The Directory of Open Access Journals covers more biomedical open access journals than other databases.

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Abstract

Background: Open access (OA) journals disseminate research papers free of charge to the reader. Traditionally, biomedical researchers use databases like MEDLINE and EMBASE to discover new advances. However, biomedical OA journals might not fulfil such databases' criteria, hindering dissemination. The Directory of Open Access Journals (DOAJ) is a database searchable at article level, focusing exclusively on OA journals.

The aim of this study was to investigate DOAJ's coverage of biomedical OA journals compared with the conventional biomedical databases.

Methods: Information on all journals listed in five conventional biomedical databases (MEDLINE, National Library of Medicine, PubMed Central, EMBASE and SCOPUS) and DOAJ were gathered. Journals were included if they were 1) actively publishing, 2) full OA, 3) prospectively indexed in one or more database, and 4) of biomedical subject. Impact factor and journal language were also collected. DOAJ was compared with conventional databases regarding the proportion of journals covered, along with their impact factor and publishing language. The proportion of journals with articles indexed by DOAJ was determined.

Results: In total, 3,236 biomedical OA journals were included in the study. Of the included journals, 86.7% were listed in DOAJ. Combined, the conventional biomedical databases listed 75.0% of the journals; 18.7 % in MEDLINE; 36.5% in PubMed Central; 51.5% in SCOPUS and 50.6% in EMBASE. Of the journals in DOAJ, 88.7% published in English and 20.6% had received impact factor for 2012 compared with 93.5% and 26.0%, respectively, for journals in the conventional biomedical databases. Of journals exclusively listed in DOAJ, only one had received an impact factor. A subset of 51.1% and 48.5% of the journals in DOAJ had articles indexed from 2012 and 2013, respectively.

Conclusions: DOAJ is the most complete registry of biomedical OA journals compared with five conventional biomedical databases. However, DOAJ only indexes articles for half of the

biomedical journals listed, making it an incomplete source for biomedical research papers in general.

Background

The idea of open access (OA) in the field of scientific research is to create a publishing platform, where knowledge is freely available for all (Chan et al. 2002) and not bound by commercial interests (Giglia 2007). From 1993 to 2009 the number of published OA articles increased from less than 250 to more than 191,000 articles a year, covering an estimated 20% of all scholarly articles published in 2008 (Bjork et al. 2010; Laakso et al. 2011). OA research papers can be deposited in online archives, published in OA journals, or both (Bjork et al. 2010). OA journals combine being freely available with the benefits of traditional scholarly communication subjected to editorial quality control through peer review processes.

In the field of biomedical research, both subscription-based and OA journals are indexed in online databases such as MEDLINE, EMBASE, and PubMed Central. Journals are included according to strict selection criteria (Peña et al. 2004; U.S. National Library of Medicine 1988; U.S. National Library of Medicine 2014c). Such criteria may create a barrier for newly formed OA journals to be indexed in the conventional biomedical databases, even if these journals publish high quality papers – hence making them hard to find for readers. This may hinder timely dissemination of research and thereby compromise the purpose of OA. The Directory of Open Access Journals (DOAJ) (Directory of Open Access Journals 2014c) was founded in 2003 and at the time of this study contained more than 9,700 OA journals. More than 5,600 of the journals are searchable at article level. By easing inclusion criteria (Directory of Open Access Journals 2014f), DOAJ offers a window for newly established OA journals to get indexed in a database, which is searchable at article level and freely available to researchers – thereby facilitating the availability of papers published in OA journals.

The purpose of this study was to investigate the distribution and overlap of biomedical OA journals between DOAJ and conventional biomedical databases.

Methods

Databases

In order to investigate the distribution of biomedical OA journals between DOAJ and the conventional biomedical databases, we retrieved journal lists from DOAJ and the following four conventional biomedical databases: MEDLINE, PubMed Central (PMC), EMBASE and SCOPUS, see **Table 1**. Furthermore, data from the Journal Citation Reports (JCR) 2012 Science and Social Sciences edition were downloaded and included as well. Data from the U.S. National Library of Medicine's (NLM) journal catalogue was also included. Data on activity, OA-status, publication language and 2012-impact factor were collected from the five databases and Journal Citation Reports.

Data collection and inclusion criteria

Journal lists were freely available from the websites of DOAJ, EMBASE (including a listing of MEDLINEs journals), SCOPUS, PubMed Central and NLM and were retrieved May 2014. Data from JCR were retrieved using institutional access via the University of Copenhagen and retrieved January 2014.

Journals were identified either by their unique International Standard Serial Number (ISSN) or Electronic ISSN (EISSN). Journal records listed without either of these were excluded. All journals were cross-matched on ISSN and EISSN, so journals with ISSN incorrectly registered as EISSN (and vice versa), were correctly matched.

We constructed our dataset by merging the databases one by one, and aggregating data for matching journals. **Figure 1** illustrates the process. From this comprehensive list, we drew our sample of journals following four inclusion criteria: Only

journals that were 1), actively publishing, 2), releasing all content free of charge immediately upon publication (full and immediate OA), 3) prospectively indexed in one or more of the included conventional databases and/or DOAJ and 4), considered to be of biomedical subject, were included in our study.

We only included actively publishing journals. Since manually collecting information on the latest issue from every journal was deemed too labour intensive, the following database denotations for activity were used: For journals listed in SCOPUS, each was labelled as "active/inactive" in the journal list. No similar variable was available for journals in MEDLINE, EMBASE and PubMed, so in order to avoid underestimating the share of active OA journals herein, all journals indexed in MEDLINE, EMBASE or PubMed Central were considered active. Exceptions were made for journals explicitly noted as inactive by an end publication year (MEDLINE, DOAJ) or a "predecessor"-status (PMC) (Fogelman 2009), as long as this was not contested by information from one or more of the other databases. Where data on activity was collected manually, journals were considered active, if they had published at least one article in 2013 or 2014.

For our study, only journals granting full and immediate access to all content were considered to be OA journals, in accordance with the Bethesda Statement on Open Access Publishing (Suber 2003), and the DOAJ selection criteria (Directory of Open Access Journals 2014f). Subscription journals with optional OA for individual articles (hybrid OA), subscription journals allowing the authors to archive free versions of individual articles, journals providing OA to only part of their contents (e.g. research articles only) and journals providing OA to their content after an embargo period (delayed OA) were not considered full OA for our study's purposes. SCOPUS, DOAJ and PubMed Central provided info on OA-status. If any one of these databases had labelled the journal as OA, it was included. For 403 actively publishing journals, OA-status could not be determined via data from the

downloaded journal lists. OA-statuses for these journals were collected manually using the journals' websites.

Since the journal must be both currently publishing and grant full and immediate OA to all content to be eligible for indexing in DOAJ (Directory of Open Access Journals 2014f), all journals listed in DOAJ were assumed to fulfil these two criteria – except when an end year of publication (when the journal had ceased to publish) was listed in DOAJ.

DOAJ, MEDLINE, PubMed Central, SCOPUS and EMBASE index the contents of their selected journals prospectively. NLM's catalogue contains titles from all of PubMed – including MEDLINE's and PMC's repertoires as the active sources for new citations. Furthermore it contains titles no longer being indexed, along with non-biomedical titles etc. (U.S. National Library of Medicine 2002). Therefore titles only listed in NLM's catalogue were not considered prospectively indexed in any of the included databases.

Both DOAJ and SCOPUS index journals from a broad spectrum of scientific fields. Only journals of a biomedical subject were included for this study. The chosen biomedical subjects from DOAJ and Scopus are presented in **Table S1** and **S2**, respectively. Journals indexed in EMBASE, MEDLINE and PubMed Central were considered biomedical, since these databases only index journals of biomedical subject (Embase 2014; U.S. National Library of Medicine 1988; U.S. National Library of Medicine 2014b).

Of the included journals, 552 were not in DOAJ. For these, data on activity and OA-status were collected manually via their respective websites. Journals found inactive or not full OA were excluded. In total, 434 journals were left after exclusion of erroneously included journals.

Furthermore, 283 journals had no language information available through the databases. Languages for these journals were collected manually.

Seventy-three included journals had conflicting information on activity (5 with an end publication date, 10 denoted as "predecessor" and 58 denoted as "inactive" by SCOPUS). These were manually checked for activity and OA-status. Nine of these journals were inactive, and were excluded. All of the journals were full OA.

To determine how many of the journals indexed in DOAJ had opted to submit their contents metadata to DOAJ, we downloaded article metadata from DOAJ's XML-based metadata server (Directory of Open Access Journals 2014e). We used a modified OAI-PMH (Open Access Initiative Protocol for Metadata Harvest) (Lagoze et al. 2008) C# client for scraping the required article metadata (**Table S3**). Journals were considered to have their content indexed in DOAJ for 2012 and/or 2013, if any indexed articles from this period, carried the journal's ISSN.

Data validation

To check for wrongfully exclusion of journals, 100 journals, excluded for being inactive or subscription based, were randomly sampled and manually checked via the NLM catalogue and the journals' respective websites. The access level of any active journal was determined on availability of both current issue contents and archived content.

Another random sample of 160 (~5%) included journals was drawn to verify activity, OA-status, language category, impact factor and whether the journal was indexed in DOAJ. These data were manually collected from the journals' websites, JCR and DOAJ.

Data presentation

Primarily, we determined the distribution and overlap of OA journals between the conventional biomedical databases and DOAJ. All analyses were carried out with SPSS 22 software (IBM Corporation, Armonk, New York, USA). Continuous data (not normally distributed) are reported as median (range), [interquartile range]. Binomial data are reported in percentages.

Results

Data validation

The sample of 100 excluded journals yielded 57 active journals; hereof 1 full OA journal (Oklahoma Law Review), which was not of biomedical subject, even though it was categorized under *'Medicine'* in SCOPUS. Overall, none of the sample journals fulfilled the inclusion criteria.

The sample of 160 (~5%) included journals yielded the following:

- All examined journals were active full OA-journals, except for 1 journal (BMC Pharmacology), which had fused with BMC Clinical Pharmacology (which had been rightly excluded) in 2012 to form another new journal. This new OA-journal was already included in our cohort, and so the predecessors were removed from the cohort.
- All journals were correctly labelled as not in DOAJ (n = 33), or in DOAJ (n = 126).
- For 5 journals, language had been collected manually, since no information was available through the databases. Of the remaining 154 journals, 3 had been incorrectly labelled regarding English/non-English language.

- All journals with a 2012 impact factor (n = 33) had had the correct impact factor assigned during the dataset build. The remaining 126 journals had correctly been assigned no 2012 impact factor.

Findings

Overall journal distribution by database type (DOAJ or conventional), language (English/non-English) and impact factor are shown in **Table 2**. In total, 3,236 biomedical OA journals were included in this study. Of these, 89.2% published in English and 19,5% had received an impact factor for 2012, with a median value of 1.257, range 0.013 - 153.459.

The proportions of journals in the respective databases are summarized in **Table 3**. We found, that 86.7% (2,804 journals) of the included OA journals could be found in DOAJ. In contrast, each of the conventional databases accounted for lesser proportions of our sample. Combined, the conventional biomedical databases had 75% (2,429 journals) of the included journals listed, 18.7 % in MEDLINE, 36.5% in PubMed Central, 51.5% in SCOPUS and 50.6% in EMBASE. PubMed was found to have the largest proportion of OA journals among the conventional biomedical databases with 56.4% (1,824 journals) listed therein. However, of these journals 334 (18.3%) were prospectively indexed in neither MEDLINE nor PMC. These titles were listed in the NLM's catalogue, and therefore did not have full and current content in PubMed. Hence only 46.1% (1,490 journals) of the biomedical OA journals are being prospectively indexed in full for PubMed via MEDLINE and PubMed Central.

Publishing in English was common for the journals in DOAJ (88.7% of journals) and the journals in the conventional biomedical databases (93.5% of journals) (**Table 2**). However, of the 807 journals found only in DOAJ, a smaller proportion of 76.5%

published in English. Meanwhile this share was 92.6% of the 432 journals found only in the conventional databases.

Considering journal impact factor (**Table 2**), 20.6% of the journals in DOAJ had received impact factor for 2012 with a median value of 1.316, interquartile range (IQR): [0.619-2.456]. For journals listed in the conventional biomedical databases, 26.0% had received 2012 impact factor with a median value of 1.263, IQR: [0.615-2.426]. Journals only found in DOAJ (807 journals) and journals found only in the conventional databases (432 journals) had only 1 journal (0.1%) and 53 journals (12.3%), respectively, that had received an impact factor for 2012. The median impact factors in these two groups were 0.994 and 0.372, respectively.

A subset of the journals listed in DOAJ had articles from 2012 (51.1% of the journals) and 2013 (48.5% of the journals) indexed in DOAJ (**Table 4**). Of the journals listed only in DOAJ, 40.5% and 40.4% had articles from 2012 and 2013, respectively, indexed in DOAJ.

Discussion

Main findings

This study found that DOAJ is the single most complete database, when it comes to listing biomedical OA journals. Even combined, MEDLINE, PMC, SCOPUS and EMBASE did not match DOAJ's coverage. Each of the conventional biomedical databases covered about half of the journals relevant to this study. Even endowed with high coverage, DOAJ in itself however, does not cover the entire biomedical OA field, leaving 13.3% of biomedical OA journals to be located elsewhere.

The journal subsets not found in DOAJ, and not found in the conventional biomedical databases, respectively, were both characterized by fewer journals with 2012 impact factor, and a lower median impact factor value. Only one journal outside the conventional biomedical databases had received an impact factor for 2012. This could imply that being selected for the conventional biomedical databases is crucial for receiving an impact factor, and that uptake in DOAJ alone does not prompt journals to receive an impact factor. Of the journals in DOAJ, the conventional biomedical databases, and in both, equally high rates of journals in English were found. However, journals not listed in the conventional biomedical databases but only in DOAJ had a significantly smaller proportion of journals publishing in English. This association could imply that the biomedical OA journals publishing in other languages than English are less likely to be selected for the conventional biomedical databases than for DOAJ.

Strengths and limitations

This study focussed on a single scientific field to keep "cultural" differences between the various scientific disciplines from skewing the overall picture. Several large databases were included in this study, and hence a large number of potentially relevant journals were screened to be included in the study. We applied four relevant inclusion criteria to define our cohort from database metadata, where after it got honed through subsequential manual exclusion of ineligible journals, which had been wrongfully included. We based the systematic inclusion of journals on an assumption that our database data were correct. We assumed that all journals in DOAJ were both active and full OA. The activity of OA journals in DOAJ has earlier been contested (Morris 2006), who found that up to 14% were not currently active. DOAJ has changed a lot since 2005, and currently use a standardized application form (Directory of Open Access Journals 2014d), along with running exclusion of

inactive journals (Directory of Open Access Journals 2014b). So to validate our assumption, and because the journals' metadata derived from all databases could be faulty, we conducted a limited data validation of both included and excluded journals. This revealed high concordance between database data and manually collected data, ensuring that only ineligible journals had been left out, and only eligible journals had been included. One limitation of this study is that we exclusively included full OA journals – e.g. excluding journals providing OA to scientific content only, journals exercising delayed OA along with journals employing hybrid OA business models. One could argue, that inclusion of these journals would alter our results, since these business models do not comply with the DOAJ selection criteria (Directory of Open Access Journals 2014f), thus these journals would not contribute to the segment found in DOAJ.

Perspectives

Medicine is one of the scientific fields previously shown to rely on OA journals rather than self-archiving for distributing OA content (Bjork et al. 2010). PubMed is the primary search engine for many biomedical researchers, making thousands of journals searchable, counting approximately 1800 OA journals. To display results from OA titles only, the user can enable the "Free Full Text"-filter when searching PubMed (U.S. National Library of Medicine 2014a). Similarly DOAJ can be searched at article level using Boolean operators. A major condition for considering DOAJ equal to the conventional biomedical databases would be DOAJ's indexation of individual journal articles in such a fashion, so they become searchable for the readers. However, we found that only about 50% of the biomedical journals had actually opted to get their articles indexed in DOAJ. This is an important fact to consider, as it means DOAJ's coverage at the article level is lacking compared to the databases where article indexation is a main feature. With 807 biomedical OA journals not reachable via the

conventional biomedical databases, but readily found through DOAJ, we may raise the question whether searches in DOAJ should be included along the conventional PubMed and EMBASE searches when conducting systematic reviews of the biomedical literature. However, as only about 40% of these journals have current content available and searchable through DOAJ, the actual gain from searching DOAJ for individual articles would be limited.

When online databases select journals for their repertoires, they do so following pre-specified selection criteria. For the conventional biomedical databases included in this study, selection criteria include the quality of content, production and home pages, along with the editorial work and the quality of peer review (Peña et al. 2004; Scopus 2014; U.S. National Library of Medicine 1988; U.S. National Library of Medicine 2014c). Furthermore, journals applying to e.g. MEDLINE must have a minimum number of papers published and comply with specific technical requirements (U.S. National Library of Medicine 1988). These criteria are set in order to secure the user a certain level of scientific quality within the included journals and their papers. The biomedical OA journals not found in the conventional biomedical databases might presently be unable to comply with specific selection criteria. For example, complying with technical demands like those of PMC's (U.S. National Library of Medicine 2014c) can be costly for small independent journals. DOAJ aims to cover all OA journals (Directory of Open Access Journals 2014a) and indexes journals that target academic researchers by primarily publishing research papers (Directory of Open Access Journals 2014f). For inclusion in DOAJ, full text papers must be available in full and for free, immediately upon publication (Directory of Open Access Journals 2014f). Journals should be registered with an International Standard Serial Number (International Standard Serial Number International Center 2014) and exercise peer review (Directory of Open Access Journals 2014f). Thus, DOAJ's selection criteria are not as subjective as those of some of the conventional biomedical databases'. DOAJ demonstrates a database model, where biomedical

OA journals not presently selected for the conventional biomedical databases, can still have their contents indexed and made available and searchable for readers, aiding dissemination of their content.

Conclusions

The Directory of Open Access Journals includes the main part of biomedical OA journals. The conventional biomedical databases each lack around 50% of relevant biomedical OA journals. However, the fact that journals are not required to have their articles indexed in DOAJ impedes DOAJ's usefulness to researchers, when performing systematic searches and when reviewing the literature.

Table 1. Properties of the included databases.

	DOAJ	MEDLINE	PubMed Central	SCOPUS	EMBASE
Type and size of content	9,700 journals.	5,600 journals.	2,100 journals.	34,000 journals and book series.	8,400 journals.
Subjects	All scientific and scholarly.	Biomedicine and clinical medicine.	Biomedicine and clinical medicine.	Health, life, social and physical sciences.	Broad biomedicine, focus on pharmacology and clinical medicine.
Journal quality control.	Peer review.	Peer review.	Peer review.	Peer review.	Peer review.
Can be searched by abstracts, authors and journal title	Yes	Yes	Yes	Yes	Yes
Specific, hierarchical topic search available	No.	Yes (MeSH).	Yes (MeSH – not for all entries).	Yes (MeSH and Emtree among others).	Yes (Emtree).
Availability	All content must be available online.	Either available online or in print.	Articles must be supplied for archiving.	All content must be available online.	Either available online or in print.
Special requirements or topics of evaluation	Full and immediate open access to all of a journal content required.	Life span of at least 12 months and 40 published articles required. Evaluates standing and contribution.	XML-submission of full-text articles required.	Evaluated on journal policy, quality, standing, regularity and availability.	Evaluated on scientific and editorial quality.
Access cost	Free.	Free.	Free.	Institutional subscription only.	Institutional subscription only.
Uses	Indexes and links to journals' homepages, along with providing journal metadata. Links to full text articles, when provided by the journal.	Links to full text articles, as well as free full text (if available).	Archives full free text articles from OA journals, and free articles from subscription journals under the NIH Grant Policy.	Links to full text articles.	Links to full text articles.
References	(Directory of Open Access Journals 2014f; Directory of Open Access Journals 2014g)	(Falagas et al. 2008; Peña et al. 2004; U.S. National Library of Medicine 1988; U.S. National Library of Medicine 1990)	(U.S. National Library of Medicine 2014c)	(Falagas et al. 2008; Scopus 2014)	(Embase 2014; Peña et al. 2004)

DOAJ; Directory of Open Access Journals, *MeSH*; Medical Subject Headings, *XML*; Extensible Markup Language.

Figure 1. The inclusion process for the biomedical open access journals.

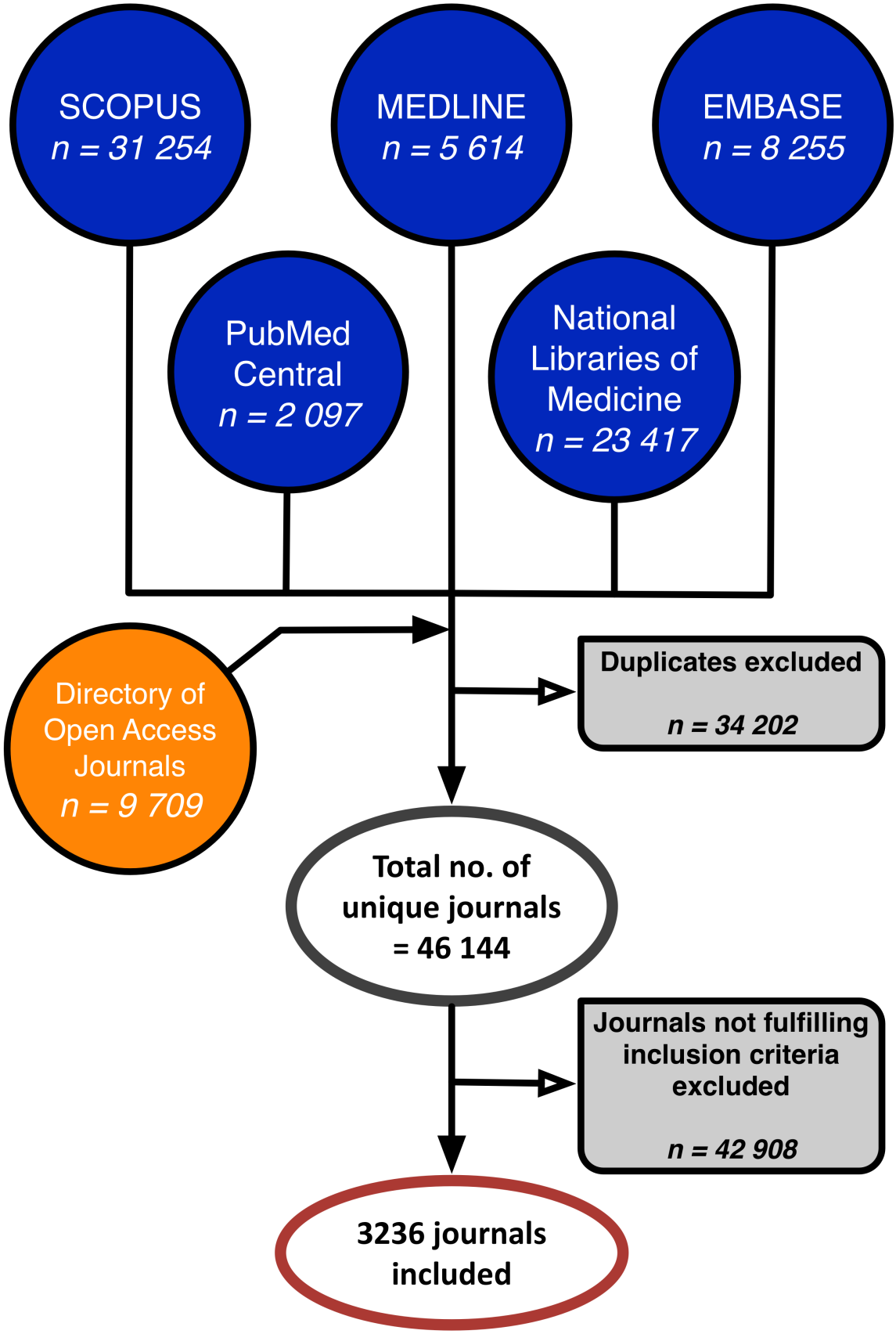

Table 2. The distribution and overall characteristics of biomedical open access journals between the Directory of Open Access Journals and the conventional biomedical databases.

	In DOAJ	Only in DOAJ	In both DOAJ and conventional biomedical databases	Only in conventional biomedical databases	In conventional biomedical databases	All open access journals
Number of biomedical OA journals (% of total (n))	86.7 (2804)	24.9 (807)	61.7 (1997)	13.3 (432)	75.0 (2429)	**100 (3236)**
English language journals (% (n))	88.7 (2488)	76.5 (617)	93.7 (1871)	92.6 (400)	93.5 (2271)	**89.2 (2888)**
Received impact factor 2012 (% (n))	20.6 (579)	0.1 (1)	28.9 (578)	12.3 (53)	26.0 (631)	**19.5 (632)**
Impact factor 2012 (median (range) [interquartile range])	1.316 (0.013-15.253) [0.619-2.456]	0.372 (0.372-0.372) [0.372-0.372]	1.320 (0.013-15.253) [0.619-2.458]	0.994 (0.076-153.459) [0.558-1.892]	1.263 (0.013-153.459) [0.615-2.426]	**1.257 (0.013-153.459) [0.615-2.423]**

DOAJ; Directory of Open Access Journals, *OA*; open access. *Conventional biomedical databases* include: MEDLINE, PubMed Central, EMBASE, SCOPUS and U.S. National Library of Medicine.

Table 3. The distribution of biomedical open access journals among the included databases.

Database	Journals indexed (% (n))
DOAJ	86.7 (2804)
PubMed	56.4 (1824)
- **MEDLINE**	18.7 (605)
- **PubMed Central**	36.5 (1181)
- **Rest of PubMed**[a]	10.3 (334)
SCOPUS	51.5 (1667)
EMBASE	50.6 (1636)

DOAJ; Directory of Open Access Journals.
[a] journals only listed in PubMed via the National Library of Medicine's catalogue, but not prospectively indexed in PubMed via MEDLINE or PubMed Central. They are included as they are prospectively indexed in one or more of the other databases.

Table 4. The proportion of biomedical open access journals listed in the Directory of Open Access Journals with their content indexed at article level.

	Articles published in 2012	Articles published in 2013
Share of journals in DOAJ with indexed articles, (% (n))	51.1 (1434)	48.5 (1359)
Share of the journals *only* in DOAJ with indexed articles, (% (n))	40.5 (327)	40.4 (326)

DOAJ; Directory of Open Access Journals.

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