Citation patterns in open access journals

Fredrik Åström
Lund University Libraries, P.O. Box 134, SE-22100 Lund, Sweden
University of Technology, Journalism, Information and Media Studies Group, P.O. Box 123, Broadway, NSW 2007, Australia

Abstract

Introduction. Along with the great expansion of research being published in Open Access (OA) journals over the last decade, the interest for analysing the OA literature using informetric methods has also increased. Most studies have focused on the citation impact of OA journals and whether OA publishing increases the chances of a research publication being cited. Fewer analyses, however, have investigated whether OA and non-OA journals in the same research fields are citing the same literature; and to what extent this reflects whether it is the same kind (and thus comparable) research that is published in the two forms of scholarly publications.
Method. The analyses were performed on articles from 45 journals in five different fields: three OA journals, three non-OA and a control set of three more non-OA journals. The citation structures in the journals were analysed through MDS maps building on co-citation analyses, as well as a more thorough comparison investigating overlaps of cited authors and journals between the different journals.
Results. The results are not unambiguous: in biology and biotechnology there are signs of differences of research orientation in-between journals, however not related to whether the journals are OA or non-OA publications; whereas genetics and microbiology show a strong core of journals and authors being cited by all journals. Yet another pattern is found when analysing zoology, where the separation of research areas within the field seems more dependent on whether research was published OA or non-OA.

Conclusions. The results of the analyses suggests that it is hard to draw any overall conclusions on the matter of whether research published in OA journals is likely to have a larger citation impact or not. The differences between research fields are simply too substantial to make any claims on a more general level. It should however be noted that the results should be interpreted with some caution. The subject categories used in the analyses are those of Thomson Reuters' *Journal Citation Reports*, a subject classification that is not entirely unproblematic. And at the same time: using journals as basis for field definitions, and the journal selection process in itself, is also related to a set of different problems.

Introduction

When discussing scholarly communication over the last decade or so, one issue that has been brought up to an increasing extent is open access publishing of academic text, while at the same time: quantitative analyses of publications and citations are increasingly used as indicators to assess scholarly productivity, quality and impact. Relatively few quantitative, or scientometric, analyses has been done on open access (OA) research, but there seems to be a tendency towards openly accessible research being cited more – and presumably having a greater impact in the research community – than non-open access (NOA) research publications (e.g. Antelman 2004; Hajjem, Harnad and Gingras 2005; Harnad and Brody 2004; Zhang 2006). The analyses showing these tendencies are not, however, uncontested (e.g. Craig *et al* 2007), something that might be an indicator on the problem of OA-available research is still a relatively new medium for disseminating research, while the things we know about scholarly communication in general through scientometrics is based on communications structures developed throughout the whole of the 20th century. This is not, however, the only problem that needs addressing.

In the use of scientometrics, one of the main assumptions is that citations reflect impact and even quality, built on the idea of research being accumulatively organised and we build on the knowledge of our predecessors, thus citing research of high quality. This has lead to the development of quality indicators such as the journal impact factor (Garfield & Sher 1963) and the *h*-index (Hirsch 2005). One of the problems identified with these general indicators of research quality is that they do not consider the differences of publication and citation practices in different research fields, nor variations between different kinds of articles such as research and review articles; something that has lead to the development of different strategies for normalization of publication and citation counts such as ‘the crown indicator’ (van Raan 2003). A core aspect of this issue is the question on to what extent we are counting the same things when we are using scientometric indicators to evaluate research, or if we are trying to compare ‘apples and oranges’, an issue that has been raised in relation to OA research publications by e.g. Harnad and Brody (2004).

Another application of scientometric/informetric methods is using citation analyses to map intellectual and social structures of research fields, assuming that texts, scholars or journals being cited together (Marshakova 1973, McCain 1991, Small 1973, White and Griffith 1981) – or texts, authors and scholars citing the same literature (Jarneving 2007a; 2007b, Kessler, 1963, Vladutz and Cook 1984) – also have common research interests. Also here, issues of differences between research areas and media for communicating research has been noticed. The impact of journal selection for analysing research fields has been addressed by e.g. Åström (2002); and in a study of XML research, Zhao (2004) found different research orientations with little communications between the orientations within the XML field, published in on one hand, traditional journals covered by the ISI Thomson databases; and on the other: OA research freely available on the world wide web.

Given the latter idea of using scientometric methods for analysing intellectual structures in research fields, it should be possible to compare OA and NOA journals within the same field, to see whether it is actually the same kind of research being published; and thus, whether it is meaningful to compare research published in the two genres of journals or if comparing the two actually is a matter of trying to compare ‘apples and oranges’? More specifically, the research questions of this article are:

- What citation structures can be found in OA and NOA journals respectively?
- To what extent are those citation structures comparable?
- Do these differences – if any – in citation structures reflect different research orientations in OA and NOA journals respectively, within the same field?

It should be noted, that by open access in the context of this study is meant research articles published in journals being openly accessible, i.e. what is referred to as ‘gold’ open access and not research being achieved in an openly available institutional or subject oriented repositories following the ‘green’ line of open access.

Material and methodology

The basic idea was to find sets of OA and NOA journals from a variety of research fields being indexed in the ISI citation indices, and compare the citation structures in the OA and NOA journals respectively within each of these research fields. As already mentioned a core issue when performing these kinds of analyses is to select a comparable set of journal articles to analyse; thus, finding journals’ being as similar as possible is of vital importance. To accomplish this, three different databases were utilized: *ISI Journal Citation Reports* (JCR, Thomson Reuters 2008a), *Directory of Open Access Journals* (DOAJ, Lund University Libraries 2008a) and *Journal Info* (Lund University Libraries 2008b). The first step was to identify matching subject categories in JCR and DOAJ where the classification depth stopped at the same level of specificity. The next step was to find a minimum of three journals in the ISI *Web of Science* databases (Thompson Reuters 2008b) classified as OA journals in DOAJ within these categories, reducing the amount of available categories from 58 to 15; and also, to identify OA journals having published throughout the period of 2003-2006.

To further secure the comparability of the journals, searches were made in *Journal Info* on each of the journal titles in the remaining categories, matching comparable NOA and OA journals as indexed in *Journal Info*; and within this step, also eliminating journals focusing on e.g. specific regions. At this point, only journals being indexed in *Science Citation Index* (SCI) remained. The original idea was to compare journals in fields covering the entirety of the academic landscape. However, since JCR was used as tool for journal selection, those journals indexed in *Arts and Humanities Citation Index* (A&HCI) was eliminated from the start; and when the minimum of three OA journals indexed in the ISI databases within a subject category was found, no categories from the *Social Science Citation Index* (SSCI) remained.

The last step of the selection process entailed a qualitatively based match of journal titles to further ensure topic similarity, as well as eliminating journals primarily publishing review articles; and finally, to narrow it down to six journals per field (three OA and three NOA), the JCR *Journal Impact Factor* was used. At this point, a control set of NOA journals was also selected, on the same premises as the other journals, to be able to verify whether variations between the OA and NOA journals was just depending on a random differences between journals in general, or whether the results actually reflect differences between OA and NOA journals per se. The result of the selection process was a total set of 45 journals in five subject categories (Table 1).

Subject	Journal name (N=no of articles 2003-2006)		
	NOA	OA	Control
Biology	Biol Bull-US (N=320)	Biol Res (N=226)	Bioscience (N=664)
	Folia Biol-Prague (N=129)	P JPN Acad B-Phys (N=204)	Folia Biol-Krakow (N=221)
	Theor Bi (N=94)	J Bioscienc Es (N=325)	J Biol Syst (N=121)
Biotechnology & Applied Microbiology	Appl Biochem Micro+ (N=414)	BMC Biotechnol (N=132)	Trends Biotechnol (N=462)
	Prep Biochem Biotech (N=115)	Electron J Biotechn (N=123)	Biotechnol Adv (N=139)
	Food Biotechnol (N=88)	Food Technol Biotech (N=253)	Food Microbiol (N=19)
Genetics and Heredity	Community Genet (N=113)	BMC Genet (N=557)	Genomics (N=731)
	Conserv Genet (N=358)	J Genet (N=137)	Genome Biol (N=696)
	Genome Res (N=975)	BMC Genomics (N=666)	Trends Genet (N=489)
Microbiology	Arch Microbiol (N=469)	Acta Protozool (N=153)	Res Microbiol (N=461)
	Microbiol Res (N=205)	Int Microbiol (N=153)	Trends Microbiol (N=426)
	Med Microbiol Immun (N=140)	Microbiol Immunol (N=499)	J Microbiol (N=306)
Zoology	Acta Zool-Stockholm (N=114)	Acta Zool Acad Sci H (N=150)	J Zool (N=603)
	Zoology (N=133)	Contrib Zool (N=78)	Zool J Linn Soc-Lond (N=151)
	J Zool Syst Evol Res (N=144)	Zoosystema (N=134)	Zool Scr (N=126)

Table 1: Journals selected for analysis

Having identified the source item journals, all research articles from 2003-2006 was downloaded through *Web of Science* and formatted and analysed using the *Bibexcel* (Persson 2008) software. By extracting the information from the 'cited references' field for each article, a ranked list of cited authors or cited journals could be produced for further analysis. Within each research area, analyses were performed on the references from the sets of OA and NOA journal articles separately as well as together; and in addition to that, on the control set of journal articles.

The first set of analyses performed were first author co-citation analyses (ACA), as suggested by White and Griffith (1981, White and McCain 1998). Based on the ranked list of cited authors, the highly cited authors were selected; and by matching how often each author occurred together with the other selected authors in the reference lists of the source item articles, a co-citation matrix could be made (Table 2).

	Altschul JF	Bradford MM	Byrne M	Chia FS	Chomczynski P	Clowney L	...
Altschul JF	1						...
Bradford MM	0	1					...
Byrne M	0	0	5				...
Chia FS	2	0	0	0			...
Chomczynski P	1	0	0	0	0		...
Clowney L	0	0	0	0	0	0	...
...	...	...	...	...	...	...	...

Table 2: Example of co-citation matrix

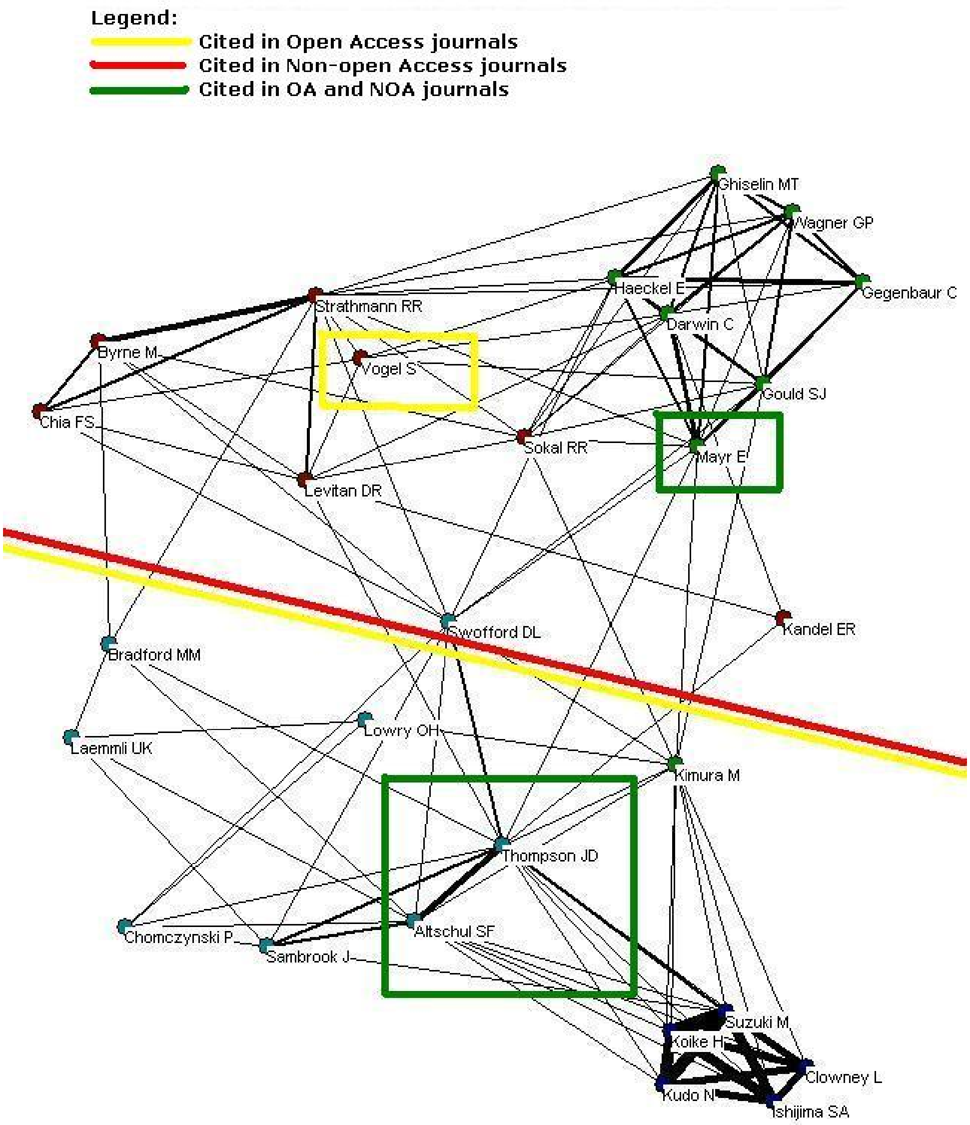
The relations between co-cited authors in the matrix are multi-dimensional: and based on the matrix itself, it is hard to make any interpretations of the relations represented therein. Therefore, the data in the matrix is used as input in a multidimensional scaling analysis (MDS), an analysis where the co-citation frequencies between different authors (e.g. Altschul and Chia are co-cited twice) are used as proximity measures. Based on this, the MDS draws a two- or three-dimensional scatter-plot of the relations between all the authors included (Kruskal and Wish 1978), a scatter-plot that can be read as a map of the relations between the cited authors. The underlying assumption here is, that the more two authors are cited together – and thus being placed closer together on the map – the more those two have in common in terms of intellectual interests. For the purpose of the investigations in this paper, four maps was initially produced for each of the five research areas: one based on the references in the articles in the OA and NOA journals, one each based on the OA and NOA journals respectively and one based on the control set of journal articles. After that, the maps were compared, to see which authors on the OA+NOA map did also occur on the individual OA, NOA and control maps. Apart from the comparison of the maps, groups of authors with strong links in-between them were investigated to see if they reflected specific research areas within the wider field. However, since the maps are based on a relatively small selection of authors depending on limitations in how many units the MDS algorithm can handle, a substantially larger set of authors, as well as journals, were investigated to see to what extent OA and NOA articles cite the same literature. This was done by calculating the percentage of shared references between OA and NOA articles, thus: if 30 out of a total of 300 cited authors were cited in both OA and NOA journal articles, the overlap between the two are 10%. Apart from analysing the overlap of citations between the OA and NOA articles, the overlap between the control set and the OA and NOA articles were also investigated.

Results

Biology

In the first analysis, the one on research articles from biology journals, a map of the 28 most cited authors in the OA and NOA journals combined was produced, based on the frequency of their co-occurrences in reference lists of the source journals. In addition to this, the same kind of maps were produced based on the cited references in OA, NOA and the control set of NOA journals respectively, to see if there are any overlap in terms of cited authors as well as if authors cited by OA and NOA journal articles seem to be grouped together or if there is any distinction in terms of spatial orientation in the map (Figure 1).

Figure 1: First author co-citation analysis of biology articles 2003-2006



Apart from the proximity of frequently co-cited authors, the co-citation strength – i.e. the frequency of co-citation between authors – is also represented by the thickness of the lines between them. This is because a two-dimensional representation of multi-dimensional relationships necessarily contains some compromises. Thus, if authors A and B, as well as B and C are frequently co-cited, while A and C are not: A and B as well as B and C should be placed close to each other while A and C are further apart. This is not entirely unproblematic, since A and C are relatively close through the mutual close connection to B. To compensate for this problem with the MDS analysis, Bibexcel supplements the original MDS scatter-plot with the representation of co-citation strength through thickness of lines. Based on this information, we can see that there are four groups that are more closely related to each other than the rest of the cited authors. At the top left is a cluster of scientists containing Chia, Byrne and Strathmann, studying microorganisms; and on the top right we have evolutionary researchers such as Darwin, Ghiselin, Gegenbaur and Mayr. On the lower half of the map, we also have two clusters: one very distinct group of biochemists – with e.g. Koike, Ishijima and Clowney – and one with Thompson, Altschul and Sambrook, representing an orientation towards molecular biology.

When we start comparing this map with the individual OA, NOA and control set maps, we can see that out of the 30 most cited authors in the NOA journals, 16 of them are also present on the map; and with a few exceptions, all located at the upper half of the map. Of the 29 authors cited by OA journals, 15 – i.e. almost the same amount as NOA cited authors) can be found in the map, although primarily on the lower half. Thus, we can see a clear difference in spatial organisation of the OA and NOA cited authors and the overlap – the number of authors cited in both the OA and NOA journal articles – is only three. However, before jumping to conclusions that there is a distinct difference in terms of what kind of research is published in OA and NOA journals respectively, it should be noted that out the 31 cited authors analysed in the control set of journals, none are present in the combined map of OA and NOA co-citations, nor in the separate OA and NOA maps. As the co-citation analyses are made on a fairly small amount of authors, a more in-depth analysis of overlaps of citations between OA and NOA journals was performed (Table 3).

	Cited authors		**Cited journals**	
	Discrete no of authors	**Relative no of citations**	**Discrete no of journals**	**Relative no of citations**
OA-NOA	5%	7%	48%	76%
Control-NOA	4%	4%	35%	52%
Control-OA	4%	5%	23%	39%

Table 3: Amount of shared references between OA-NOA research articles in biology 2003-2006

The calculation of overlaps between the different journal types was performed on two levels: both on the author and journal level. The reason for this was to, aside from seeking verification of the author co-citation analyses in the map, also to see whether any differences in citation traffic on a more structural level could be identified in-between OA and NOA journal articles. Furthermore, the percentages on both author and journal level were calculated both on the number of overlapping authors as well as the number of citations remaining after removing authors and their citation frequencies being cited in only OA, NOA or control set journals. The main reason for this was to be able to control for whether an author cited in both OA and NOA journals was also highly (or to a lesser extent) cited in both types of journals.

The results of the analyses of citation overlap between journal types in biology are corroborating the resulting maps of the co-citation analyses. There is little overlap between OA and NOA journals, but there is also a very small overlap between the control set journals and the OA and NOA journals respectively. This suggests a differentiation of research orientations in biology journals that cannot be explained by whether the journals are published openly accessible or not. It is more likely a reflection of biology being a large research field with a wide variety of research orientations.

Biotechnology and Applied Microbiology

In the co-citation analysis of the 25 most cited biotechnology scientists, we can se one very strong cluster at the lower right side of the map, containing Lowry, Bradford and Laemmli and representing a biochemistry orientation towards research on proteins; and a similar cluster, although less distinct, can be seen at the top right with e.g. Rabonovich and Koroleva. On the top left, we can also see a somewhat peripheral pair of co-cited authors (Ribereau Gayon and Singleton) who are oriented towards enology, i.e. the chemical processes involved in wine making (Figure 2).

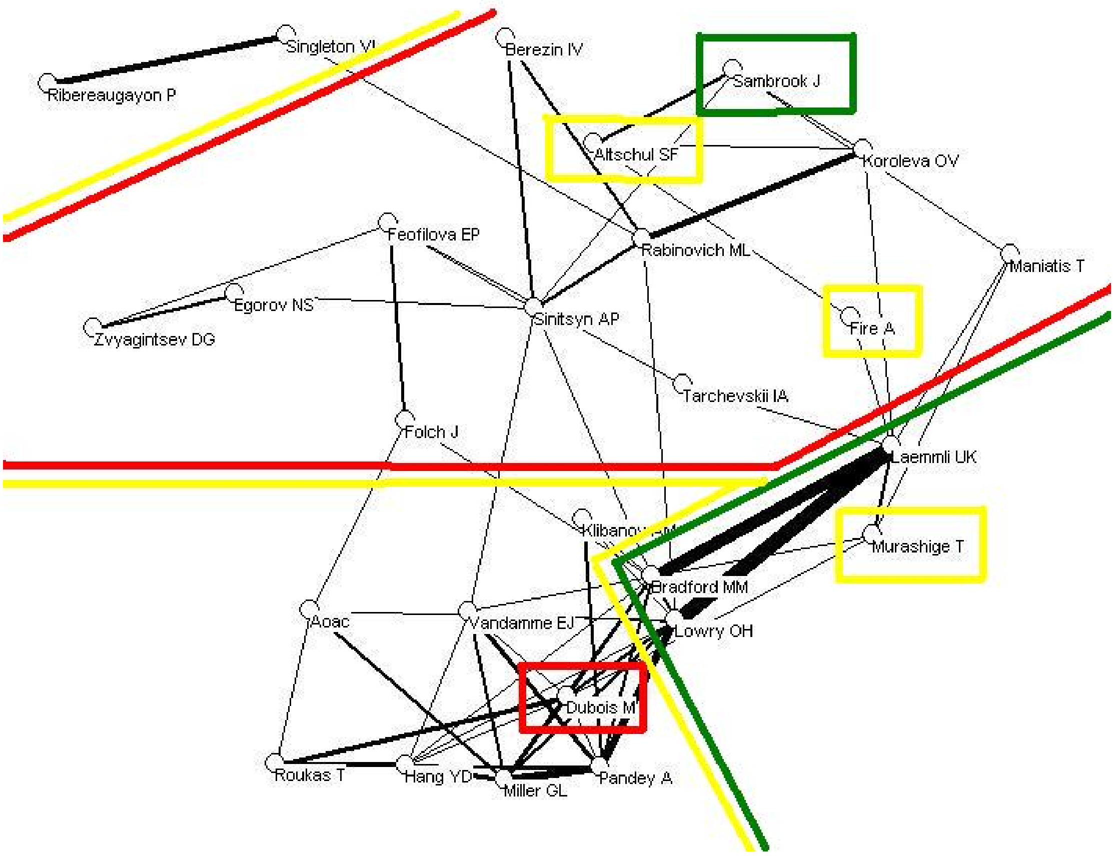
Figure 2: First author co-citation analysis of biotechnology articles 2003-2006

Legend:

Cited in Open Access journals

Cited in Non-open Access journals

Cited in OA and NOA journals



As with the biology map, there is a general orientation of NOA cited authors at the top half of the map, whereas most of the authors primarily cited by OA journal articles are located at the lower half. It should be mentioned that whether an author or a group of authors are located at the top or the bottom, or to the left or right, is of no significance. The directions on the map are basically arbitrary, whereas the meaningful information is in the reciprocal relations expressed in the distances between different authors. There is one difference in comparison with the biology map though. Although the number of cited authors in the OA+NOA map being present at both the separate OA and NOA maps are equally low, in this map the co-citation strength between them is much stronger, separating them from the OA and NOA fields of the map to a larger extent. At the same time, as with the biology map, there are no matching authors between this map and the map based on the control set of journals; and when comparing the control set map with the individual OA and NOA maps, there is only one matching cited author between the control set and the OA map. And as well as with the biology map and citation overlap analyses, the results of the biotechnology map are also quite well reflected in the citation overlap analyses (Table 4).

	Cited authors		Cited journals	
	Discrete no of authors	Relative no of citations	Discrete no of journals	Relative no of citations
OA-NOA	8%	16%	61%	75%
Control-NOA	1%	1%	55%	73%
Control-OA	11%	11%	69%	84%

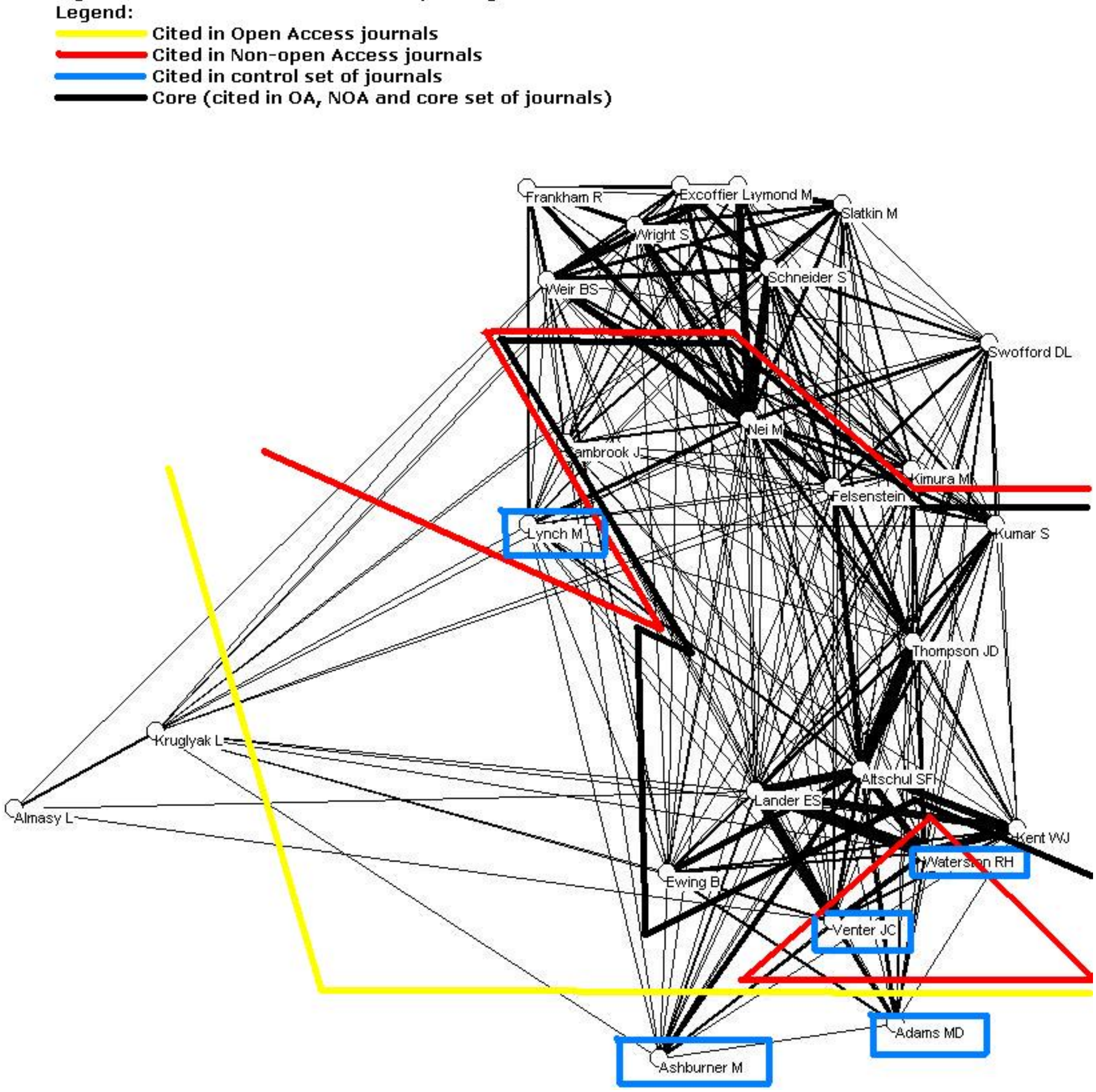
Table 4: Amount of shared references between OA-NOA research articles in biotechnology 2003-2006

In comparison with the biology analyses, the overlap between citations from OA and NOA journals is slightly larger, especially when looking at the cited journals. And although the journal citation overlap is also larger than in biology when comparing the control set and the OA and NOA journals, the low amount of overlaps on the author level suggests this is probably more a reflection of biotechnology being a smaller and narrower field with fewer journals than biology.

Genetics and Heredity

The genetics map shows two main groups of authors with high co-citation frequencies: on the top half of the map we find a group of evolution theorists such as Nei, Weir and Slatkin; and on the lower half cited authors oriented towards molecular biology and biotechnology. Thus we could say that we have a distinction between on one hand a group of more empirically and theoretically oriented authors, and on the other, a group of technique and methodology oriented authors. (Figure 3).

Figure 3: First author co-citation analysis of genetics articles 2003-2006



The structure revealed in this map is very much different from the earlier maps. Not only do the cited authors from the control set of journals come into play in a whole other way than in biology and biotechnology: out of the 25 cited authors being present in the map, more than half of these authors are also included in the individual map of the control set journal articles. Also, the map also shows a core of authors being cited in all journals, whether from OA, NOA or control set articles; whereas very few OA cited authors are not included also in the control set citations. The biggest departure from the main structure of the map is the relatively large representation of only NOA cited authors in the theoretically and empirically oriented cluster at the top half of the map. The presence of a core source of citations, both in terms of authors and journals is also clearly visible in the analysis of citation overlap between OA and NOA journals; and is even further substantiated by the comparison of the control set journals to the OA and NOA journals respectively. (Table 5).

	Cited authors		Cited journals	
	Discrete no of authors	**Relative no of citations**	**Discrete no of journals**	**Relative no of citations**
OA-NOA	32%	45%	67%	84%
Control-NOA	47%	58%	72%	92%
Control-OA	39%	50%	67%	89%

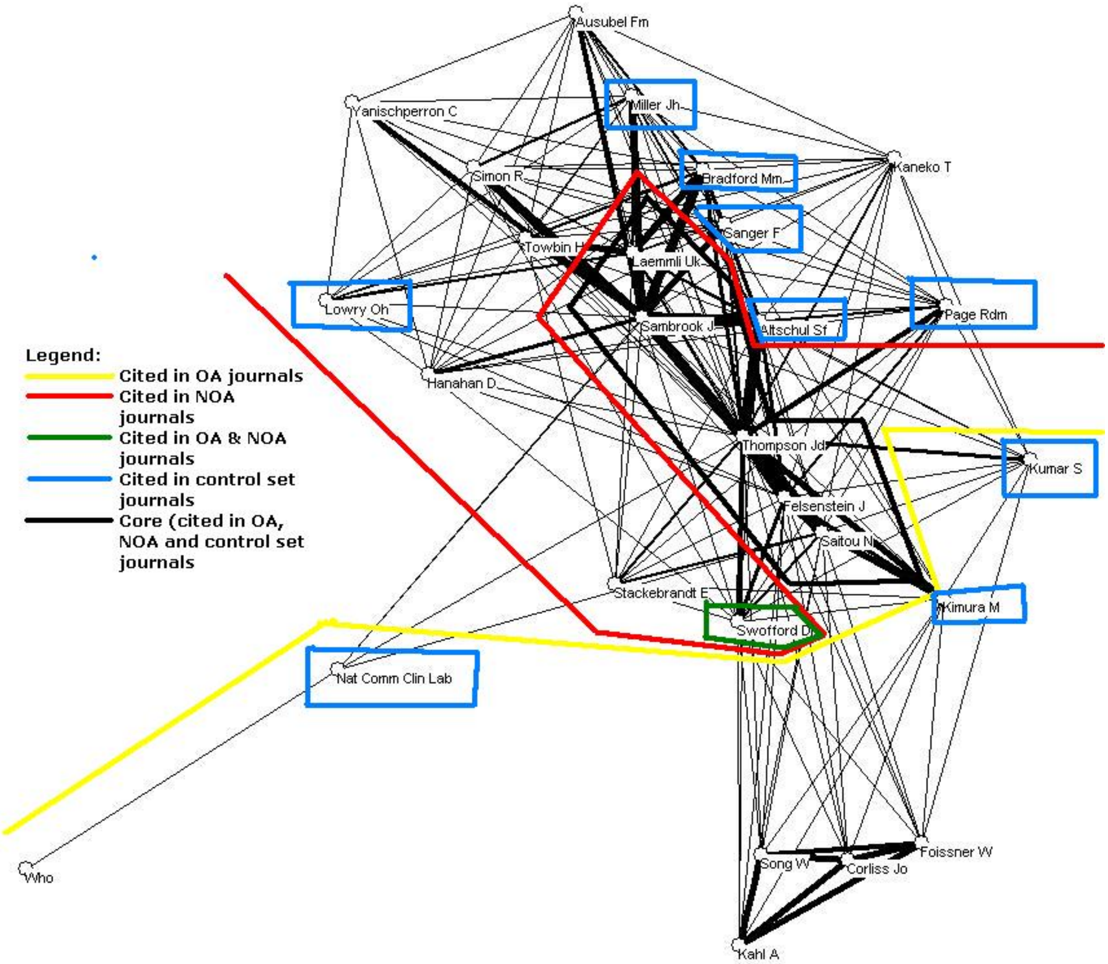
Table 5: Amount of shared references between OA-NOA research articles in genetics 2003-2006

This would suggest that genetics research builds to a substantial amount on a stable set of theories and methodologies commonly acknowledged by the research community, which means that genetics is a fairly homogeneous research field, regardless if the results are published in OA or NOA journals.

Microbiology

The co-citation map of microbiology shows many similar traits to the one based on genetics research articles, both in terms of spatial organisation and clustering, as well as the distribution of citations coming from OA and NOA journal articles (Figure 4).

Figure 4: First author co-citation analysis of microbiology articles 2003-20036



There are two main clusters to be identified: on the upper half a more methodologically oriented cluster with a focus on biomedical and biotechnological processes; and on the lower half, a more empirically oriented cluster. And, as with the genetics map, there is also a strong core present in the map with authors frequently cited in OA, NOA and control set journals articles. However, aside from the core, the spatial orientation also show groups of authors cited in either OA journals (on the lower half) or NOA journals (on the top half). And as opposed to the first two maps of biology and biotechnology, there is also a larger overlap of citations between NOA and control set journals the between OA journals and the control set, something that is also visible in the citation overlap analysis (Table 6).

	Cited authors		Cited journals	
	Discrete no of authors	**Relative no of citations**	**Discrete no of journals**	**Relative no of citations**
OA-NOA	16%	32%	52%	75%
Control-NOA	32%	53%	64%	87%
Control-OA	21%	35%	55%	83%

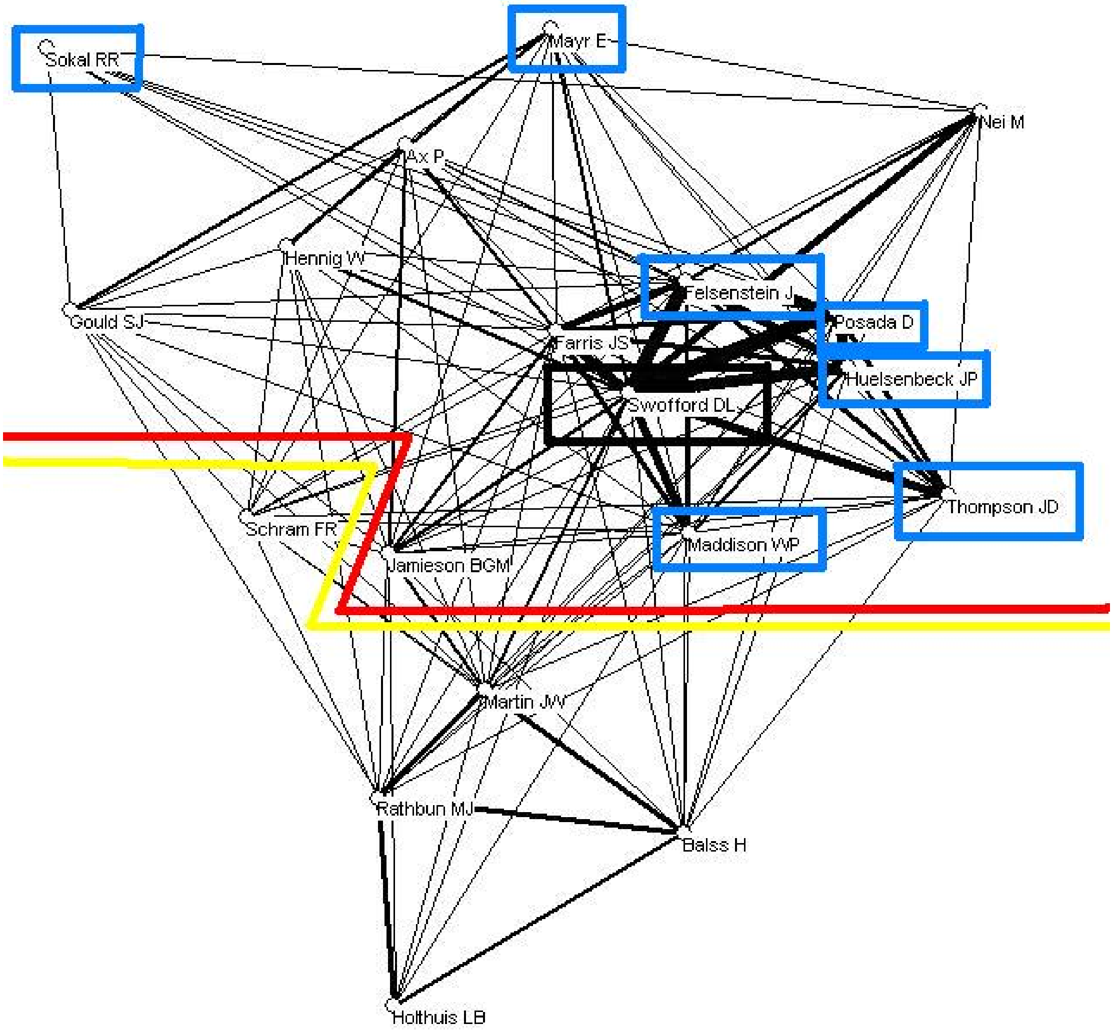
Table 6: Amount of shared references between OA-NOA research articles in microbiology 2003-2006

The overlap of citations between OA and NOA articles is higher than in e.g. biology, however, not nearly as high as in genetics; and at the same time: the difference in overlap between control set citations and OA and NOA citations respectively is higher than in both genetics and biology. Although there is a strong common core of citation sources in microbiology, we can also see a difference between OA and NOA citations, where NOA published articles seem to be closer connected to the core, whereas the OA articles represent a research orientation.

Zoology

In the co-citation map of zoology, we find a structure more resembling the first two maps, although the focus on one particular cluster is even clearer than in the biology and biotechnology (Figure 5). Here, Felsenstein, Swofford, Thompson et al represent one strong genetics oriented cluster, while most other authors are dispersed over the map. There is one more cluster, although not nearly as clearly identifiable; and that is the gathering of marine biologists at the lower end of the map. Also, as with the first two maps, there is also a clear distinction between citations from the OA and NOA journal articles. However, as opposed the biology and biotechnology, the NOA citations are also present in the control set co-citation map, whereas the only author cited in both the OA and control set articles is also cited in the NOA journals.

Figure 5: First author co-citation analysis of zoology articles 2003-2006
Legend:
Cited in Open Access journals
Cited in Non-open Access journals
Cited in control set journals
Cited in OA, NOA and control set journals



This is also supported by the results of the overlap analyses, where the overlap between NOA and OA citations is relatively small, at the same time as the difference in overlap between on one hand control set and NOA, and on the other control set and OA is the biggest when comparing the five research areas analysed. This would actually suggest that, based on research orientation reflected in citations, in zoology, there are different areas of research being presented in Open Access journals and Non-open Access journals (Table 7).

	Cited authors		Cited journals	
	Discrete no of authors	Relative no of citations	Discrete no of journals	Relative no of citations
OA-NOA	10%	12%	43%	54%
Control-NOA	35%	46%	61%	76%
Control-OA	5%	9%	44%	59%

Table 7: Amount of shared references between OA-NOA research articles in zoology 2003-2006

Conclusions

When looking at the five maps, we find two main variations in terms of how the represent the structure of research orientations, showing either one strong centre as with e.g. microbiology and zoology, or with a more distributed structure with two or maybe three noticeable clusters. In terms of how the citations are coming from OA, NOA or control set journals, we find three different structures. The first is represented by biology and biotechnology, where there seem to be differences between citation patterns in different sets of journals. However, since the overlap between the OA and NOA citation patterns respectively and the control set is small, the differences does not see to be related to whether the journals are published openly accessible, but is probably more related to differences between journals in a wider field.

The results of the co-citation analyses represented in the maps were also reflected in the citation overlap analyses. In no cases where there any significant differences in relation to whether compared authors or journals was highly cited in e.g. OA journals while having low citation frequencies in NOA journals. The increasing differences between the discrete number of cited authors and relative number of citations in fields with a higher frequency of commonly cited authors can be explained by the ‘Matthew effect’ (Merton 1968), i.e. the more times an author is cited, the likelier is it that the author will attract even more citations. Also the analyses on journal level showed the same tendencies as the co-citation and author citation overlap analyses, however on a different scale. That the figures are substantially higher for the journals is not surprising, since within ay given field, there are fewer journals than authors to cite. Neither did the journal level analyses show any differences in citation patterns on a more structural level.

In terms of citation patterns in OA and NOA journals, the cases where a clear difference based on whether the journals were openly accessible or not was zoology and – to a lesser extent – microbiology. And whereas nothing conclusive can be said about differences in citation patterns in OA and NOA journals respectively, we can say that there are differences in terms of citation patterns in OA and NOA journals between different research fields, something that would call for a stronger awareness of field differences when comparing the impact of OA and NOA journals, as well as when trying assess and compare the impact or quality of research through citation analyses in general.

Perhaps a more interesting conclusion based on these analyses though, would be the relatively large variations in citation patterns between the different research fields having been analysed here, not the least since all research fields included in these analyses are quite similar and with substantial overlaps in terms of research foci as well as in cited authors and journals. This conclusion must, however, be approached with some caution. The categorization of journals selected for the analyses is primarily based on the Thomson JCR subject categories, a subject classification that is far from perfect, and as mentioned in the introduction, the impact of using journals as symbols for subject areas in general, as well as the cautiousness required in selecting journals, is not without problems. The close similarity between the research fields analysed is coincidental, the original intent was to find a set of fields more differentiated from each other, but due to the strictly set selection criteria to ensure a reasonable level of comparability, in the end, these five were all that remained.

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