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EDITORIAL: INORGANIC BIOCHEMISTRY – A BRIEF SCIENTOMETRIC PERSPECTIVE WITH FOCUS ON EASTERN EUROPE AND ROMANIA

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Based on data collected from the Scopus database, inorganic biochemistry appears to pursue an exponential increase across the world, possibly slowed down by the advent of the separate field of metallomics. Almost one-third of the publications originate from the United States of America – with China, Germany, United Kingdom, India and Japan providing another third. The two leading journals of the field, JIB and JBIC, have provided less than 5% of the total publications that may be labeled as bioinorganic. Eastern Europe provides ~10% of the total world output with Poland, Russia and the Czech Republic by far the largest contributors – followed at some distance by Hungary and Romania. An increased tendency for publishing in local lower-impact journals and in conference proceedings is noted for Eastern Europe, more so in Romania than in the more active countries of the region.

Key words: bioinorganic chemistry, inorganic biochemistry, scientometric, Romania.

AT THE INTERNATIONAL LEVEL

A search in the Scopus database using the criterion ((ALL(inorganic biochemistry) OR TITLE-ABS-KEY (bioinorganic) OR TITLE-ABS-KEY (biological inorganic) OR TITLE-ABS-KEY(metalloprotein) OR TITLE-ABS-KEY (metalloenzyme) OR TITLE-ABS-KEY(bio-inorganic) OR TITLE-ABS-KEY(biometal) OR TITLE-ABS-KEY(biological metal))) was conducted in February 2015 in order to probe the research related, broadly speaking, to bioinorganic chemistry – on the theme of the role of metals in biology and medicine. Based on this search, Fig. 1 shows the evolution of the number of publications over the past ~60 years; data from 1930 onwards are included in all statistics discussed in this paper. The notable cisplatin moment at ~1970 is commonly recognized as having led to a sharp increase in the development of the field (Cowan, 1993, Kraatz and Metzler-Nolte, 2006, Lippard and Berg, 1994). The sharp increase at ~1996 does coincide with the early years of the Society for

Biological Inorganic Chemistry and their dedicated journal JBIC – but also with the beginning of a more comprehensive coverage of journals in the internet era. The current exponential increase initiated after ~2000 seems set to continue.

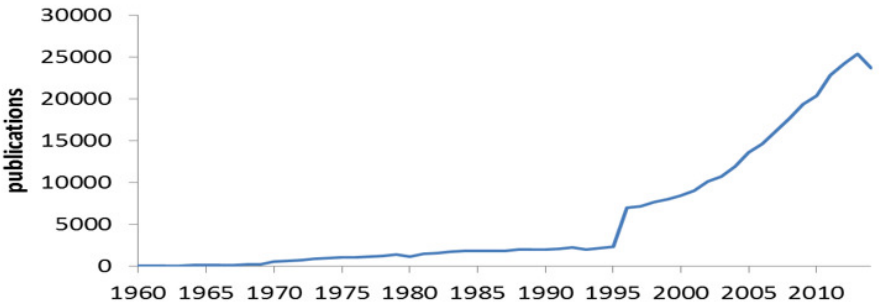

Fig. 1. Time evolution for publications related to bioinorganic chemistry (see text) cf. Scopus.

Table 1 shows the journals contributing the highest number of articles to the field. Leading inorganic and biochemical journals are present alongside wider-scope ones. Physical and analytical chemistry as well as environmental ones are also present. The two main journals dedicated to the field, JIB and JBIC, cover ~3% of the total number of publications that invoke the keywords employed in our search (bioinorganic, biological inorganic, and related).

Table 1

Journals publishing the highest numbers of papers related to bioinorganic chemistry

Journal	**Papers**	**Journal**	**Papers**
Inorganic Chemistry	6610	Journal of Chromatography A	1125
JACS	5868	J Coord Chem	1055
Journal of Inorganic Biochemistry	5382	Organometallics	1048
Biochemistry	4761	Journal of Molecular Biology	1040
Journal of Biological Chemistry	4114	Plant and Soil	1008
Inorganica Chimica Acta	3759	Journal of Molecular Structure	983
Dalton Transactions	3321	Bioresource Technology	976
Polyhedron	2377	Environmental Pollution	975
ABB	2167	Talanta	944
Journal of Physical Chemistry B	2012	Journal of Bacteriology	899
Chemistry A European Journal	1973	Acta Crystallographica Section E	855
Soil Biology and Biochemistry	1931	Journal of Organic Chemistry	855
Chemical Communications	1902	Biol Trace Elem Res	851
JBIC	1819	Water Research	827
BBRC	1793	Chemical Reviews	822
FEBS Letters	1737	Appl Environ Microbiol	819
Env Sci Technol	1719	Biochemical Pharmacology	816
Angew Chem Intl Edn	1660	Eur J Biochem	811

Table 1 (continued)

PNAS	1656	J Phys Chem C	810
PloS One	1524	Toxicol Appl Pharmacol	804
Science of the Total Environment	1469	Biochemical Journal	789
Spectrochimica Acta Part A	1454	RSC Advances	778
Eur J Inorg Chem	1405	Environ Toxicol Chem	776
Langmuir	1405	PCCP	771
Analytical Chemistry	1399	Tetrahedron	766
Analytical Biochemistry	1342	Free Radic Biol Med	760
Chemosphere	1329	Ecotoxicol Environ Safety	744
J Phys Chem A	1295	BBA Biomembranes	727
Analytica Chimica Acta	1167	Biophysical Journal	716
Coord Chem Rev	1140	Inorg Chem Commun	709
J Hazard Mater	1135	Geochim Cosmochim Acta	704
J Organomet Chem	1125	Transition Metal Chemistry	686

In terms of the countries where the authors are affiliated, Table 2 shows the USA to have produced almost one-third of all publications in the field – followed, with contributions more than three times smaller, by China, Germany, the UK, and India. Fig. 2 then gives a general overview of the situation for the rest of the world.

Table 2

Countries contributing the largest numbers of publications to the field, 1930-2015

Country	**Items**	**Country**	**Items**	**Country**	**Items**	**Country**	**Items**
United States	96152	United Kingdom	21380	France	15447	Spain	11354
China	31553	India	20021	Canada	14351	Australia	9048
Germany	23107	Japan	19120	Italy	13939	Brazil	6934

Further related to Fig. 1, it may be noted that a similar search for *metallomics* in the same database for the same time interval reveals ~6,000 results, with an even sharper increasing trend than for inorganic biochemistry – and in fact with a ~20% increase in 2014 over 2013. Contrasting this to the apparent *decrease* in Fig. 1 for 2014 over 2013 for inorganic biochemistry publications, one may explain the difference by the lower indexing rates of some of the lower-profile or less-active journals in the much larger field of inorganic biochemistry – whereas the metallomics field, by virtue of being much newer and smaller, may be argued to be more restricted to frontier-like publications that are inherently more dynamic. Nevertheless, the difference in numbers – ~1,700 for metallomics over ~25,000 for inorganic biochemistry in 2014 – does not suggest that metallomics research has expanded at the expense of inorganic biochemistry – but rather in parallel and stemming from it.

The institutions providing the highest outputs in the field are listed in Table 3.

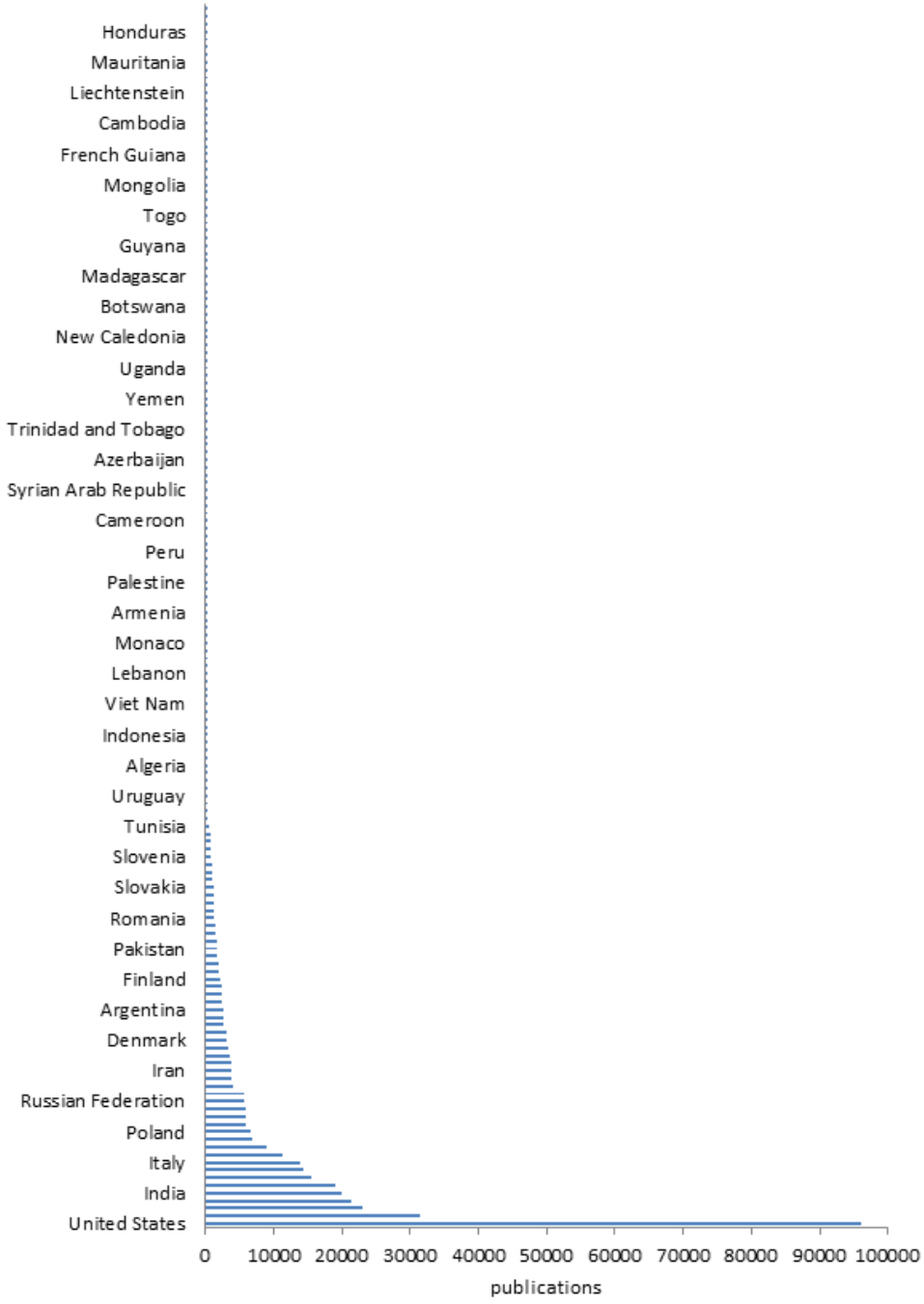

Fig. 2. General overview of bioinorganic publication counts across the world, 1930-2015.

Table 3

Institutions featuring the highest contributions in numbers of bioinorganic publications

Institution	Items	Institution	Items
Chinese Academy of Sciences	2056	The University of Georgia	1201
Universidade de Sao Paulo – USP	2003	Ohio State University	1185
CNRS France	1960	University of South Carolina	1177
University of Oxford	1763	University of Delaware	1147
UC Davis	1645	Stanford University	1143
University of California, San Diego	1642	Lunds Universitet	1141
University of California, Los Angeles	1631	University of Toronto	1132
Russian Academy of Sciences	1565	University of Arizona	1125
Consiglio Nazionale delle Ricerche	1540	University of Sydney	1125
UC Berkeley	1524	Nanjing University	1124
Osaka University	1500	University of Notre Dame	1111
Kyoto University	1419	Kyushu University	1108
Università degli Studi di Firenze	1397	The University of British Columbia	1106
Eidgenossische Technische Hochschule Zurich	1384	Georgia Institute of Technology	1106
University of Wisconsin Madison	1383	Zhejiang University	1096
University of Texas at Austin	1367	University of Maryland	1090
University of Minnesota Twin Cities	1320	University of Colorado at Boulder	1085
University of Tokyo	1297	University of California, Santa Barbara	1085
University Michigan Ann Arbor	1271	University of Queensland	1083
Texas A and M University	1269	Pennsylvania State University	1061
University of Florida	1264	Cornell University	1060
Massachusetts Institute of Technology	1255	Hebrew University of Jerusalem	1037
University of Washington Seattle	1208	Université Pierre et Marie Curie	1013

The highest-contributing authors across the world are listed in Table 4.

Table 4

Authors with the largest numbers of publications in the field, 1930-2015

Name	No.	Name	No.	Name	No.	Name	No.
Rheingold, A.L.	545	Gray, H.B.	200	Moura, I.	156	Shaik, S.	140
Solomon, E.I.	322	Fukuzumi, S.	195	Nam, W.	156	Adam, V.	140
Bertini, I.	320	Adams, R.D.	191	Neese, F.	154	Armstrong, F.A.	139
Smith, M.D.	308	Williams, R.J.P.	186	Banci, L.	151	Hadjiliadis, N.	138
Lippard, S.J.	293	Yap, G.P.A.	185	Messori, L.	151	Dyson, P.J.	137
Sadler, P.J.	273	Scozzafava, A.	180	Stucky, G.D.	150	Karlin, K.D.	137
Keppler, B.K.	251	Moura, J.J.G.	171	Kizek, R.	150	Ascenzi, P.	136
Supuran, C.T.	246	Zink, J.I.	169	Butcher, R.J.	150	Lu, Y.	135
Kozlowski, H.	234	Zur Loye, H.C.	166	Canters, G.W.	149	Sakurai, H.	135
Que, L.	232	Hodgson, K.O.	164	Hedman, B.	148	Mascharak, P.K.	134
Reedijk, J.	218	Lippert, B.	160	Raptopoulou, C.P.	148	Natile, G.	134

Table 4 (continued)

Sessler, J.L.	211	Hoffman, B.M.	159	Kiss, T.	143	Munck, E.	133
Van Eldik, R.	207	Bill, E.	159	Liu, J.	143	Ford, P.C.	132
Luchinat, C.	204	Sigel, H.	158	Siegbahn, P.E.M.	141	Cisarova, I.	130

Referencing against general classical fields of research, the "bioinorganic" field seems, as detailed in Table 5, circumscribed mostly around Chemistry (37%) and Biochemistry, Genetics & Molecular biology (36%) – with Agriculture, Environment, Medicine and Materials science following suit at a clear distance (10-14%). This situation is only expected, since one defines the field at the interface of chemical (inorganic) and biological systems. With much lower contributions, one can reach much more diverse fields – from dentistry to psychology, arts and economics.

Table 5

Fields/subjects where the bioinorganic papers are classified, across the world, 1930-2015

Field	**Publications**	**Field**	**Publications**
Chemistry	119906	Energy	3317
Biochem, Genetics & Mol. Biol.	114466	Computer Science	2420
Agricultural and Biological Sciences	44448	Veterinary	1665
Environmental Science	42481	Mathematics	1635
Medicine	37036	Social Sciences	1283
Materials Science	36999	Health Professions	1104
Chemical Engineering	27595	Dentistry	981
Pharmacol. Toxicol. & Pharmaceutics	26782	Nursing	871
Physics and Astronomy	21595	Psychology	252
Engineering	18178	Arts and Humanities	251
Immunology and Microbiology	16349	Decision Sciences	245
Earth and Planetary Sciences	13369	Business Manag Account	166
Neuroscience	4001	Economy Econometrics Finance	56
Multidisciplinary	3413	Undefined	1076

The types of contributions are illustrated in Table 6 – and show no particular differences from general publishing trends in science – other than a slightly lower percentage of Conference Papers compared to other fields (Silaghi-Dumitrescu and Sabau, 2014).

Table 6

Types of bioinorganic publications across the world, 1930-2015

Type of publication	**Number of items**	**Percentage vs. total**
Article	270149	84.2
Review	27011	8.4
Conference Paper	12873	4.0
Book Chapter	4475	1.4
Short Survey	1400	0.4
Book	709	0.2

EASTERN EUROPE

The same search as above, now restricted to countries generally associated with the concept of Eastern Europe, reveals (cf. Fig. 3) a similar trend in time – at numerical values representing ~10% of the global ones seen in Fig. 1. The ~1970 and ~1996 increases are both conserved, as expected.

It may be worth noting that some 10% of the publications in Fig. 3 feature USA authors, followed closely by a similar percentage from Germany, and at some distance by France and Italy.

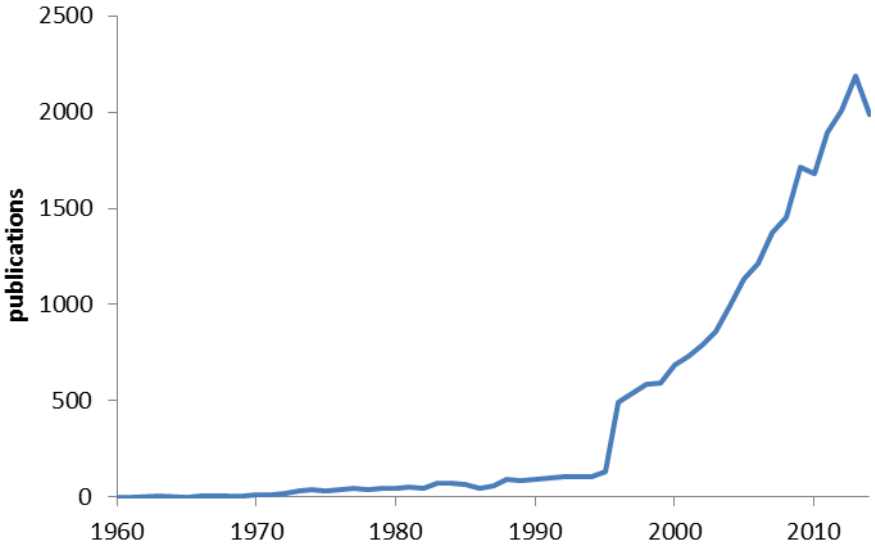

Fig. 3. Bioinorganic publications with Eastern-European affiliation.

Table 7 illustrates the journals where Eastern-European bioinorganic researchers have published the most. Compared to the general international situation (dominated, as seen in Table 1, by USA, Western Europe, China India and Japan), many journals are conserved, especially the two defining journals for the field (JIB and JBIC), as are some of the key inorganic chemistry and biochemistry journals. However, some high contributors from Table 1 (e.g., JACS, Biochemistry, Chemical Communications) are distinctly less common in Eastern Europe – while several local journals (marked in bold on Table 6 – three Russian, one Czech and one Romanian) tend to take their place. Also, the exact positions of the two dedicated journals are quite different, with JIB ranking first (as opposed to a well-defined third in Table 2) and JBIC falling from 5th to 20th; nevertheless, between the two of them, they still cover 3% of the total number of publications – similarly to Table 1.

Table 7

Journals publishing the highest numbers of papers related to bioinorganic chemistry from Eastern Europe. Journals edited in Eastern Europe are highlighted

Journal	**Items**	**Journal**	**Items**
Journal of Inorganic Biochemistry	637	Biochemistry	162
Inorganic Chemistry	396	**Russian Chemical Bulletin**	**155**
Polyhedron	390	**Collect Czech Chem Commun**	**155**
Inorganica Chimica Acta	321	FEBS Letters	153
Biochemistry Moscow	**269**	Journal of Biological Chemistry	135
Dalton Transactions	268	**Russian Journal of Inorganic Chemistry**	**127**
Journal of Molecular Structure	203	Journal of Biological Inorganic Chemistry	124
Journal of Physical Chemistry B	200	Journal of Organometallic Chemistry	116
JACS	168	Journal of Thermal Analysis and Calorimetry	113
Eur J Inorg Chem	167	**Revista de Chimie**	**109**
Journal of Chromatography A	164	Talanta	106
Journal of Physical Chemistry A	163	Microbiology	104
Chemistry A European Journal	162	Coordination Chemistry Reviews	101

As shown in Table 8, the highest-contributing countries follow perhaps expected trends, already seen in other fields of science, or indeed in general economic or social indices (Silaghi-Dumitrescu and Sabau, 2014).

Table 8

Eastern-European countries contributing to the field

Country	**Publications**	**Country**	**Publications**
Poland	6560	Lithuania	303
Russian Federation*	5920	Estonia	249
Czech Republic	3569	Moldova	115
Hungary	2306	Latvia	92
Romania	1330	Georgia	66
Slovakia	1125	Macedonia	65
Croatia	922	Azerbaijan	47
Ukraine	911	Bosnia and Herzegovina	31
Slovenia	764	Albania	25
Serbia	742	Armenia	6
Bulgaria	732	Montenegro	5
Belarus	319		

*including results listed for “Russia” as well as “Russian Federation”

The highest-contributing Eastern-European institutions are shown in Table 9. The vast majority originate from Russia, Poland and the Czech Republic – in line with the Table 8 data showing these three countries to be by far the largest contributors – with one exception each from Serbia, Slovakia, Croatia and Romania. Only one of these institutions – the Russian Academy of Sciences was also present in Table 3, among the world’s highest-active in the field.

Table 9

Eastern- European Institutions featuring the highest contributions in numbers of bioinorganic publications

Institution	Publications	Country
Russian Academy of Sciences	1543	Russia
Uniwersytet Wroclawski	926	Poland
Moskovskij Gosudarstvennyj Universitet	907	Russia
Charles University in Prague	812	Czech Republic
Inst Org Chem Biochem Academ Sci Czech Rep	699	Czech Republic
Uniwersytet Jagiellonski w Krakowie	614	Poland
Debreceni Egyetem	483	Hungary
Szegedi Tudomanyegyetem	441	Hungary
University of Belgrade	424	Serbia
Uniwersytet im. Adama Mickiewicza w Poznaniu	414	Poland
Institute Ruder Boskovic	409	Croatia
University of Ljubljana	397	Slovenia
Uniwersytet Warszawski	386	Poland
Politechnika Wroclawska	362	Poland
Masaryk University	356	Czech Republic
Vysoka skola chemicko-technologicka v Praze	302	Czech Republic
Univerzita Palackého v Olomouci	301	Czech Republic
Slovak University of Technology in Bratislava	294	Slovakia
Eötvös Loránd University	293	Hungary
A.N. Belozersky Institute of Physico-Chemical Biology	292	Russia
Universitatea Babes-Bolyai din Cluj-Napoca	277	Romania

The highest-contributing authors, listed in Table 10, originate from just five countries – with Poland and the Czech Republic again dominating by far, followed by Hungary, and then one researcher only from Romania and Russia, respectively.

Table 10

Authors with the largest numbers of publications in the field, 1930-2015

Name	Publications	Name	Publications
Kozlowski, H.	226	Micera, G.	87
Kizek, R.	145	Travnicek, Z.	83
Kiss, T.	139	Kulaev, I.S.	77
Adam, V.	135	Turel, I.	75
Cisarova, I.	130	Stochel, G.	75
Brabec, V.	109	Speier, G.	74
Sovago, I.	100	Jezowska-Bojczuk, M.	71
Schroder, D.	100	Farkas, E.	67
Bal, W.	99	Van Eldik, R.	66
Kasparkova, J.	88	Silaghi-Dumitrescu, R.	66
Baykov, A.A.	87	Avaeva, S.M.	65

The types of documents published by Eastern-European authors in this field tend to be very similar to those seen throughout the world (cf. Table 7).

Table 11

Types of bioinorganic publications from eastern-European authors

Type of publication	Items
Article	20974
Review	2012
Conference Paper	1170
Book Chapter	355
Short Survey	66
Book	51

The general fields where Eastern-European "bioinorganic" publications appear are shown in Table 12. The strong contributions of Chemistry and Biochemistry & Molecular Biology, and the general trends in the rest of the fields, are similar to the global international data from Table 5. However, the relative contributions are somewhat different, with the percentage for Chemistry increasing from 37% to 48%, while Biochemistry, Genetics & Molecular Biology decreases by 1%, and Medicine likewise decreases.

Table 12

Fields/subjects where the Eastern-European bioinorganic papers are classified

Field	Items
Chemistry	11899
Biochemistry, Genetics and Molecular Biology	8562
Materials Science	3125
Environmental Science	2530
Agricultural and Biological Sciences	2524
Physics and Astronomy	2157
Medicine	2078
Chemical Engineering	2054
Pharmacology, Toxicology and Pharmaceutics	1927
Engineering	1071
Immunology and Microbiology	1026
Earth and Planetary Sciences	723
Computer Science	265
Neuroscience	258
Energy	244
Veterinary	216
Mathematics	132
Multidisciplinary	112

ROMANIA

For Romania, the time evolution of the bioinorganic publications differs from what is seen across Eastern Europe, or globally, in more than one way (Cf. Fig. 4). The first indexed publications appear only in 1968, and the level remains constant at 1-3 publications until 1996. Thus, the early-1970 phenomenon, observed above

at international level, is only vaguely reflected by Romanian publications. The exponential increase after 2005, distinctly more abrupt than at the international level, follows a trend previously pointed out for Romanian science in general – as part of an exponential increase in GDP during the integration of the country in the EU – a success story generally ignored in Romania and abroad (Silaghi-Dumitrescu and Sabau, 2014).

Foreign co-authors cover similar percentages of the Romanian publications as seen across Eastern Europe – with Germany and France at ~10% each, followed at some distance by USA, Spain and Italy.

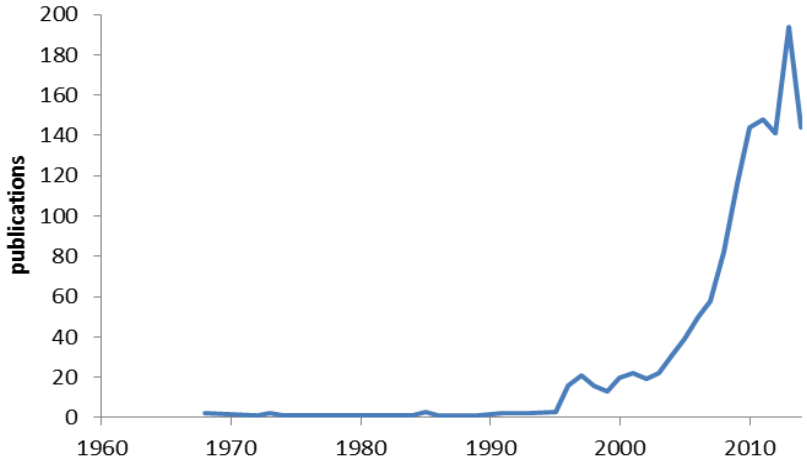

Fig. 4. Bioinorganic publications with Romanian affiliation.

Table 13 shows the highest-contributing journals for Romanian authors. As previously pointed out for scientific publishing in general, there is a marked tendency to publish in local journals (~half) – clearly more so than across the rest of the Eastern Europe (Silaghi-Dumitrescu, 2014, Silaghi-Dumitrescu and Sabau, 2014).

Table 13

Journals publishing the highest numbers of papers related to bioinorganic chemistry from Romania. Journals edited in Romania are highlighted

Journal	Items
Revista de Chimie	**109**
Revue Roumaine de Chimie	**56**
Journal of Thermal Analysis and Calorimetry	39
Journal of Optoelectronics and Advanced Materials	**22**
Inorganic Chemistry	19
Inorganica Chimica Acta	18
Polyhedron	18
UPB Scientific Bulletin Series B Chemistry and Materials Science	**17**

Table 13 (continued)

Environmental Engineering and Management Journal	**17**
Studia Universitatis Babes Bolyai Chemia	**17**
Key Engineering Materials	14
Digest Journal of Nanomaterials and Biostructures	**11**
Applied Surface Science	11
Farmacia	**10**
European Journal of Inorganic Chemistry	10
Spectrochimica Acta Part A Molecular and Biomolecular Spectroscopy	10

The highest-contributing institutions are shown in Table 14. Their placement qualitatively follows rankings previously described for various academic indices (Silaghi-Dumitrescu and Sabau, 2014).

Table 14

Romanian Institutions featuring the highest contributions in numbers of bioinorganic publications

Babes-Bolyai University of Cluj-Napoca	277
University of Bucharest	267
University Politehnica of Bucharest	167
Alexandru Ioan Cuza University	83
Institute of Physical Chemistry, Romanian Academy of Sciences	74
Petru Poni Institute of Macromolecular Chemistry	73
Gh. Asachi Technical University of Iaşi	68
Carol Davila University of Medicine and Pharmacy of Bucharest	66
Iuliu Hatieganu University of Medicine and Pharmacy of Cluj-Napoca	54
The Romanian Academy	50

The highest-contributing Romanian authors are shown in Table 15.

Table 15

Authors with Romanian affiliations publishing bioinorganic-related publications, 1968-2015

Name	Publications
Silaghi-Dumitrescu, R.	66
Olar, R.	37
Badea, M.	36
Marinescu, D.	30
Silvestru, C.	29
Silvestru, A.	21
Parvulescu, V.I.	18
Mitu, L.	17
Mihailescu, I.N.	17
Haiduc, I.	17
Negreanu-Pirjol, T.	15
Astilean, S.	15

The types of documents, cf. Table 16, reveal a distinctly higher contribution of Conference Proceedings publications – and a lower one for Reviews, compared to the rest of the world.

Table 16

Types of bioinorganic publications from eastern-European authors

Types of publications	Items
Article	1118
Conference Paper	117
Review	56
Book Chapter	26
Book	4

Table 17

Fields/subjects where the Romanian bioinorganic papers are classified

Research field	Items
Chemistry	761
Materials Science	320
Biochemistry, Genetics and Molecular Biology	253
Physics and Astronomy	213
Chemical Engineering	181
Engineering	156
Environmental Science	130
Medicine	84
Agricultural and Biological Sciences	78
Pharmacology, Toxicology and Pharmaceutics	73
Earth and Planetary Sciences	37
Computer Science	27
Immunology and Microbiology	26
Energy	12
Mathematics	11

Table 17 reveals a distinctly lower contribution of Biochemistry & Molecular biology and for Medicine compared to the rest of the world. This follows a previously-noted trend for Romanian scientific output (Silaghi-Dumitrescu and Sabau, 2014). Thus, the Chemistry contribution is now at 57%, while Biochemistry, Genetics and Molecular Biology drops to ~half the global level at 19% and is thus surpassed by Materials Science. Likewise, Medicine falls to ~half the level seen at international level.

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