Ludwik Hirszfeld and colleagues who had many foreign cooperations. Within a few years after 1989, Wrocław scientists were again able to fully carry out scientific collaborations with all regions of the world. The high number of joint articles, i.e. with US scientists as illustrated here—serves as

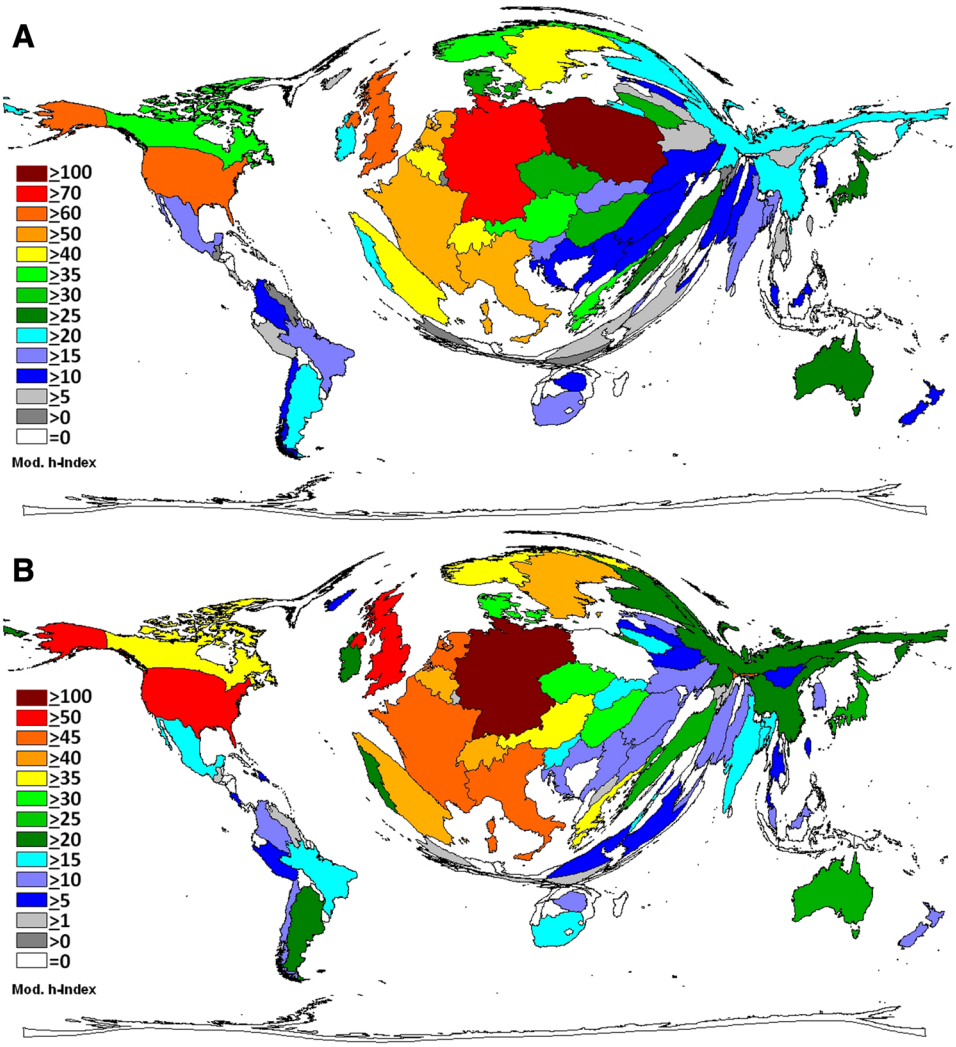


**Fig. 4** Modified H-index per country. **a** All publishing countries. **b** The collaboration countries

an example that Wrocław scientists are again involved in global high-impact research activities. It can be anticipated that these collaborative activities will stay on a high level in future years. As demonstrated by the evolution analysis of international cooperations, it took about 6–8 years to publish the first results of the fruitful collaborations of Wrocław scientists with leading Western countries such as the US or the UK that were initiated after 1989.

Interesting results were also obtained from the analysis of research areas: a wide spectrum of more than 100 different research areas are covered by biomedical researchers from Wrocław. Due to the pioneering works of Ludwik Hirszfeld and his fellow scientists, the majority of research publications focused on aspects of immunology and biochemistry/molecular biology in the 1970s. These fields drove the scientific evolution in Wrocław as discussed previously (Kierzek et al. 2013; Lonc and Gosciniak 2012). With the development of further research fields and faculties, the proportions of Wrocław biomedical sciences developed from a bipolar structure—with immunology and biochemistry as dominating fields—into a colorful architecture with the fields of experimental medicine, biochemistry and molecular biology, pharmacology and cardiovascular research playing major roles, today. This is the organic picture of life sciences present in large academic university backgrounds and comparable to large US American, British or Germany universities. The core is resembled by the two fields of immunology, originating from the works of Ludwik Hirszfeld, and biochemistry/molecular biology, originating by the pioneering works, e.g. of Wanda Mejbaum-Katzenellenbogen.

It is important to note that not all Wrocław biomedical research originates from its universities: Professor Hirszfeld is also the founding director of the Institute of Immunology and Experimental Therapy which was founded in 1952 by the Polish Academy of Sciences (PAN). This PAN institution, now named after Ludwik Hirszfeld, is the origin of more than 2200 original research articles. It constitutes—with more than ten different departments and laboratories—one of the primary cooperation partners of the Wrocław universities in the biomedical field and is a strong bond to the

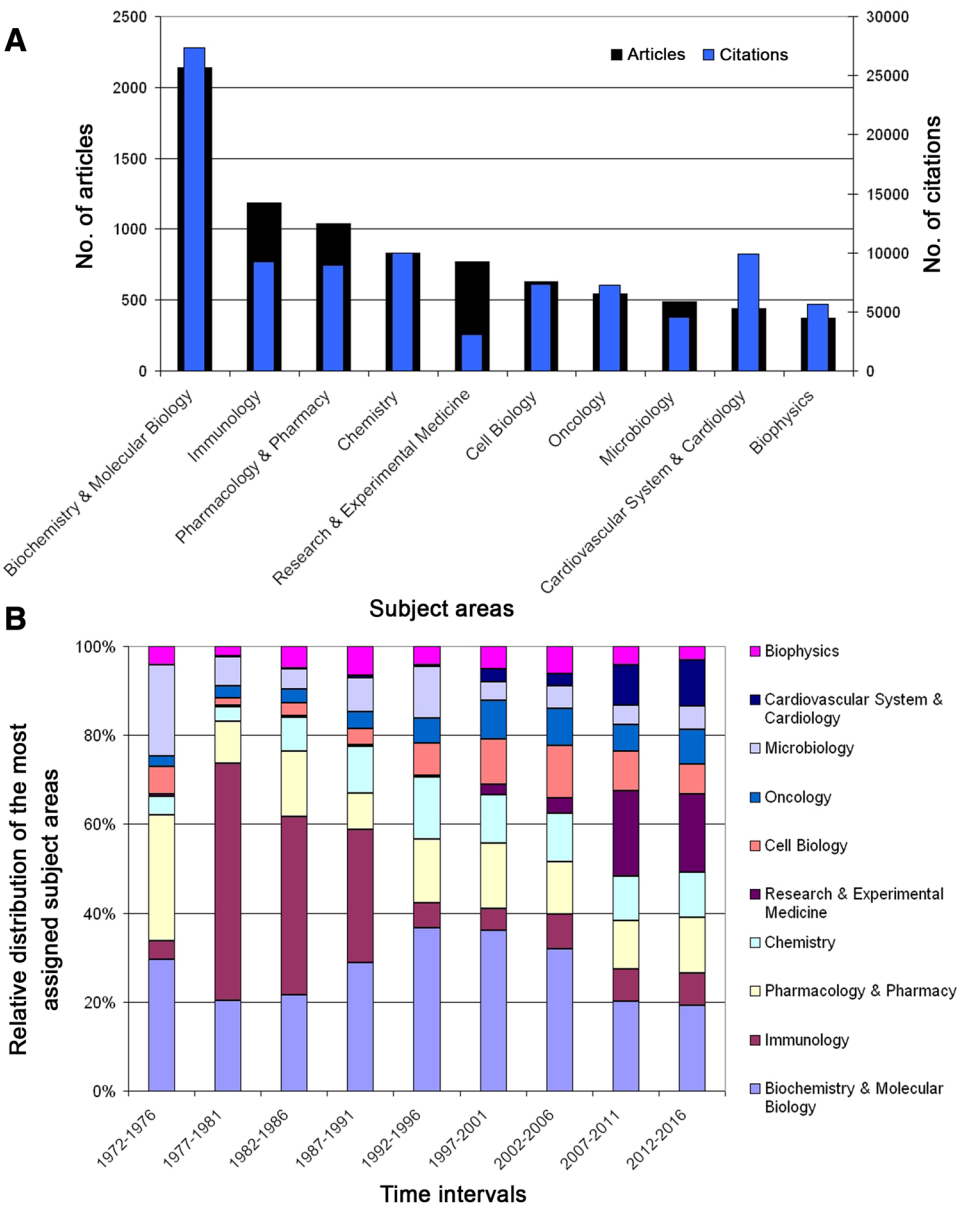


**Fig. 5** Subject areas. **a** Number of articles and the number of citations of the most assigned subject areas. **b** Development of the relative distribution of the most assigned subject areas in 5-year time intervals

international community of immunology and related fields (Kisielow 2011).

## Limitations

The present bibliometric approach should not be used to assess the input of single scientists from Wrocław over the observed time period. This assessment would lead to artificial numbers that do not reflect the real scientific activities of individual scientists. This is based on the fact that the present analysis is strictly be limited to articles which are clearly affiliated to Wrocław by the Web of Science data base. That means that all those publications in which the scientists worked abroad—as scientists in other countries or in other Polish universities or institutions—would be excluded from the analysis. Therefore, the present metrics—restricted to 10,366 biomedical research articles—should not be used for overall assessments of research performance or excellence.

It should also be mentioned that comparisons within periods of five decades are biased by changes in the scientific community due to cultural, economic and political issues, i.e. (1) the culture of scientific publishing changed over the past half century towards articles with longer lists of authors and today's scientists usually publish higher quantities; (2) increasing economic strength enabled increasing research activities leading to more scientific publications; (3) political changes facilitated research activities.

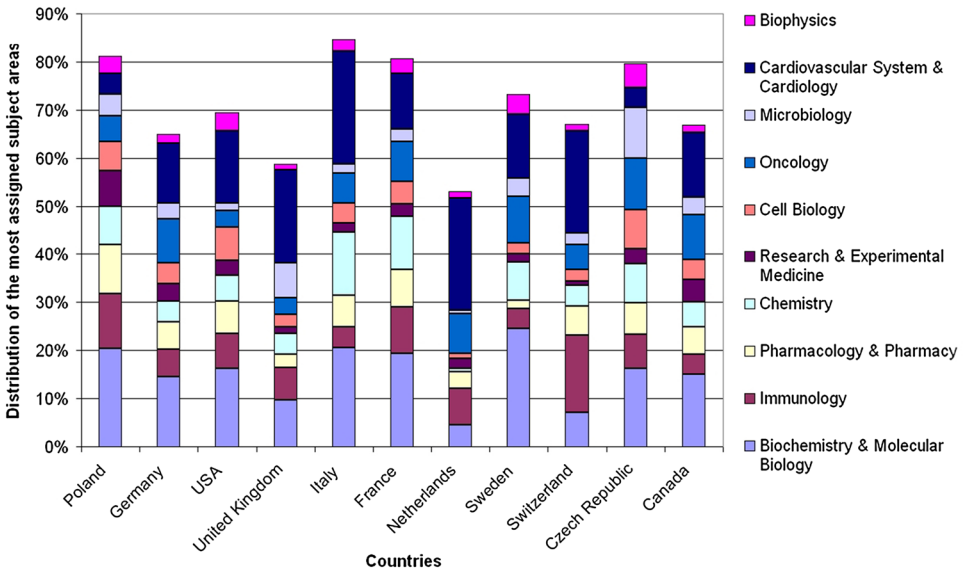


**Fig. 6** Distribution of the most assigned subject areas of the most publishing countries

In summary, the present study is the first scientometric analysis to assess the scientific progress of biomedical research in Wrocław using the combination of visualizing tools such as density-equalizing mapping and classic scientometric tools such as publication activity and citation indicators. The data demonstrates that Wrocław biomedical sciences have developed into a strong regional and international player with a large international cooperation network.

**Acknowledgements** I thank D. Klingelhöfer for excellent technical assistance and G. Oremek for helpful discussions. This study is dedicated to Ludwik Hirszfeld, founder of Archivum Immunologiae et Therapiae Experimentalis and first dean of the medical faculty of Wrocław after the Second World War, and his colleagues who—by their scientific virtue—rebuild the excellent scientific reputation of the *Alma Mater Wratislaviensia* that had been destroyed by Nazi Germany.

**Funding Sources** None declared.

## Compliance with Ethical Standards

**Conflict of interest** The authors declare that they have no competing interest.

## References

Al-Mutawakel K, Scutaru C, Shami A et al (2010) Scientometric analysis of the world-wide research efforts concerning Leishmaniasis. Parasit Vectors 3:14

Balinska MA (2002) Ludwik Hirszfeld: scientist and humanist. Sci Eng Ethics 8:269–271

Bruggmann D, Handl V, Klingelhofer D et al (2015a) Congenital toxoplasmosis: an in-depth density-equalizing mapping analysis to explore its global research architecture. Parasit Vectors 8:646

Bruggmann D, Lohlein LK, Louwen F et al (2015b) Caesarean Section—a density-equalizing mapping study to depict its global research architecture. Int J Environ Res Public Health 12:14690–14708

Bruggmann D, Elizabeth-Martinez A, Klingelhofer D et al (2016a) Endometriosis and its global research architecture: an in-depth density-equalizing mapping analysis. BMC Womens Health 16:64

Bruggmann D, Maule LS, Klingelhofer D et al (2016b) World-wide architecture of osteoporosis research: density-equalizing mapping studies and gender analysis. Climacteric 19:463–470

Bruggmann D, Richter T, Klingelhofer D et al (2016c) Global architecture of gestational diabetes research: density-equalizing mapping studies and gender analysis. Nutr J 15:36

Carl J, Schwarzer M, Klingelhoefer D et al (2014) Curare–a curative poison: a scientometric analysis. PLoS One 9:e112026

Dobryszycka W, Kwiatkowska-Korczak J, Lisowska E (2003) Post-war biochemistry in Wrocław. Acta Biochim Pol 50:IX–X

Gastner MT, Newman ME (2004) From the cover: diffusion-based method for producing density-equalizing maps. Proc Natl Acad Sci USA 101:7499–7504

Glanzel W, Schubert A, Thijs B et al (2008) A new generation of relational charts for comparative assessment of citation impact. Arch Immunol Ther Exp 56:373–379

Glynn RW, Scutaru C, Kerin MJ et al (2010) Breast cancer research output, 1945–2008: a bibliometric and density-equalizing analysis. Breast Cancer Res 12:R108

Gorski A (2017) Personal communication

Groneberg DA, Schilling U, Scutaru C et al (2011) Drowning—a scientometric analysis and data acquisition of a constant global problem employing density equalizing mapping and scientometric benchmarking procedures. Int J Health Geogr 10:55

Groneberg DA, Rahimian S, Bundschuh M et al (2015) Telemedicine—a scientometric and density equalizing analysis. J Occup Med Toxicol 10:38

Groneberg DA, Geier V, Klingelhofer D et al (2016a) Snakebite envenoming—a combined density equalizing mapping and scientometric analysis of the publication history. PLoS Negl Trop Dis 10:e0005046

Groneberg DA, Braun M, Klingelhoefer D et al (2016b) Pancreatitis: global research activities and gender imbalances: a scientometric approach using density-equalizing mapping. Pancreas 45:218–227

Groneberg-Kloft B, Fischer TC, Quarcoo D et al (2009a) New quality and quantity indices in science (NewQIS): the study protocol of an international project. J Occup Med Toxicol 4:16

Groneberg-Kloft B, Quarcoo D, Scutaru C (2009b) Quality and quantity indices in science: use of visualization tools. EMBO Rep 10:800–803

Groneberg-Kloft B, Scutaru C, Dinh QT et al (2009c) Inter-disease comparison of research quantity and quality: bronchial asthma and chronic obstructive pulmonary disease. J Asthma 46:147–152

Hirsch JE (2005) An index to quantify an individual's scientific research output. Proc Natl Acad Sci USA 102:16569–16572

Kacala RR, Wozniak S, Porwolik M et al (2015) Remembrance of professor Tadeusz Marciniak—Lviv tradition in Wrocław. Adv Clin Exp Med 24:173–178

Kierzek A, Kuciel-Lewandowska J, Paprocka-Borowicz M et al (2013) Professor Ludwik Hirszfeld in his relations with students and junior researchers. Adv Clin Exp Med 22:909–914

Kisielow P (2011) Proceedings of the conference "Lymphocyte development, tolerance and autoimmunity: solved and open questions", held at the Ludwik Hirszfeld Institute of Immunology and Experimental Therapy, Polish Academy of Sciences, on May 12, 2011 (Wrocław, Poland): lymphocyte development, tolerance and autoimmunity: a personal perspective. Arch Immunol Ther Exp 59:327–330

Koster C, Klingelhöfer D, Groneberg DA et al (2016) Rotavirus—Global research density equalizing mapping and gender analysis. Vaccine 34:90–100

Kusma B, Scutaru C, Quarcoo D et al (2009) Tobacco control: visualisation of research activity using density-equalizing mapping and scientometric benchmarking procedures. Int J Environ Res Public Health 6:1856–1869

Kustrzycki WA, Mikulicz-Radecki J, Bauer KH, Bross W (2013) Three great surgeons, three different epochs, one clinic in Wrocław. Thorac Cardiovasc Surg 61:464–469

Lonc E, Gosciniak G (2012) Professors Rudolf Weigl and Ludwik Hirszfeld—in the meanders of history. Ann Parasitol 58:189–199

Milgrom F (1998) My association with Ludwik Hirszfeld, Wrocław 1945–1954. Arch Immunol Ther Exp 46:201–212

Moed HF (2009) New developments in the use of citation analysis in research evaluation. Arch Immunol Ther Exp 57:13–18

Ogorzalek A (2008) Embryology at the Universities of Lwow and Wrocław. Int J Dev Biol 52:135–139

Ostrowski WS (2003) Revival of biochemistry in Poland in the first years after World War II. Acta Biochim Pol 50:I–IV

Pilc A (2008) The use of citation indicators to identify and support high-quality research in Poland. Arch Immunol Ther Exp 56:381–384

Sawada S, Smith DR, Araki S (2007) The impact factor and Industrial Health. Ind Health 45:501–502

Schoffel N, Vitzthum K, Mache S et al (2009) The role of endocarditis, myocarditis and pericarditis in qualitative and quantitative data analysis. Int J Environ Res Public Health 6:2919–2933

Schoffel N, Bendels MH, Groneberg DA (2016) Ulcerative colitis: a scientometric approach to the global research output and network. Eur J Intern Med 34:e41–e43

Scutaru C, Quarcoo D, Takemura M et al (2010) Density-equalizing mapping and scientometric benchmarking in Industrial Health. Ind Health 48:197–203

Smith DR, Gehanno JF, Takahashi K (2008) Bibliometric research in occupational health. Ind Health 46:519–522

Undas A, Wiesner-Spyrczynska M (2016) Polish scientists among the most influential scientific minds in 2015. Pol Arch Med Wewn 126:113–115

Vitzthum K, Mache S, Quarcoo D et al (2009) Scoliosis: density-equalizing mapping and scientometric analysis. Scoliosis 4:15

Wojtkiewicz-Rok W (2002) The effect of Lvov medical tradition on development of medical sciences in postwar Wrocław. Wiad Lek 55:354–359

Wong ML (2001) Bright light of learning snuffed out in Breslau. Nature 410:865

Zajaczkowski T (2014) History of medicine, surgery and urology in Breslau/Wrocław. Ann Acad Med Stetin 60:113–126

Zarsky V (2012) Jan Evangelista Purkyne/Purkinje (1787–1869) and the establishment of cellular physiology–Wrocław/Breslau as a central European cradle for a new science. Protoplasma 249:1173–1179