Navigating the Forest with Tree Diagrams to Visualize Library Research Support

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Purpose and goals

Libraries use data visualization to display bibliographic and library collection data, often selecting a simple bar chart and line graph to represent this data. This study uses the fan-chord diagram – one of several visualizations from the tree family – to examine research interests and journal needs of faculty, post-doctoral scholars, graduate students, and research scientists at The Ohio State University. Tree visualizations effectively illustrate branching knowledge and can display the inter-relationships between grant funding, journal usage, research publications, and more. Filtered by local taxonomies, the fan-chord diagrams created for this project show a misalignment for various disciplines between the top journals researchers choose to publish their results and the journal titles they reference. This misalignment is also present for journal titles citing the original published research. Used in tandem with more common visualizations, tree diagrams provide libraries with a more holistic view of journal use, helping to answer the simple question "to what extent does our collection meet our author's research needs?"[1]

Design, methodology, or approach

A list of NIH (National Institutes of Health) funded projects of Ohio State University researchers was downloaded from the NIH RePORTER, filtering for FY2010 to FY2022.[2] Associated research publications published between 2018 and 2022 were then downloaded from the same database. Lists of referenced publications and citing publications were next generated for each research publication using the sample Python script provided for NIH iCites database API. A second Python script was then written to gather the journal titles, journal abbreviations, authors, author affiliations, publication years, and major medical subject headings (MeSH) for each PMID on the research publications, reference publications and citing publications lists. A third script also normalized author affiliations by assigning Scopus affiliation identifiers. Unique starting points or nodes were then assigned to journal titles on the research publication lists and end points or nodes were assigned to journals on the reference publications and citing publications lists using Tableau Prep. All lists were then related in the Tableau data source window and directory-level data for local authors was added to facilitate meaningful filtering. Last, to create curved lines between starting and ending points on the fan-chord diagrams, a simple Excel file with 100 points was added to the data model.

Findings

The resulting visualizations provide a colorful, interactive profile of journal usage for NIH funded researchers in each academic unit at The Ohio State University. Filters allow users to choose an academic unit to display and up to 50 branches showing the top journals Ohio State researchers use to reference papers or the top journals citing Ohio State research. The top MeSH terms assigned to the referenced papers and the citing papers display in word clouds and text appears under the department name to summarize the amount of NIH funding awarded to researchers affiliated with the unit, the

number of NIH projects, the number of research publications associated with the funding and the number of journals publishing the Ohio State authored research. A bar chart shows the top journals publishing NIH funded research authored by researchers in the selected unit and lollipop charts show the top journals referenced by these researchers and citing this research. When filtered, the dashboards clearly indicate that for various disciplines, the top journals publishing Ohio State researchers' results are not in alignment with the journal titles Ohio State researchers' reference or the journal titles citing this research.

Action & Impact

Present day data visualization is grounded in mathematics and the base formulas used to construct curves for fan-chord diagrams and other tree family visualizations may be applied towards other more advanced charts. Code libraries are available to create these visuals in Python and R, but these tools require time and effort to master and additional skills and knowledge to embed interactivity. Instructions documenting the steps and calculations required to build tree and chord diagrams in Tableau are freely available and once built, these advanced visualizations can be combined with other visualizations to present a more coherent picture. Using raw data to develop local Tableau dashboards allows academic libraries to readily share and filter data using meaningful local taxonomies.

Ongoing requests from researchers for instructions outlining how to create tree family diagrams in Tableau, R, Python, and other tools indicate interest in this type of visualization continues to grow. Learning the math required to construct the visualizations for this project has helped the author teach others how to build these visualizations.

Practical implications or value

Using alternative approaches to present data, academic librarians can better answer at the discipline level whether our collections meet the needs of campus researchers. Tree family visualizations offer a mechanism to display relationships and information flows. When used in tandem with other visualizations, tree diagrams enhance the presentation of assessment results, inspiring conversation, and data-informed action.

Topic Keywords

Data visualization, organizational performance, open data

Introduction

Libraries develop profiles of use when making decisions about collections and library programs. Some profiles, like the California Digital Libraries Journal Weighted Value Algorithm, are mathematically based, using download, citation, journal ranking, and cost data with formulas to assign value to a journal title.[3] Other profiles comb data from Scopus, Web of Science, Journal Citation Reports, surveys and more to assemble visualizations and reports modeling library impact and the value of library investments.[4] Such data increasingly allows the library community to ask the simple question "to what extent does our collection meet our authors' research needs?"[5]

This study builds on a previous study exploring ways to visualize how libraries help scholars develop and sustain research agendas by provisioning information scholars use to inform their work.[6] The previous study modeled open data gathered from the NIH RePORTER database and linked federal research funding awarded to BTAA (Big Ten Academic Alliance) faculty to publications resulting from each award. The current study examined funding awarded to researchers affiliated with The Ohio State University alone, and the publications associated with this funding. The goal was to explore alternative, impactful ways for summarizing and sharing this data. Specifically, the project investigated creating a new, interactive profile of use with:

- filters, allowing liaison and collection development librarians to filter data by academic unit, division (when applicable), and fiscal year;
- dynamic narrative text, showing the number of NIH projects awarded to an academic unit's researchers during the time selected, the total value of these projects, the number of publications supported by this funding, and the number of times these publications were cited;
- fan-chord diagrams linking the top journals publishing a unit's NIH funded research to the top journals Ohio State researchers referenced in these publications;
- fan-chord diagrams linking the top journals publishing an academic unit's NIH funded research to the top journals citing this research; and
- Word clouds, showing the Medical Subject Headings (MeSH) assigned to the referenced publications and citing articles.

Collectively, the visualizations for each filtered profile highlight diverse interests and journal needs of Ohio State researchers, helping to inform the development of library collections and programs.

Literature review

When answering questions about library collections, visualization choices range from the simple bar chart to the more involved network diagram. (Table 1) To inform vendor negotiations for e-journal prices, Spratt shared a series of bar, line, and pie charts showing resource inflation by product, cost-per-use, and percent total spending by vendor.[7] Kilb and Jansen created a mixture of tree maps, area graphs, line charts, and horizontal and vertical bar charts to evaluate an e-journal and e-book package, showing a number of measures on these visualizations, including an in-house value benchmark, the total number of books used, the number of books with more than 5 downloads over a 5 year period, a ratio of books used versus the books available over the same 5-year period, and more.[8]

Table 1. **Choices of authors visualizing library collection or citation data.**

Study	Bar Chart / Histogram	Stacked Bar Chart	Line Graph	Pie / Donut Chart	Tree Map	Area Chart	Bubble Graph	Pareto Chart	Symbol or Choropleth Map	Network Diagram
Belter & Kaske 2016			X	X				X		X
Finch & Flenner 2016							X			
Gao & Wallace 2017					X					
Haren 2014	X		X						X	
Kilb & Jansen 2016	X		X	X	X	X				
Mani et al. 2021	X	X	X		X				X	X
Mani et al. 2022	x								x	x
Morris 2022	X			X						
Spratt 2018	X		X	X						
Wissel & DeLuca 2018		X			X				X	
White 2019			X	X				X		
Yu and Hayes 2018		X	X							X

Other libraries have experimented with visualization to explore the nuances of a specific collection. Wissel & DeLuca assembled a colored histogram, stacked bar chart, symbol map and a series of tree maps to promote "the major themes, subjects, eras, and authors" of a collection of Italian history and literature.[9] Finch and Flenner used Excel to generate bubble charts exploring the relationship between library expenditures, the number of course hours by major, and the number of books purchased for each major.[10] Haren also used Excel for a collection mapping exercise to create pie charts, bar graphs, a histogram, and a choropleth map. The pie charts provided an aggregate-level view of the collection by subject discipline, publication format, and publication language.[11] The histogram depicted the number of titles held, with publication date grouped in 10-year intervals. to examine the topical holdings, as well as publication formats and locations of items in a multi-disciplinary Latin American Studies collection.

Other libraries have visualized citation analyses to demonstrate library value, improve collection analysis, and help academic libraries "develop a better understanding of their core users," and develop a "a more sophisticated approach towards reference, instruction, and materials acquisition."[12] Belter and Kaske created a network diagram to show the co-citation network of articles referenced by researchers affiliated with the National Oceanic and Atmospheric Administration (NOAA).[13] This exercise was to determine if journals identified as core were considered core by various groups of NOAA authors. Other visuals included a line chart plotting a percentage of references cited by NOAA authors by the age of the reference in years, showing the bulk of titles referenced by NOAA authors were less than four years old. White visualized references cited by geological sciences faculty with a series of text tables and pie charts. Like Belter and Kaske, he also included Pareto charts to show the cumulative percentage of references cited by the percentage of journals analyzed.[14] Gao and Wallace used tree maps to examine research focuses for the departments of chemistry, computer science, and psychology at the University of Houston.[15] The maps present word frequencies resulting from LDA topic modeling analyzing article and conference proceeding titles. Morris assembled COUNTER5 usage data, Scopus citation data and holdings data from OCLC's WorldShare to evaluate large e-journal packages and determine whether a library's collection satisfied its researchers' needs. The combined data was then analyzed with a series of Power BI generated bar, donut, and pie charts showing the top journal packages used and journal titles referenced, the most frequently referenced open access titles, the number of references by subject category and more.[16]

As research impact services mature, libraries now help universities visualize citation data for a multitude of purposes.[17] Mani, Hayes, Dodd, and Yu and Mani, Cawley, Dodd, and Hayes introduce bibliometrics and information visualization as a service for academic libraries, providing several examples illustrating

how libraries can visualize citation data to highlight the impact of federally funded research programs. Figures in their publication included a histogram, bar chart, stacked bar chart, line graph, tree map, choropleth map, symbol map and heat map, as well as several more advanced visualizations, including network diagrams identifying faculty collaboration networks and intertwined research interests and a Sankey diagram linking authors to research topics and collaborating institutions.[18] Yu and Hayes created more advanced visualizations for an impact assessment of the Cancer Cell Biology program at the University of North Carolina's Lineberger Comprehensive Cancer Center. Citation data from both proprietary and freely available government resources, including the NIH iCite database was assembled, analyzed, and shared via a series of network diagrams showing co-author collaboration networks, international organizational collaboration networks, external organizational collaboration networks, topic network maps and more.[19] A second series of impact studies of the UNC Chapel Hill's Clinical Translational Science Awards program visualized data using a dual-axis combination bar and line graph, showing the annual number of publications produced by faculty affiliated with the university's CTSA program from 2008 to 2016 and the number of times these publications were cited; a line graph plotting Scopus' average Field-Weighted Citation Impact (FWCI) value with the average NIH Relative Citation Ratio (RCR) for these publications; a network diagram showing the most productive researcher's co-authorship networks; and a network map illustrating the co-occurrence of Medical Subject Heading (MeSH) terms for publications addressing health disparities.[20]

Publication space constraints, along with data volume, and other concerns sometimes limit bibliometric researchers to visualizing high-level aggregate data for focused populations. With software and programming languages such as Python, R Shiny, Power BI or Tableau, researchers can now create dashboards and other tools allowing peers to create large aggregate visualizations that may be filtered down to a lower level of detail. Dashboards created for the author's previous study modeled data pulled from the NIH RePORTER database and provided filters allowing users to select a BTAA school, choose a major MeSH term, and then select a profile of a journal title associated with the MeSH term.[21] The chosen filters then automatically adjusted

- a strip plot displaying the RCR values for each individual article published by faculty in the journal;
- call-out numbers displaying a return-on-investment and a cost-per-use value calculated for the filtered data;
- a line chart showing the number of downloads;
- dynamic narrative text showing the number of articles published by the filtered faculty in the journal and the number of articles filtered faculty referenced in the journal and the number of articles that cited the articles BTAA faculty published in the journal; and
- a text table showing the number of grants associated with articles published in the journal, the value of these grants, and more.

This project explores additional ways to visualize Ohio State researchers interests and journal needs using an interactive dashboard of fan-chord tree diagrams in tandem with dynamic narrative text, simple horizontal bar and lollipop charts, and word clouds. Tree diagrams show inter-relationships between data, with nodes connected by links. In nature, trees start with roots and branch out, serving as "significant metaphors for describing and organizing human knowledge" throughout history.[22] The tree diagrams for this project set the publication journal as the trunk, or starting node of the tree diagram

and then creates branches using the referenced journals and the citing journals as the end nodes. The size of the branches indicates the magnitude of the flow between the nodes in relation to the other flows in the diagram, or the overall number of articles Ohio State authors referenced in a journal, or the number of times a journal cited articles written by Ohio State authors. When filtered by academic unit, division, and fiscal year the dashboard shows that for various disciplines, the top journals publishing the outputs of Ohio State researchers are not in alignment with the journal titles Ohio State researchers reference or the journal titles citing this research.

Design, methodology, or approach

The Data Model

Ohio State ranked 11th in the nation for research and development expenditures in FY2022, with NIH awarding $239.11M of these funds.[23] The current data model reorganizes and enhances the data model used in the previous project to visualize the relationship between grant funding and investments in library collections. It differs slightly in that data was related for analysis both at the article level and the journal level.[24] Publications attached to NIH funds awarded to Ohio State researchers between FY 2010 and FY 2022 were downloaded from the NIH RePORTER and compiled into one file. A join file listing the core project number and associated PMIDs for each publication was then used to link the publication list back to a list of Ohio State researchers NIH funded projects, also compiled from the NIH RePORTER. The export file for publications included the core project number, publication title, publication authors, journal title, the PMID, the Relative Citation Ratio (RCR) for the publications, and more. The export file for Ohio State NIH grant funding included the core project number and subproject numbers; the NIH 3-character activity code used to identify the type of grant program (i.e., R01, P30, T32, etc..); the grant's administering agency, institute, or center, the contact PI / project leader, and more. Overall, 2,002 unique core project and subproject numbers associated with 8101 unique publications authored by Ohio State researchers appeared in the data. (Table 2)

Table 2. Summary of data gathered

Category	Value
Number of NIH grants 2010-2022	2,002
Number of publications 2018-2022	8,101
Number of references 2018-2022	606,678
Number of citations 2018-2022	219,126

Local directory data was then enhanced by adding a Scopus author-identification number to each entry if available, or local identifier if not available. The directory was then related to the NIH funded projects in Tableau using a list of PMIDs and author identifier numbers assembled from the Scopus API. A list of PMIDs referenced by each publication and PMIDs citing each publication was next generated using the iCite API and then enhanced using a Python script that gathered data for the referenced and citing articles from PubMed, including article title, journal abbreviation, journal title, journal year, and major MeSH terms. These two lists were then imported into a Tableau Prep file to assign the starting and ending nodes.[25] A combined list of referenced and citing journals was then exported from Tableau Prep and related to the original publications list in Tableau using the PMID. A simple Excel file with 100 points was created next and related to referenced and citing journal list with the calculation 1=1 to create the curved lines between the starting and ending points. Last, the major MeSH terms for the Ohio State

researchers' publications, the referenced journal articles, and the citing journal articles were related back to their respective lists.

The Dashboard Visualization

The resulting dashboard provides a colorful, interactive, profile of journal usage for NIH funded researchers in each academic unit and corresponding division (if applicable) at Ohio State. (Figure 1) Filters allow users to select the academic unit and corresponding division, set the fiscal years of the NIH funding, and display up to 20 top journals publishing research authored by unit faculty, post-doctoral scholars, graduate students, and research scientists. (Figure 2) These filters are placed in a floating container with the add show/hide button feature applied to maximize dashboard real estate and minimize viewing distractions. A menu icon displays when the container is hidden, and an X icon displays when the container is open to quickly show users where to access the filters. Additional text appears under these icons and on the tooltips for them, with instructions for displaying hidden filters in Tableau.

The narrative text rests immediately below the filters icon and dynamically updates the amount of NIH funding awarded to the academic unit during the fiscal years selected. The total number of projects is calculated using the NIH activity code, institute code, serial number, and subproject number for the grant. The total number of publications authored by Ohio State researchers and supported by this funding is then displayed, followed by the number of journals this research was published in and the number of times this research has been cited.

Users may select from 1 to 20 of the top journals publishing articles authored by researchers in academic unit. This filter is directly applied to the bar chart beneath the narrative text showing the top journal publishing unit research, by number of papers. Hovering over the gray bar for each journal opens a tooltip allowing users to view the number of NIH funded unit researchers' articles published in the journal between the fiscal years selected. Additional instructions embedded in the title and the tooltip for each journal inform users that they may select a bar to change the visualizations below this bar chart and see journals the unit's researchers referenced what journals cited research published by the unit researchers in the selected journal.

The teal fan-chord diagram immediately below the gray bar chart shows the publication selected on the bar chart as the base or trunk, and the top 50 or fewer journals Ohio State researchers referenced as branches. Tooltips placed on the tip of each chord or tree branch show the total number of unique papers Ohio State researchers referenced in each journal.

Figure 1. The filtered dashboard.

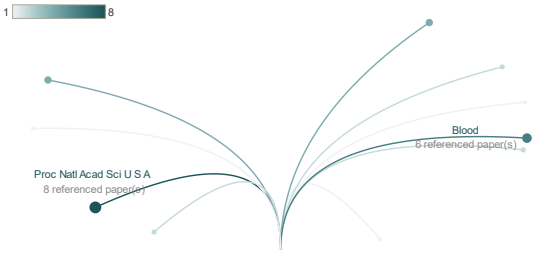
From 2015 to 2020 NIH awarded $2.63M to Food Science and Technology researchers to support 4 projects. Food Science and Technology researchers then authored 69 articles published in 45 journals. As of January 21, 2023, this research was cited 601 times.

Top journals publishing Food Science and Technology research, by number of papers

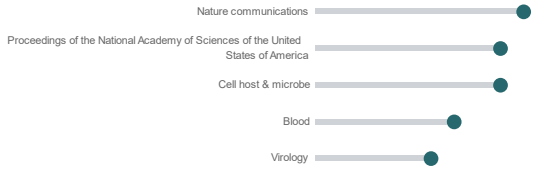
Select a bar to change the visualizations below and see what Food Science and Technology researchers publishing in this journal referenced and what journals cited research published by Food Science and Technology researchers in this journal.

Food Science and Technology faculty who published articles in Nature communications referenced papers in the following titles:

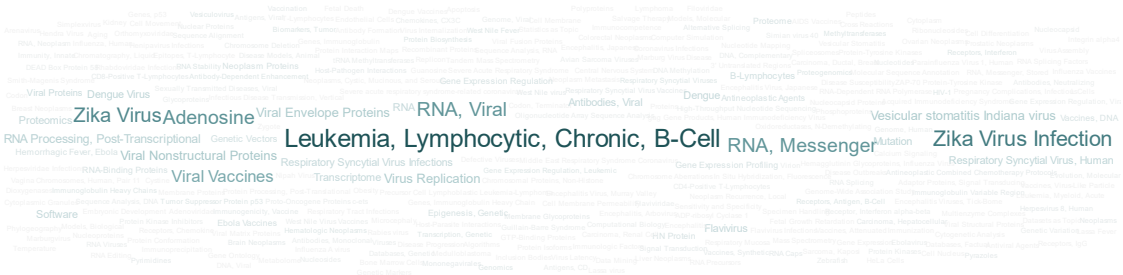
(Roll over the circles below for more information).



The top journals referenced by Food Science and Technology researchers who published articles in Nature communications were:

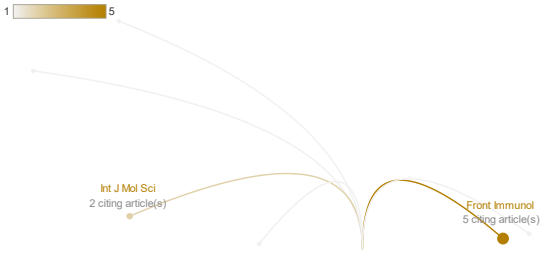


Top topics, referenced papers

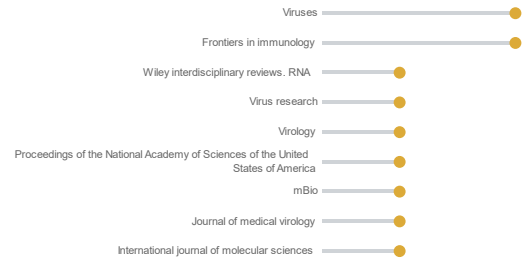


Food Science and Technology faculty who published articles in Nature communications referenced papers in the following titles:

(Roll over the circles below for more information).



The top journals citing research published by Food Science and Technology in Nature communications were:



Top topics, citing papers

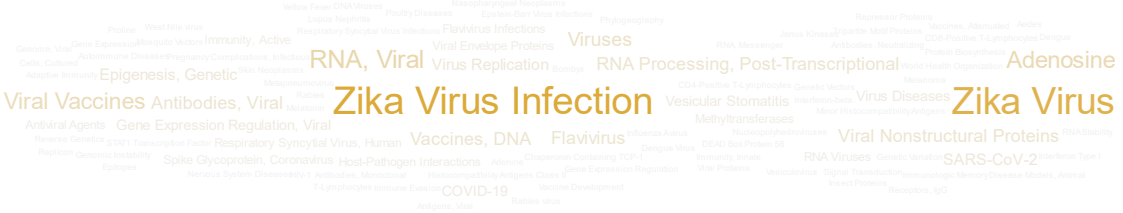


Figure 2. Dashboard filters.

A sequential color palette displays magnitude, showing the overall number of papers referenced in each journal in relation to each journal represented on the diagram. The lollipop chart to the immediate right of the tree diagram bolters this magnitude, by showing the same comparison using a slightly different view. Each lollipop shows the number of titles referenced, and the length of the bars clearly shows some titles are referenced more than others. Tooltips placed on the tip of each lollipop display the total number of unique papers Ohio State researchers referenced in each journal.

A word cloud showing the top major MeSH terms assigned to each paper referenced appears immediately below the fan-chord diagram and lollipop chart, providing a quick understanding or overview of Ohio State researchers interests and the research interests of peers citing Ohio State research. Tooltips for each word reveal the number of times each term was assigned. Word size and color indicate the significance of the term in relation to other terms.

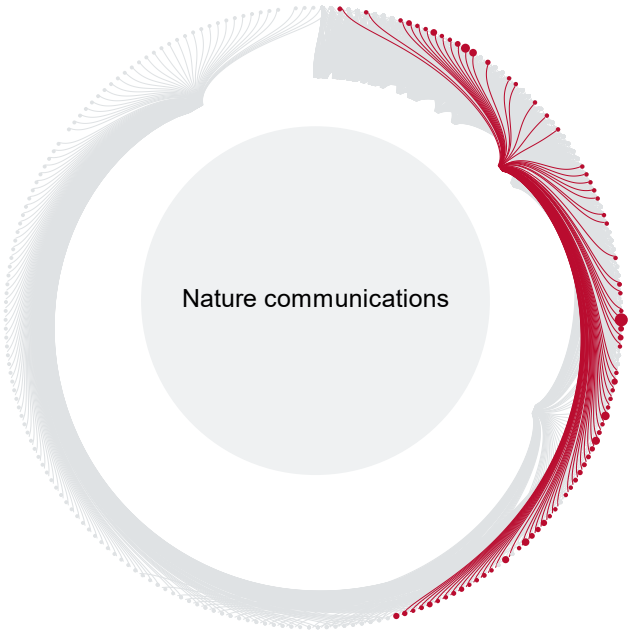
The yellow fan-chord diagram, lollipop chart, and word cloud provide the same information for the citing journals. The base or trunk of the fan-chord diagram shows the publication selected on the gray bar chart and the branches show the journals citing the papers published by Ohio State researchers in the selected journal. Branch color shows the overall number of papers in each journal citing the papers published by Ohio State researchers in the selected journal. The lollipop length reveals that some journals cite Ohio State research more than others, and the MeSH terms for the citing articles displayed on the word cloud give a broad idea of how Ohio State fits in the broader research ecosphere.

Practical implications or value

The fan-chord diagram is just one of many examples from the tree family of visualizations that meaningfully displays reference and citation data in relation to other library data for decision-making. Simple modifications to the math and data structure used to create this diagram generate other tree family data representations, including the circular Sankey diagram (Figure 3), network diagrams (Figure 4) and more. In figures 3 and 4, the journal publishing researcher papers is positioned in the central

nodes and the journals researchers referenced and the journals citing the original research are placed in outer nodes. The lines and nodes are initially colored gray and are highlighted in red when the user chooses to view referenced journals only. Magnitude is represented by the size of the outer node circles, which shows the number of papers referenced in each journal in relation to other journals referenced. The size of the outer circle dynamically changes based on whether the user chooses referenced journals or citing journals.

Figure 3. Circular Sankey diagram showing journals referenced in articles published by Food Science and Technology researchers in *Nature communications*



The network diagram in Figure 4 shows the journals researchers referenced in articles published in the selected journal title *Nature Communications*. Hovering over an outer node displays a tooltip stating the number of articles researchers referenced in a particular title. (Figure 5) Size of outer node circles also represents magnitude, showing the number of times researchers referenced each journal in articles published in the selected journal title, which is positioned in the center of the visual.

Figure 4. Fan-chord diagram for referenced papers from figure 3 reconfigured as a network diagram by displaying all nodes for referenced journals.

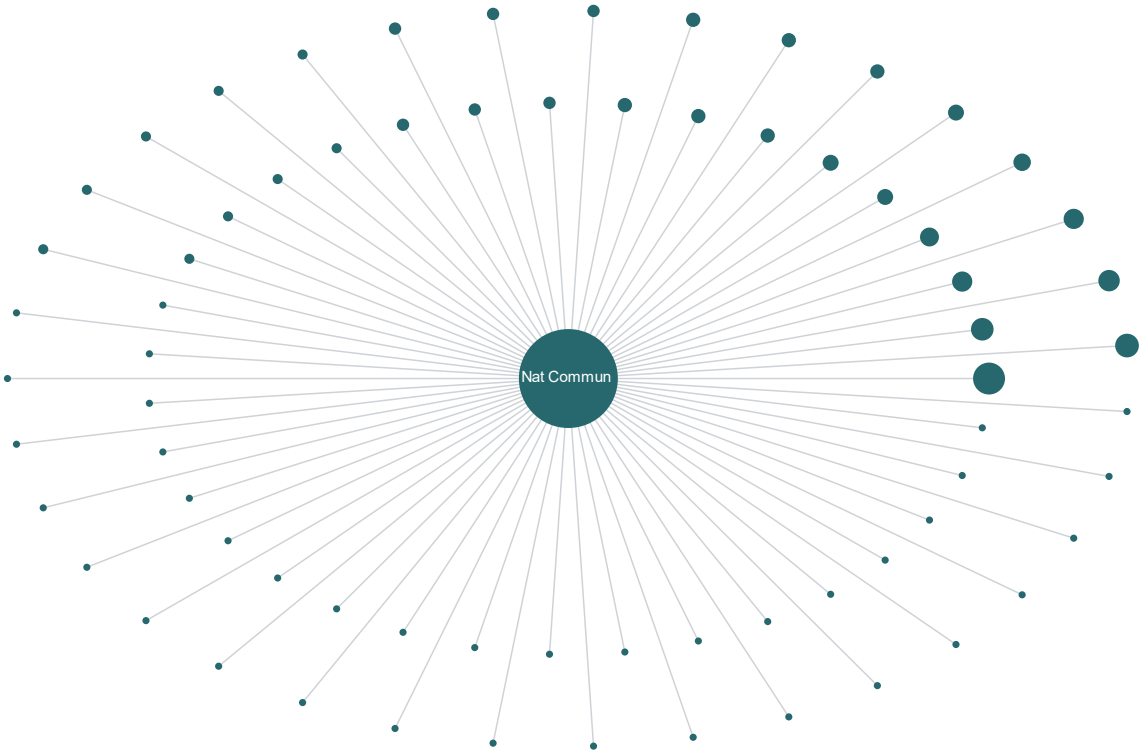
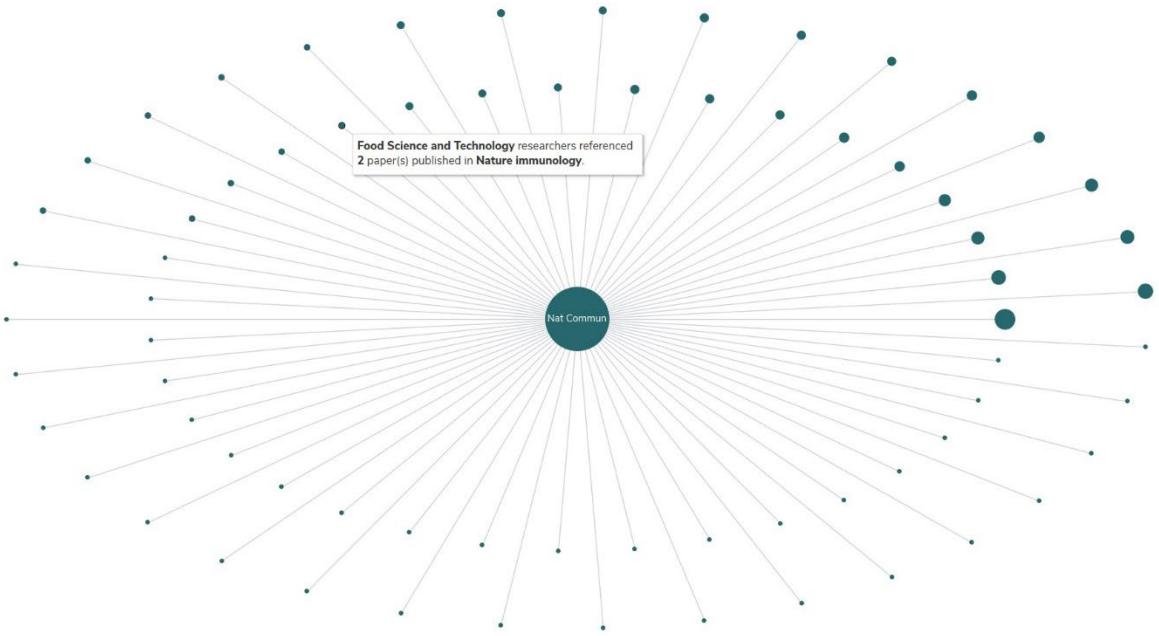
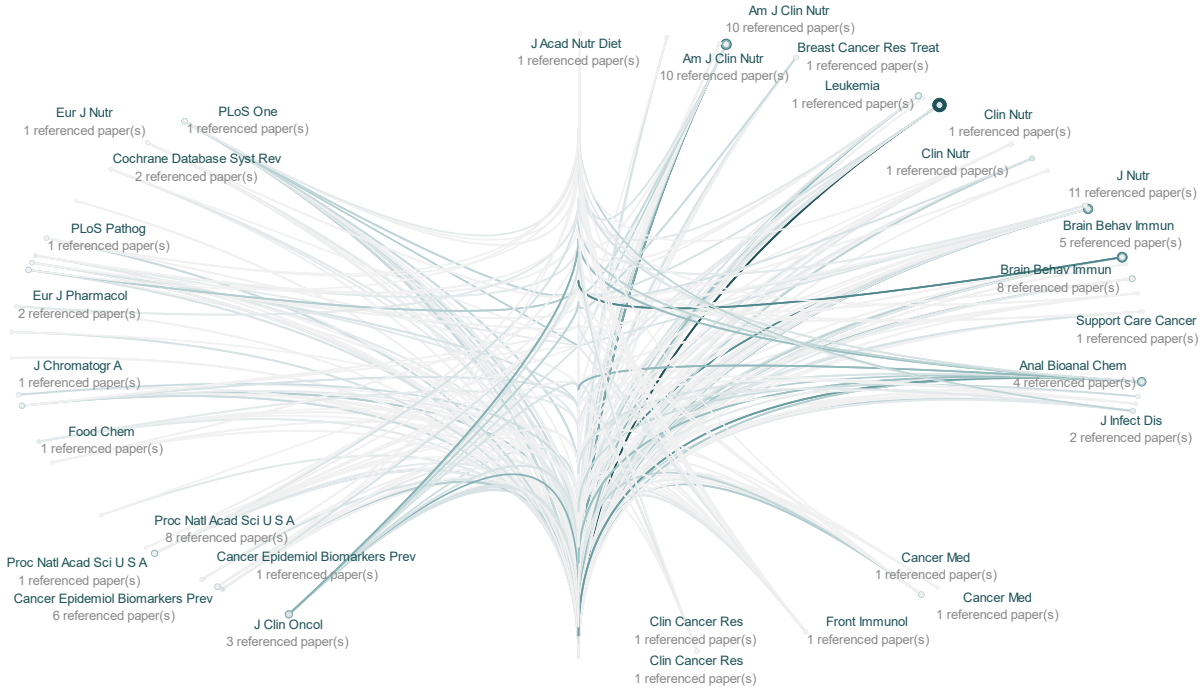


Figure 5. Example of a tooltip displaying when the outer node for *Nature immunology is selected.*



Removing the option to select a journal title to filter the fan-chord diagrams for just one publication journal shows the entire web of journals required to support one academic unit's research enterprise (Figure 6) Here the outer node for each journal publishing articles authored by researchers in the academic unit is connected to the outer nodes for each journal referenced in these articles.

Figure 6. Full chord diagram showing the inter-relationships of publication journals and referenced journals



Used with simple bar charts, line graphs, dynamic narrative text and more, tree family diagrams can effectively answer "to what extent does our collection meet our author's research needs?" Users can view the interrelationships between titles researchers access to inform their research and remain abreast of current developments and trends in their respective fields. Tree diagrams show that the journal titles referenced by each academic discipline do not necessarily align with the journal titles citing articles published by university researchers. The word clouds provided with the tree diagrams in this study also provide an overview of topics explored by university researchers and peers citing each academic unit's research.

Structuring data models both at the aggregate journal title level, and more granular article level also opens opportunities for displaying relationships and information flows. While librarians may be primarily interested in analyzing aggregate use by academic unit, using referenced journals as a proxy, the academic unit itself may not only ask what journals are citing our researcher's work, but who is citing this work, and what institutions sponsor the individuals citing our researcher's work? Tree family visualizations offer a mechanism to display these relationships, enhancing the presentation of assessment results, inspiring conversation, and facilitating data-informed action.

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