Analysis of National Institutes of Health K99/R00 Transitions and Outcomes from 2007-2022

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Abstract

Postdoctoral research fellows are highly skilled and trained researchers within the academic biomedical research workforce. Those that aspire to continue academic research careers typically seek tenure-track faculty positions as a principle investigator. In the United States of America, the National Institutes of Health (NIH) sponsors a Pathway to Independence Award (K99/R00) mechanism designed to facilitate the transition from postdoctoral fellow to faculty by providing 5-years of funding support during the postdoctoral and faculty phases. This makes postdoctoral fellows with K99/R00 awards attractive candidates for institutions looking to hire faculty because it shows that the candidate has a track record of NIH funding and the institution receives indirect costs when the R00 is awarded. This analysis explores how many K99 recipients successfully converted to R00 awards from 2007 to 2022, which institutions they had the K99 and R00 awards at, and success rates for receiving subsequent R01 funding. This analysis also examines geographic location of K99 and R00 institutions and how often postdoctoral fellows with K99 awards were retained at their home institution for the R00 portion of the award or moved to a different institution. The findings of this analysis show that ~170 K99 awardees convert to R00 each year and between 20-35% of those are retained at the institution they received their K99 award at for the R00 phase. Certain elite institutions produce the most K99 awardees while others hire the most R00 faculty, and there are significant differences by institution whether faculty candidates with K99 awards are retained at their home institution or move to a new institution for the R00 phase.

Introduction

Postdoctoral research fellows are a driving force of academic biomedical research. They typically have either a terminal medical degree (i.e., MD) or doctorate (i.e., PhD) which means they have completed a significant amount of education and training. Postdoctoral fellows that aspire to continue in academic research typically seek faculty appointments on the tenure-track. These tenure-track faculty positions are highly coveted and competitive positions that often require significant success as a graduate student and postdoctoral fellow in publishing manuscripts and receiving extramural grant funding.[1] These positions are also becoming more difficult to achieve due to the increasing number of PhD graduates but stagnant number of tenure-track faculty positions.[2]

Within the United States, one of the most prestigious award mechanisms to facilitate the transition from postdoctoral fellow to tenure-track faculty member in the biomedical sciences is

the Pathway to Independence Award (K99/R00) mechanism sponsored by the National Institutes of Health (NIH). This provides salary support and funding for postdoctoral fellows during the K99 phase of the award and provides $250,000 in total support for 3 years during the R00 phase of the award. There are many benefits to the individual and institution for having a K99/R00 award. The candidate has protected funds for their salary during both the postdoctoral phase and faculty phase in addition to some funds for research during the postdoctoral phase, depending on the NIH granting institute. During the R00 phase, the award provides a significant amount of indirect funds to the faculty's institution. Having a K99/R00 award also demonstrates to the hiring institution that the candidate has a track record of receiving extramural funding which is a requirement for future success in the academic research career. The success rate for receiving a K99/R00 award is relatively high compared to research project grants (i.e., R01s) at 26.5% for FY 2022.[3]

The K99/R00 pathway to independence award was launched in 2006[4], and there is one K99 that was awarded in the year 2006. The following year, there were 184 funded K99 projects according to NIH Reporter. In 2007, the first four R00 awards were also funded, and these increased to 67 projects in the year 2008, according to NIH Reporter. Thus, by 2007-2009, the K99/R00 grant mechanism was beginning. K99 awards undoubtedly help candidates achieve a tenure-track faculty position, and the topic of what faculty hiring committees look for or expect has been published previously.[5] Faculty hiring practices in disciplines including business, history, and computer science have previously been examined and found to be heavily influenced by the prestige of the doctoral degree granting institution of the candidate. Further, the impact attaining other career development grants (K01, K08, and K23 awards) has been shown to increase the likelihood of attaining future NIH funding. There has also been an examination of career development awards on attaining R01 funding which demonstrated that roughly 90% of K99 awardees received the R00 funding and 50% subsequently attain R01 funding. It has been about 15 years since the K99 mechanism was introduced, and to our knowledge, the trajectories of where K99 awards are made and where the corresponding R00 awards are activated at has not been explored. Here, we explore how many K99 awardees successfully convert to the R00 award each year from 2007-2022 and at which institutions these occur. We also examine how many of those that convert the K99 to R00 award stay at the same institution for the R00 phase or move to a new institution and show these geographically across the United States.

Methods

All data examined in this manuscript is publicly available from NIH Reporter (https://reporter.nih.gov/). Filtered data will be provided by the corresponding author upon reasonable request.

Data acquisition and analysis: Datasets for each K99 and R00 year were downloaded from NIH Reporter using the "Advanced Search" function to include only the year range (2007-2022) and only the grant of interest (i.e., K99 or R00). Duplicate values containing additional awards for the same contact PI (i.e., supplemental awards or multiple years of the same award) were removed. The latest available fiscal year for the K99 award was retained and the earliest available fiscal year for the R00 was retained. The K99 and R00 institution were aligned and confirmed that the contact PI name was identical before removing the contact PI name from the dataset. The institutions were analyzed using Microsoft Excel and Graphpad Prism (version 9.4.1). The list of K99 institutions and R00 institutions were plotted as Sankey diagrams using SankeyMATIC. The images are exported at 600dpi at sufficient resolution to allow zooming in and out in order to read the institution text. The K99 and R00 location maps were generated on ObservableHQ using a map layer and overlaying heatmap dot blot by latitude and longitude coordinates from the NIH Reporter dataset. Data on R01 awards was exported from NIH Exporter for each year from 2007 to 2021 (most recent available year) and the time from each candidate's first R00 project start date to R01 budget start date was calculated.

Results

In 2007, there were 56 K99 awardees that successfully converted the K99 to R00 award in 2008 (Fig. 1A). This amount increased in the following year to 168 successful conversions and averaged 169.5 conversions per year from 2008 to 2019. In 2020, there were 167 K99 awardees that converted to an R00 in 2021. In 2021, there were 250 K99 awardees that converted to R00 in 2022 (Fig. 1A). The amount of K99 candidates that converted to R00 at the same institution (retained) was 21.4% in the 2007-2008 cycle and 30.4% in the 2008-2009 cycle (Fig. 1B). The average retention rate (K99 and R00 at the same institution) was 31.8% from the 2008-2009 cycle to the 2011-2012 cycle. Beginning in the 2012-2013 cycle, the retention rate decreased and the average from the 2012-2013 cycle to the 2021-2022 cycle was 22.1%, which is a decline of ~10% from the 2008-2011 cycles (Fig. 1B). This is in line with what Pickett reports that ~20% of K99 recipients received their first R01 award at the same institution where they had a K99 award. While the overall total number of K99 to R00 conversions slightly

declined in the year 2020 when many pandemic-related hiring freezes took place beginning in March, the number of conversions increased by ~40% the following year in 2021 after many institutional pandemic-related hiring freezes were lifted.

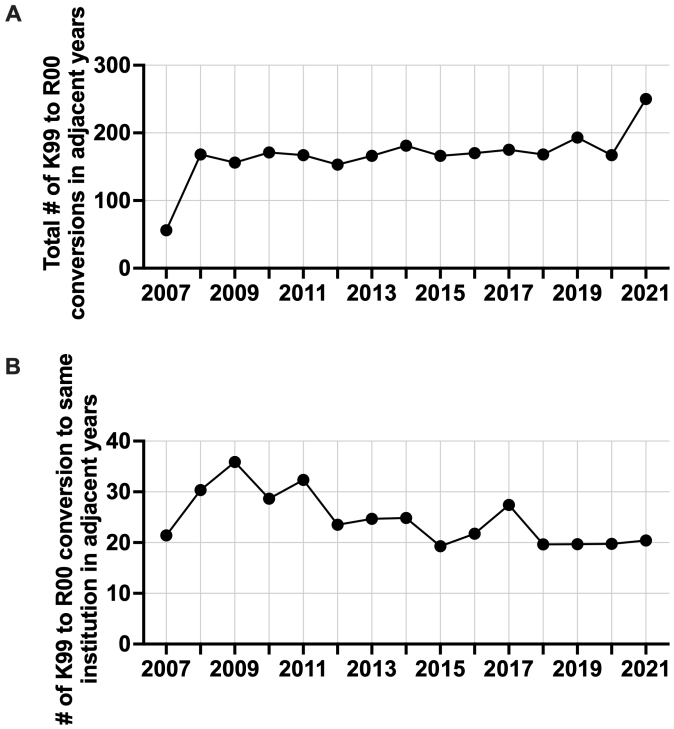


Figure 1: K99 to R00 conversions and retention rate from 2007-2022. A) Total K99 to R00 conversions from the 2007-2008 cycle to the 2021-2022 cycle. B) Number of successful K99 to R00 conversions where the K99 and R00 institution were the same from the 2007-2008 cycle to the 2021-2022 cycle.

From 2007-2022, 3,472 K99 awardees represented 256 different institutions whereas 2,841 R00 awards represented 357 unique institutions, which demonstrates that K99's are awarded at a smaller subset of institutions. The top 10% of institutions received 54% of all K99s whereas the top 10% of institutions receiving R00s accounted for 46% of all R00 awards. Stanford University has had 236 individuals awarded a K99 which is 59-fold greater than the median number of 4 awards and more than the 134 institutions that received the fewest (1-4) K99s. There were 73 institutions that have only had 1 K99 awardee. R00 awards were more dispersed among more institutions than K99 awards with 116 institutions that have only had 1 R00 awardee and 47 institutions that have had 2 R00 awardees. Only 3 institutions that have had more than 100 K99 awards from 2007-2022 (Stanford University, University of California San Francisco, and Massachusetts General Hospital); however, there no institution has had more than 62 R00 awardees and only 4 have had more than 50 (University of Pittsburgh, Massachusetts General Hospital, University of Michigan, and Johns Hopkins University). To demonstrate the geographic location of K99 and R00 awards, we plotted K99 and R00 awards on a map of the United States by institutional location as well as summed for each state (Fig. 2). K99 awards are distributed more on the west coast and east coast. R00 awards are mostly distributed on the coasts but

also have more dispersed throughout the country, particularly in the Midwest and South Eastern parts of the United States.

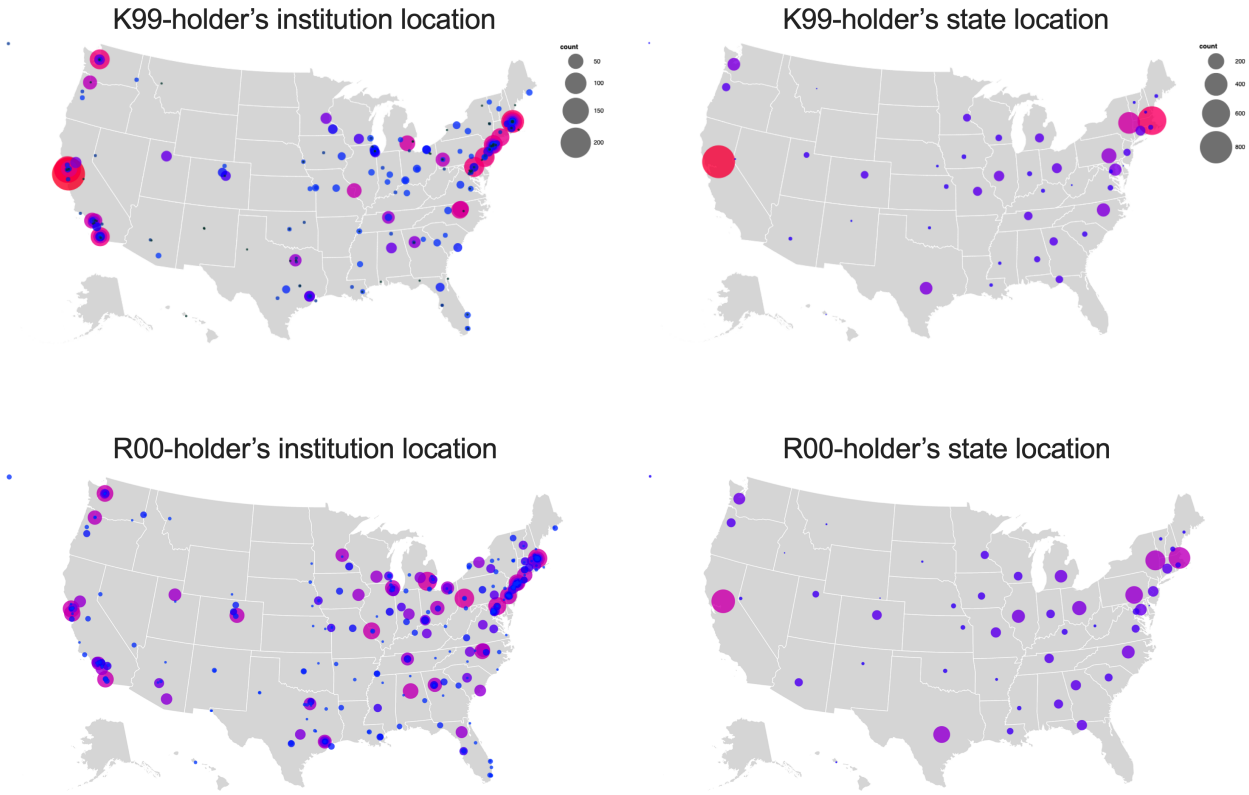
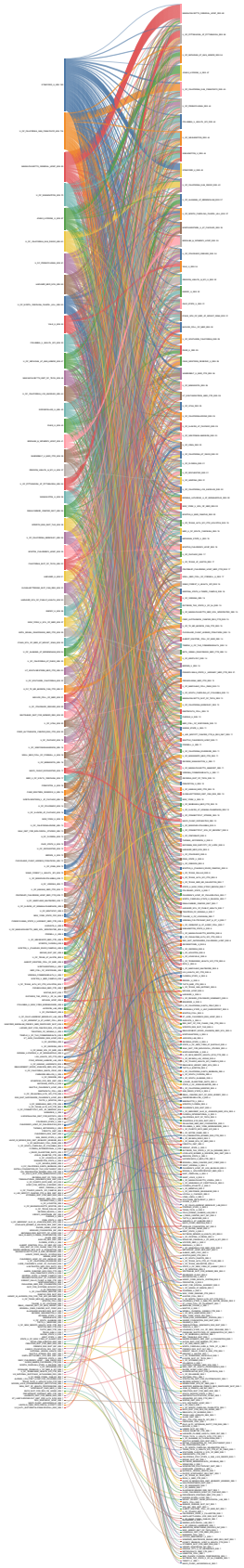


Figure 2: Cartographic representation of the number of K99 and R00 awards by institutional location and state from 2007-2008 through 2021-2022. Note no individual award or grant is counted more than 1 time.

To determine the flow of awardees from K99 institution to R00 institution , we created a Sankey diagram that includes all K99 awardees that successfully transitioned to an R00 award from 2007 to 2022 (2698 individuals) and plotted them together (Fig. 3). Stanford University had the most K99 to R00 conversions during this timespan with 163 individuals, followed by University of California, San Francisco with 116 individuals, Massachusetts General Hospital with 93, and University of Washington with 70. Massachusetts General Hospital has recruited the most faculty with R00 awards with 60 individuals, followed by the University of Pittsburgh with 58, University of Michigan with 54, and Johns Hopkins University with 47. Of institutions that have produced more than 10 K99 awardees, Massachusetts General Hospital has the highest rate of institutional retention having retained 42 of the 93 K99 awardees (45.2%). Of the 60 R00 award-holders that Massachusetts General Hospital recruited from 2007-2021, only 17 were from outside institutions, and of those, 8 were from institutions associated with Harvard (Brigham and



Women's Hospital, Dana Farber Cancer Institute, Broad Institute). There were other institutions that had higher proportion of R00 faculty candidates being retained (i.e., University of Pittsburgh, Johns Hopkins University, and Brigham and Women's Hospital). In contrast, some institutions appear to recruit most of their R00 awardees from external institutions (i.e., Northwestern University, University of Texas Southwestern, University of Utah, and Yale University).

Figure 3: Sankey diagram of all successful K99 to R00 award transfers from 2007-2022 with the K99 institution on the left and R00 institution on the right. Institutions are ranked by number of K99 awards on the left and number of R00 awards on the right. High resolution image can be found at: https://sites.uab.edu/tyrrelllab/about/k99-to-r00-transfers/

To better understand how many of the K99 awardees from each institution transitioned to R00 awards each year, and at which institutions, I plotted each 2-year cycle as Sankey diagrams showing the K99 institution on the left side of the plot along with the number of K99 awardees that successfully transitioned to R00 awards the following year. The right side of the Sankey diagram shows the R00 institution for each of the corresponding K99 awardees. Thus, each awardees trajectory can be identified along with information about institutional hiring and retention practices. The first cycle that has enough data to analyze is the 2007-2008 cycle (Fig. 4A) where Stanford University had 9 K99 awardees that successfully transitioned to R00 positions across the country including 1 awardee that was retained at Stanford for the R00 phase and 2 that moved to Johns Hopkins University. The rest were dispersed across institutions. In the 2008-2009 cycle, there were about 3 times as many successful K99 to R00 transitions; however, Stanford University still had the most with 11 in that cycle, of which, 3 were retained at Stanford while the others all went to different institutions (Fig. 4B). The 2008-2009 cycle is the first in which the University of California, San Francisco has

successful K99 to R00 awardees with 3; however, in the following cycles, UCSF ranks as one of the top institutions for successful K99 to R00 transitions (Fig. 4C & 3D).

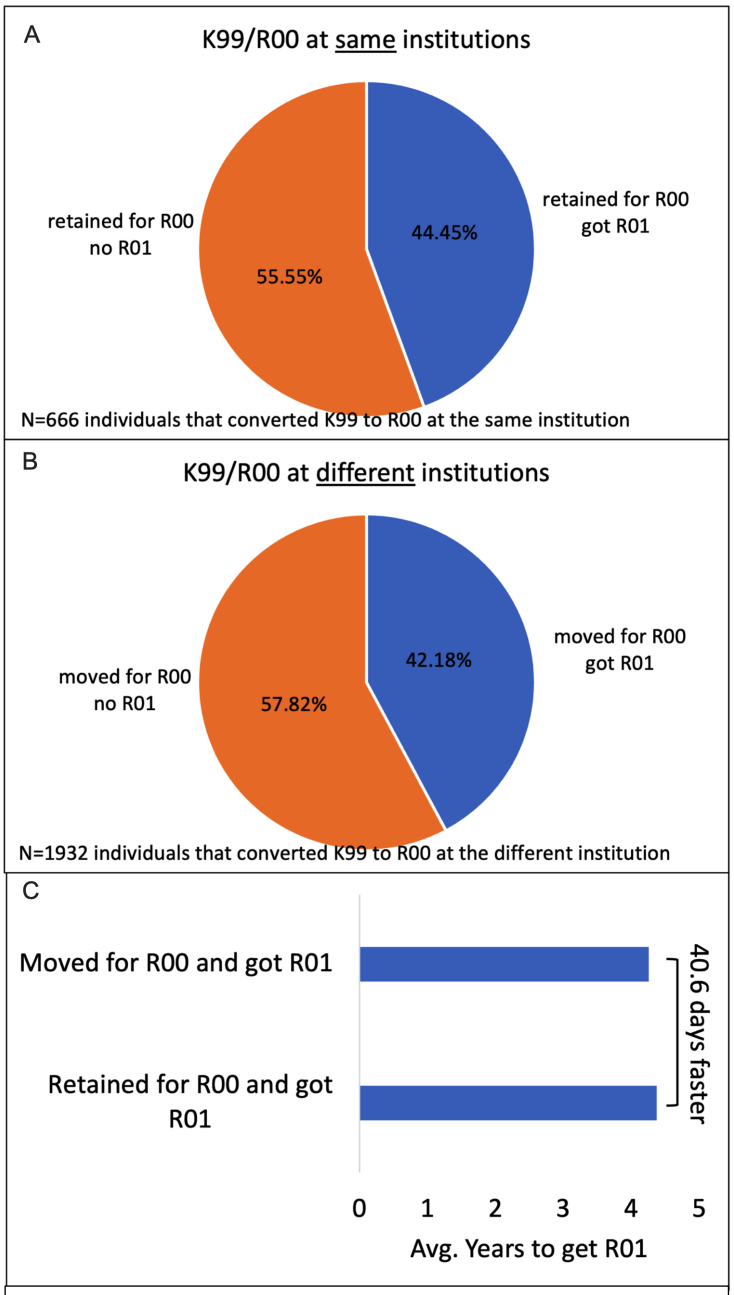


Figure 4: Percent of K99/R00 awardees with R01 funding and were at the same institution for K99 and R00 (A) or were at different institutions for K99 and R00 (B). C) Average time to achieve R01 funding from start of R00 budget date, subset by those that were retained or moved for R00.

The trends for all cycles from the 2008-2009 cycle through the 2021-2022 cycles are similar (Fig. 4A-O) with Stanford University and UCSF generally producing the most K99 to R00 transitions.

We sought to determine how those that received R00 funding at their K99 institution fared in securing R01 funding compared to those that moved to a new institution for the R00 phase. Thus, we identified the subset of those that received R01 funding and were either retained at their K99 institution for the R00 phase or moved to a new institution and calculated the percent success rate for securing R01 funding (Fig. 5A & B). There were 44.45% of R00 award recipients that received subsequent R01 funding at the same institution the had a K99 award. There were 42.18% of R00 award holders that received subsequent R01 funding after moving to a new institution to activate the R00 phase of the award. Thus 2.27% more individuals who were retained at their K99 institution for the R00 phase

received subsequent R01 funding. The subset of individuals that were retained at the same institution for the R00 award that eventually were awarded an R01 took a mean of 4.26 years to received the R01 from the project start date of the R00 award. Those that moved institutions before activating the R00 and received R01 funding took 4.27 years from the project start date of the R00 award. Thus there was an average difference of approximately 40.6 days difference in receiving R01 funding (Fig. 5C). Please note that this analysis included all successful K99/R00 awardees from 2007 to 2021. As of February 2, 2023, the NIH Exporter does not have data from the 2022 year. These data have not been censored to exclude those that most recently received R00 funding (i.e. in year 2021 or 2022) and still have active R00 funding.

Discussion

The institutions that produce the highest number of successful K99 to R00 transitions are not surprising to most academics. Generally, a handful of top institutions have an outsized number of K99 awardees that move to similarly prestigious institutions with a smaller proportion moving to less prestigious institutions for their independent faculty positions. In certain years there are instances where prestigious institutions retain a higher-than-expected number of their own K99 awardees, for example Brigham and Women's Hospital in the 2014-2015 cycle retained all 6 of its successful K99 to R00 transitioners and Massachusetts General Hospital retained 5 of its transitioners in the 2016-2017 cycle. Some institutions appear to have a culture of retaining their K99 awardees, which appears to be the case for the University of Pittsburgh (see the 2009-2010, 2010-2011, 2011-2012, 2013-2014, 2014-2015, 2016-2017, and 2021-2022 cycles). There are also certain institutions that appear to recruit a significant amount of K99/R00 holders than other institutions including Washington University in Saint Louis, University of North Carolina at Chapel Hill, University of Washington, University of Michigan, and Johns Hopkins University. This may be because those institutions happen to be expanding at the time that the K99/R00 grant mechanisms was introduced or that those institutions preferentially select candidates with external funding.

This analysis demonstrates that the bulk of K99 awards go to the most prestigious institutions in the United States that have international name recognition, are members of the Ivy League, receive the most NIH funding, and are ranked as some of the top medical schools in the world. Some of the institutions that recruit K99/R00 holders are also in this prestigious group of institutions, including the University of Michigan, Johns Hopkins University, Massachusetts General Hospital, and the University of Pennsylvania; however, other institutions that recruit

large numbers of R00 awardees are also R1 institutions but not as prestigous, including the University of Alabama at Birmingham, the University of Colorado at Denver, Ohio State University, and the University of Iowa. The net effect of the K99/R00 grant mechanism may be a redistribution of scientific talent from the most prestigious institutions to other slightly less prestigious academic centers throughout the country.

Whether an individual stayed at the same institution for the R00 phase of the K99/R00 award or moved to a new institution had no impact on future success in receiving an R01 award. There was also a negligible difference in the amount of time it took to receive an R01 for those that received one when comparing those that were retained versus moved institutions for the R00 phase. One key component of activating the R00 award is to demonstrate independence from the candidate's postdoctoral advisor. One motivation for this is that the candidate will need to establish independence from the postdoctoral advisor in order to be competitive to receive future NIH funding; however, a large part of the decision of who receives funding is determined by the grant review process. The process of reviewing the grant including determining if early career principal investigators are independent falls upon the grant reviewers who are themselves researchers, albeit generally more well-established. One clear way to establish independence is to move to a new institution; however, there are many pressures to stay at the K99 institution including familiarity with the institution, location, and family. Some may argue that if the candidate stays, the institution may reduce the offered start-up package leaving the candidate less well-suited to performing the necessary research to be competitive for R01 funding. The present analysis demonstrates that there is no difference in R01 success of investigators that have received R00 funding, and argues against the notion that candidates who stay at the K99 institution for the R00 phase are less competitive than those that move to a new institution for the R00 phase. This will require additional investigation to parse as it is also a relatively common belief that a higher proportion of those that are retained are physician-scientists with clinical duties and those that move are generally more PhD-researchers. The K99 award appears more tailored to PhD scientists as there are other NIH career development awards exclusively for physician-scientists such as the K08 award; however, the notion that physician-scientists are retained more is a possibility that should be explored.

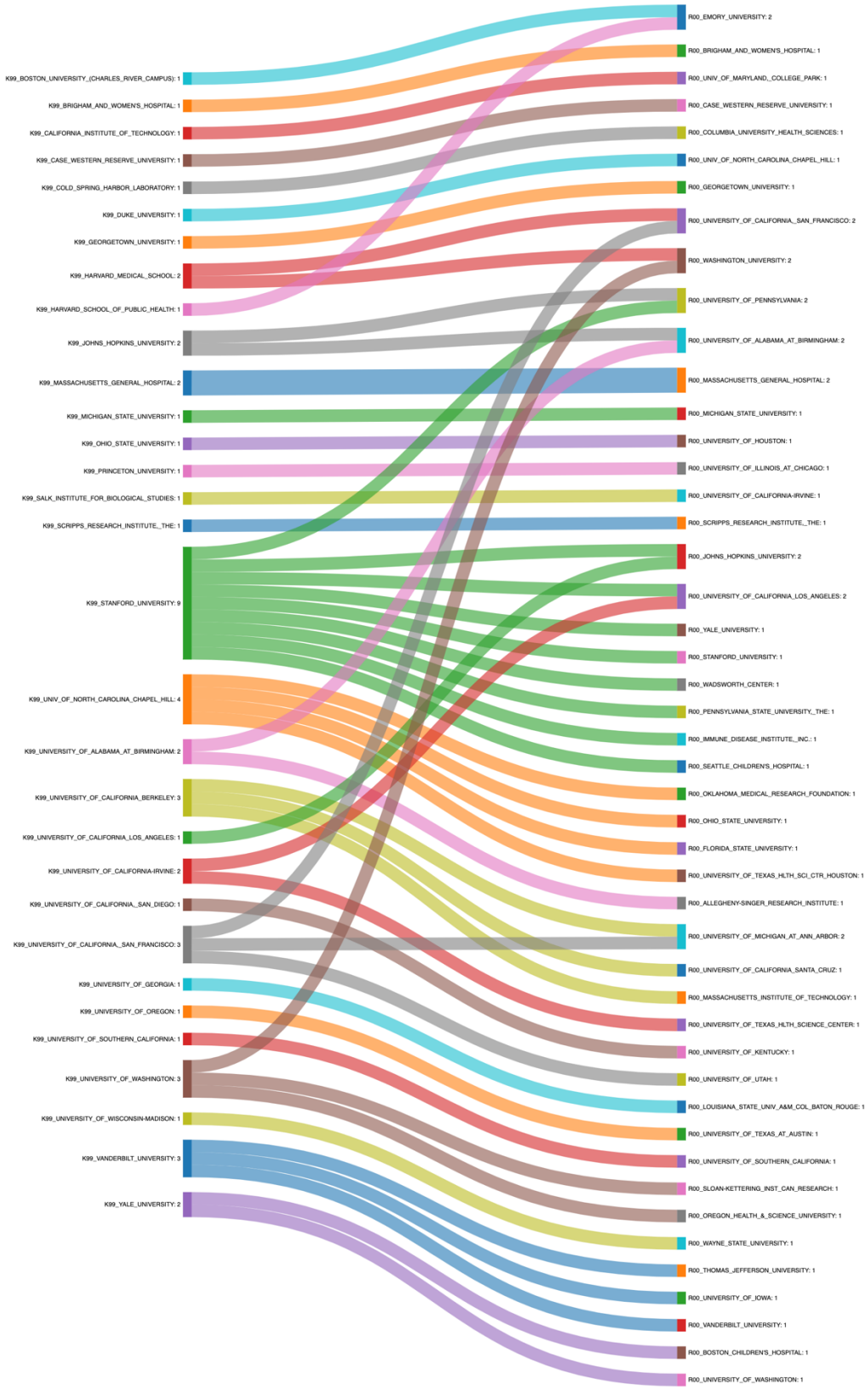
There are certainly more analyses that can be performed with these data, and there are significant limitations to these datasets and these analyses. The K99/R00 grant is only one of a handful of career development awards that the NIH sponsors although it is unique in that a

major goal is for the candidate to achieve independence. By only analyzing K99 and R00 awards, this analysis excludes all postdoctoral fellows who transition to a faculty position without a K99/R00 award and those in other fields where the K99/R00 may not be applicable or available including most ecology, social science, mathematics, physics, and chemistry research. Furthermore, this analysis excludes those that received a K99 but were either unable to transition to an R00 award for various reasons including receiving a faculty position in the United States without needing the R00, receiving a faculty position outside of the United States, pursuing another line of work, or other personal reasons. Furthermore, this analysis is limited to academic institutions in the United States and does not provide any insight into academic centers in any other country. This analysis is also limited due to the data that is publicly available through the NIH Reporter and Exporter. For example, an analysis of retention rates based on degree type or faculty type (i.e., research-only compared to physician-scientists) could be informative; however, the dataset does not include this information. Additional information on underrepresented minorities and women are also important to understand; however, the present dataset does not include this information. Future analysis should examine this.

Please note that each line in the Sankey diagrams represent an individual person with unique motivations for choice of postdoctoral research advisor, institution, and laboratory as well as autonomy in whether or not to pursue a faculty position and where that may be. These decisions are not made solely based on the offered start-up package or institutional clout, and each individual places different weight on each factor. This dataset does not take into account the motivation behind these complex decisions, and an understanding of these motivating factors would be enlightening. We hope that these data spark discussion among academic researchers, policy makers, and those within academic research institutions to reflect on grant review and hiring practices.

Disclosures: D.J.T. has no competing interests. D.J.T. was a K99 recipient who transitioned to R00 in the 2021-2022 cycle and is included in this dataset.

A 2007-2008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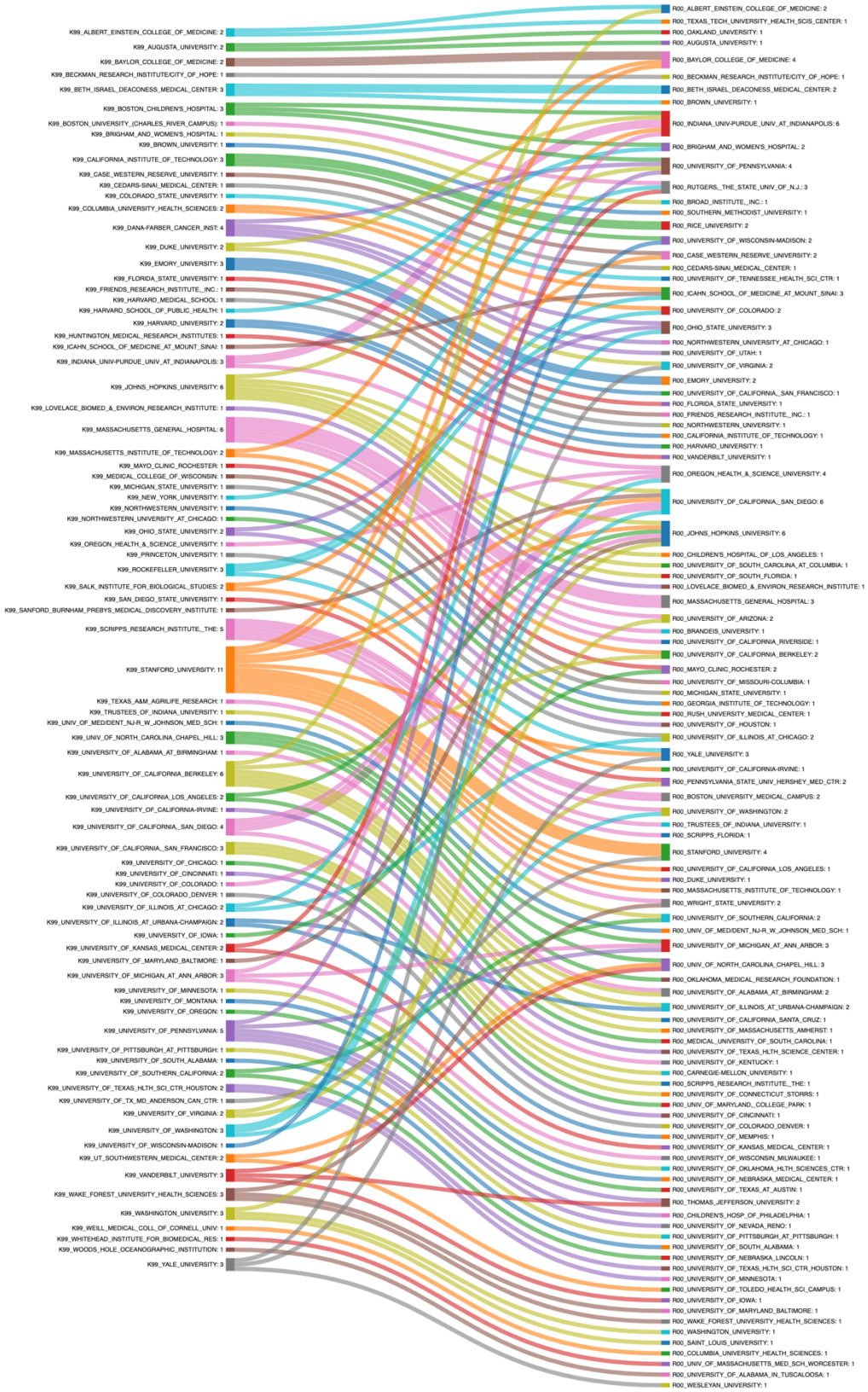

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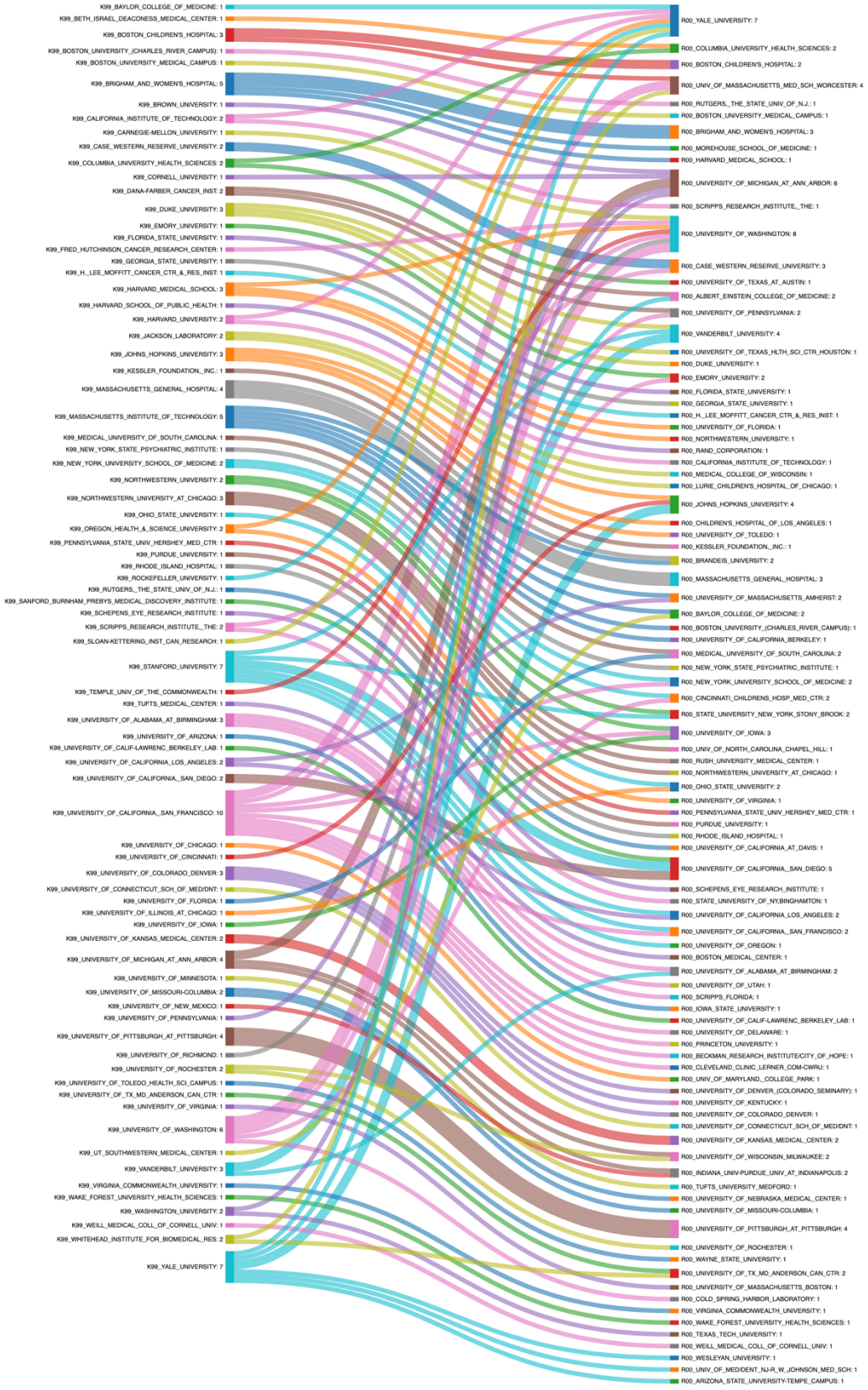

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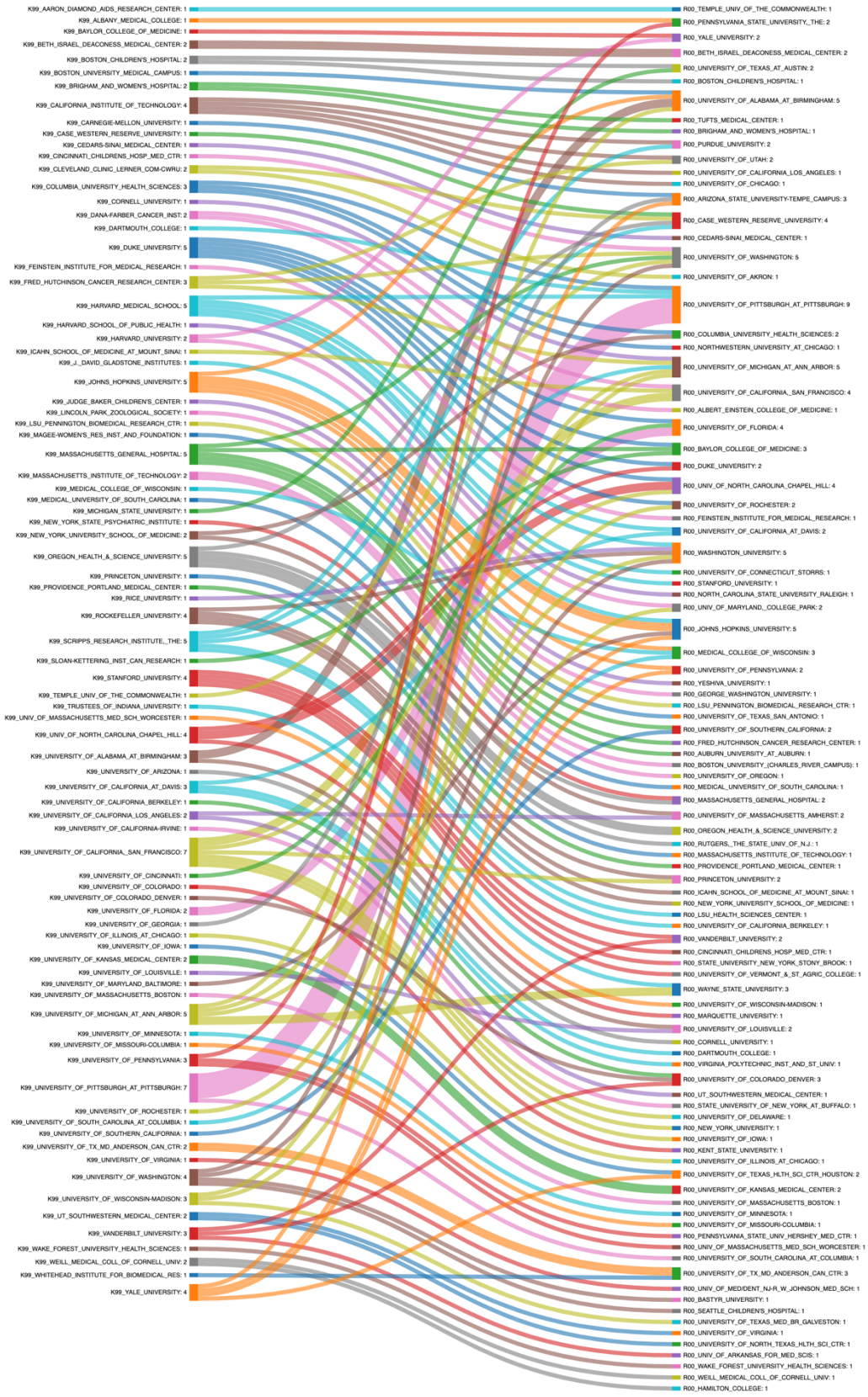
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K99_JUDGE_BAKER_CHILDREN'S_CENTER: 1
K99_LINCOLN_PARK_ZOOLOGICAL_SOCIETY: 1
K99_LSU_PENNINGTON_BIOMEDICAL_RESEARCH_CTR: 1
K99_MAGEE-WOMEN'S_RES_INST_AND_FOUNDATION: 1
K99_MASSACHUSETTS_GENERAL_HOSPITAL: 5
K99_MASSACHUSETTS_INSTITUTE_OF_TECHNOLOGY: 2
K99_MEDICAL_COLLEGE_OF_WISCONSIN: 1
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K99_NEW_YORK_STATE_PSYCHIATRIC_INSTITUTE: 1
K99_NEW_YORK_UNIVERSITY_SCHOOL_OF_MEDICINE: 2
K99_OREGON_HEALTH_&_SCIENCE_UNIVERSITY: 5
K99_PRINCETON_UNIVERSITY: 1
K99_PROVIDENCE_PORTLAND_MEDICAL_CENTER: 1
K99_RICE_UNIVERSITY: 1
K99_ROCKEFELLER_UNIVERSITY: 4
K99_SCRIPPS_RESEARCH_INSTITUTE,_THE: 5
K99_SLOAN-KETTERING_INST_CAN_RESEARCH: 1
K99_STANFORD_UNIVERSITY: 4
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K99_TRUSTEES_OF_INDIANA_UNIVERSITY: 1
K99_UNIV_OF_MASSACHUSETTS_MED_SCH_WORCESTER: 1
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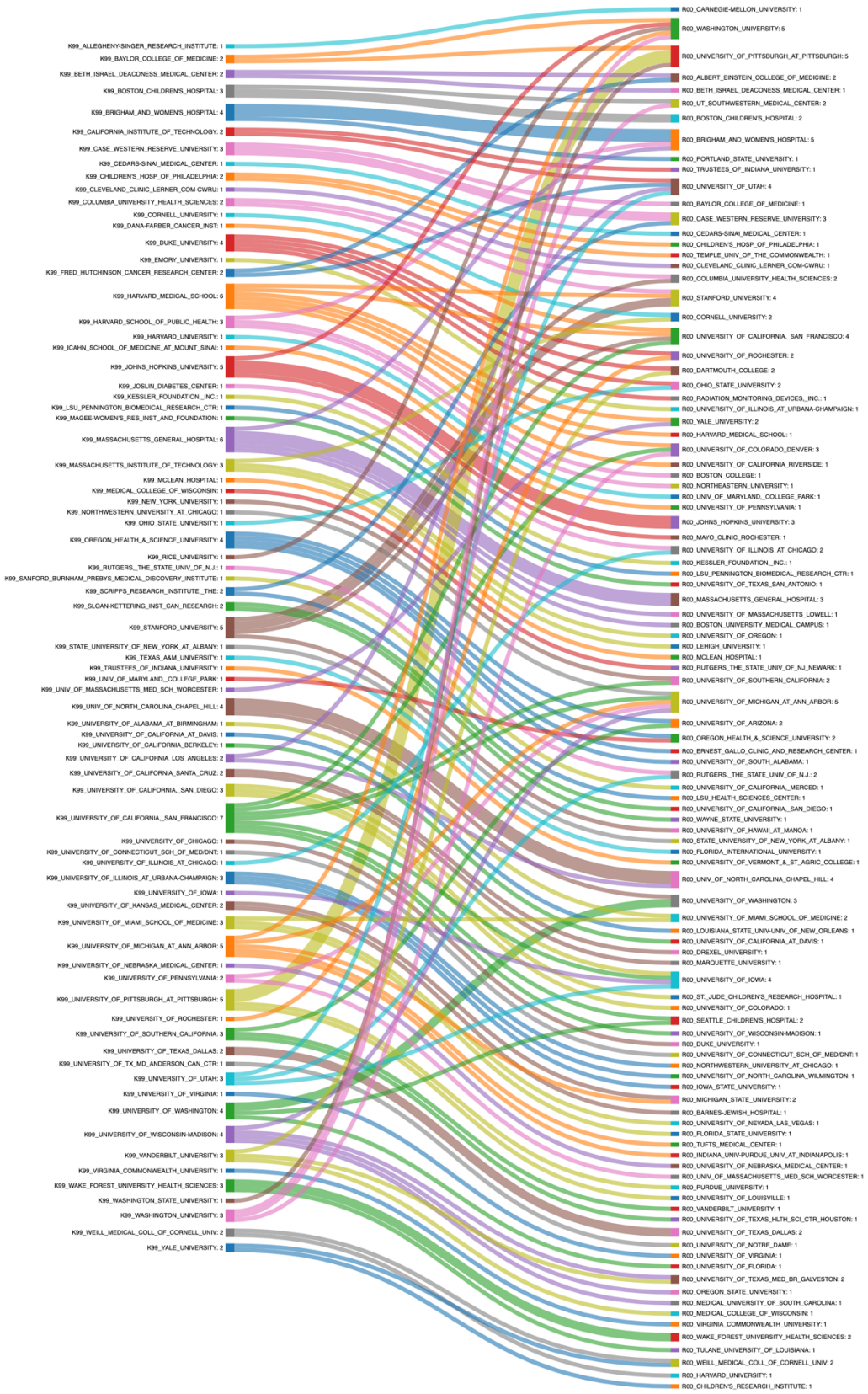

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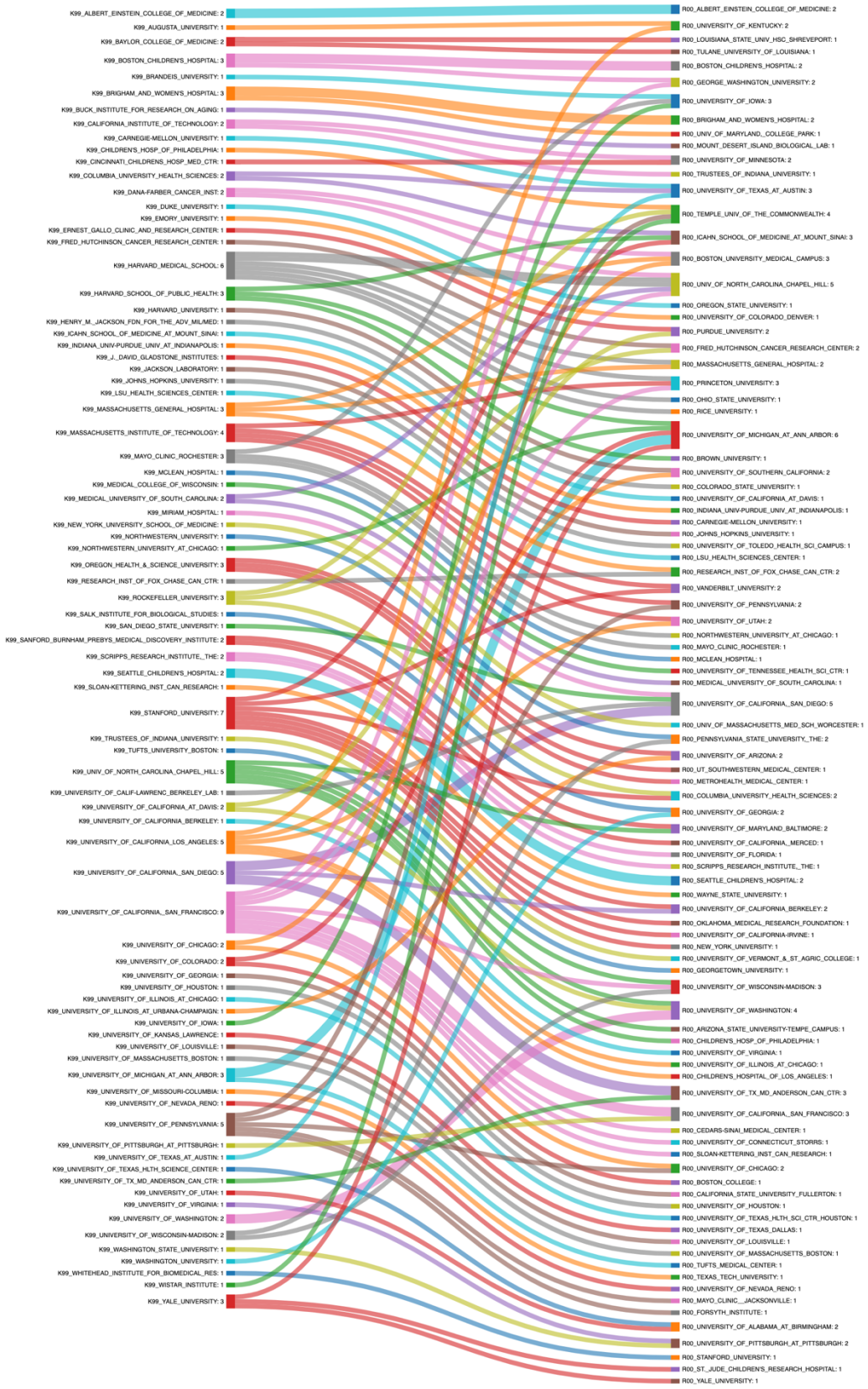

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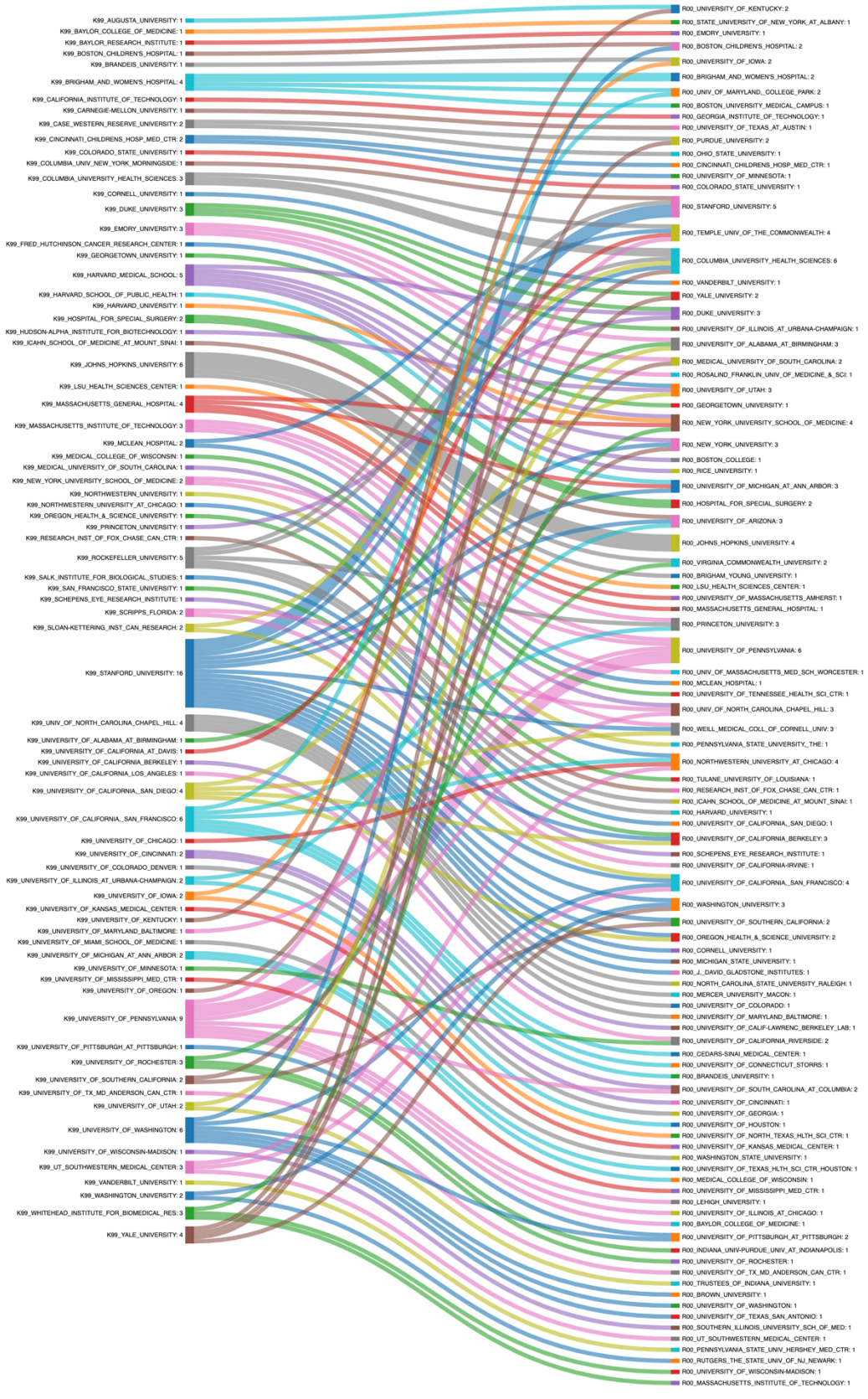

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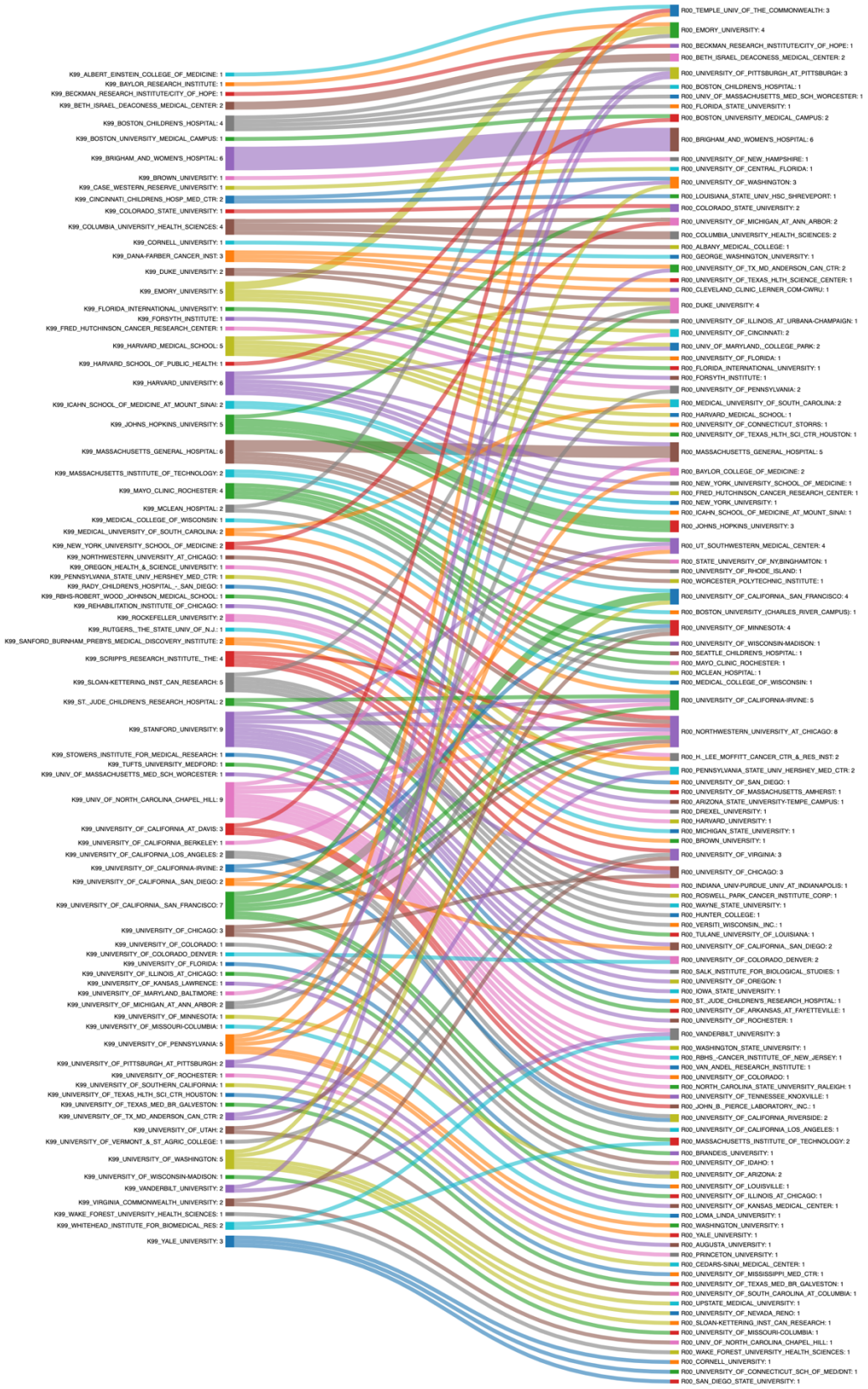

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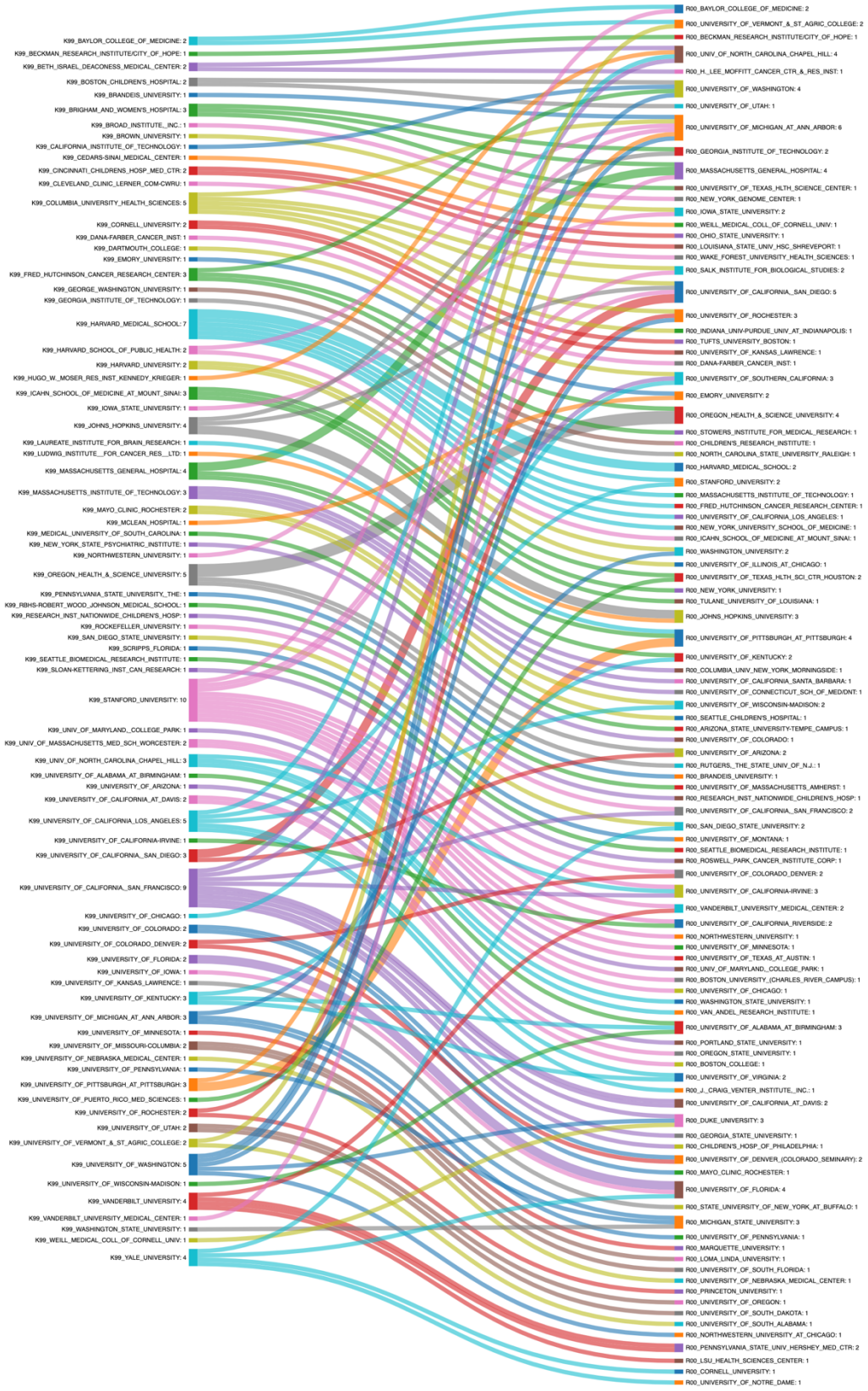
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K99_CALIFORNIA_INSTITUTE_OF_TECHNOLOGY: 1
K99_CEDARS-SINAI_MEDICAL_CENTER: 1
K99_CINCINNATI_CHILDRENS_HOSP_MED_CTR: 2
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K99_DANA-FARBER_CANCER_INST: 1
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K99_PENNSYLVANIA_STATE_UNIVERSITY_THE: 1
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K99_SAN_DIEGO_STATE_UNIVERSITY: 1
K99_SCRIPPS_FLORIDA: 1
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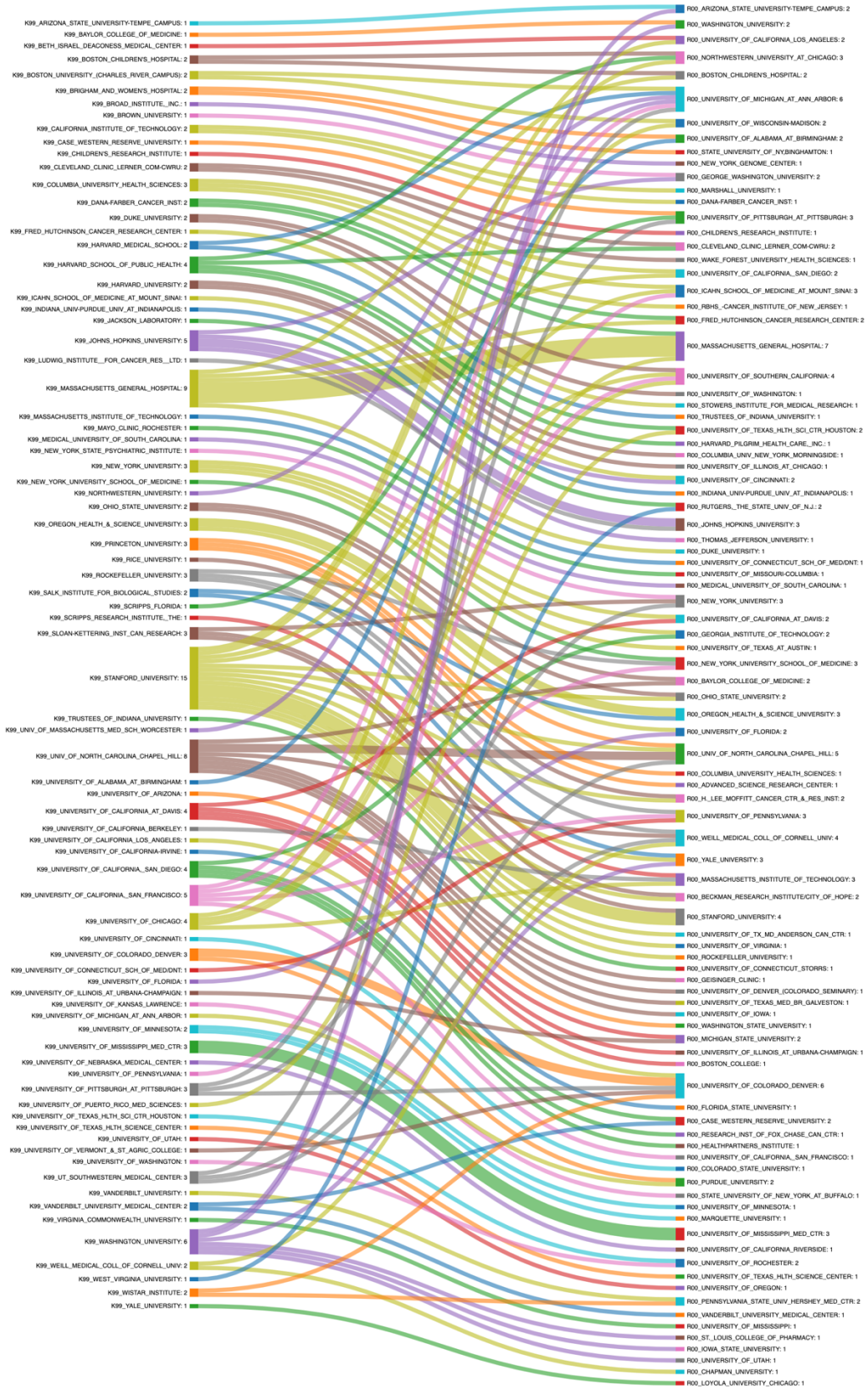
346 J 2016-2017



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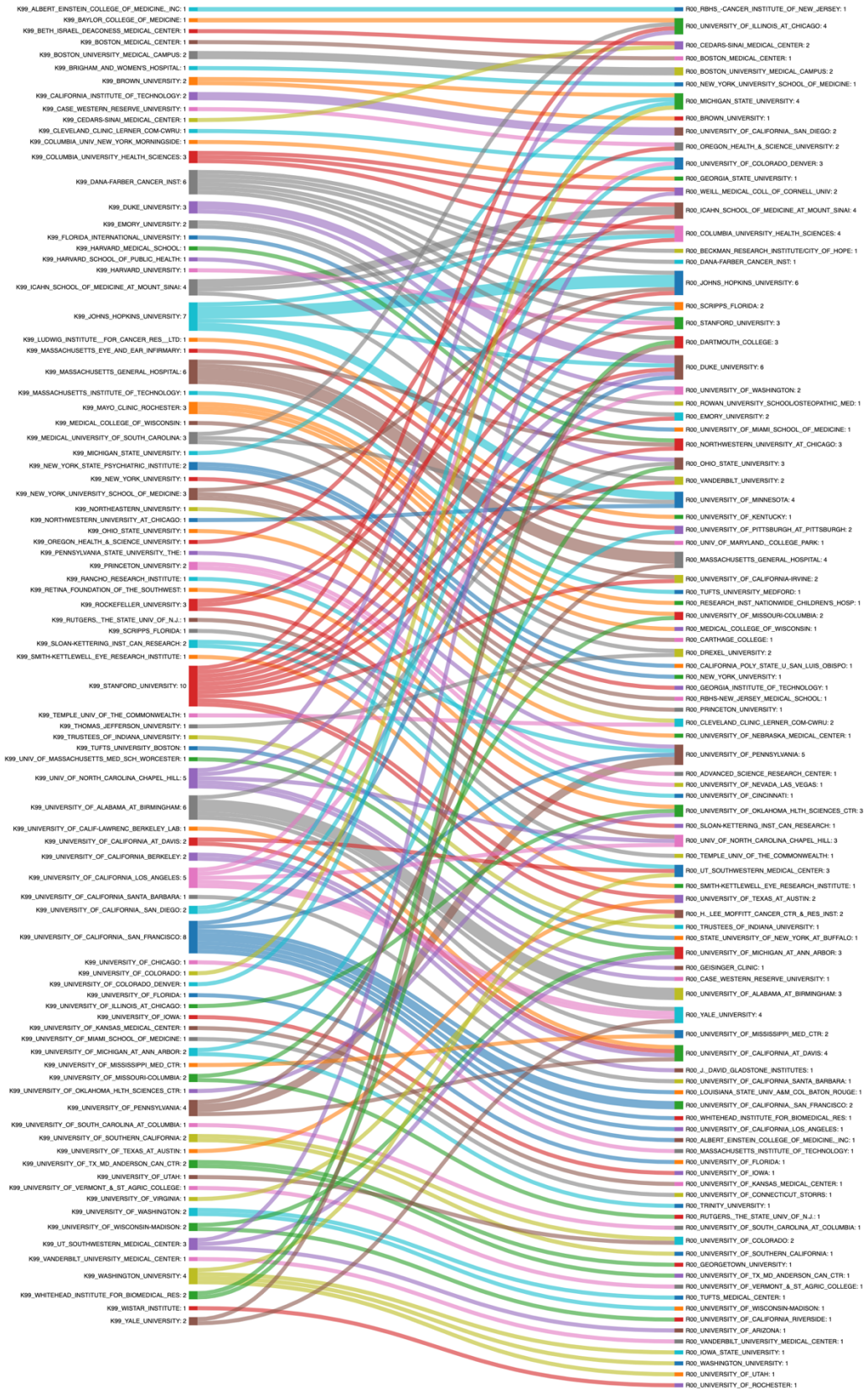
348 K 2017-2018



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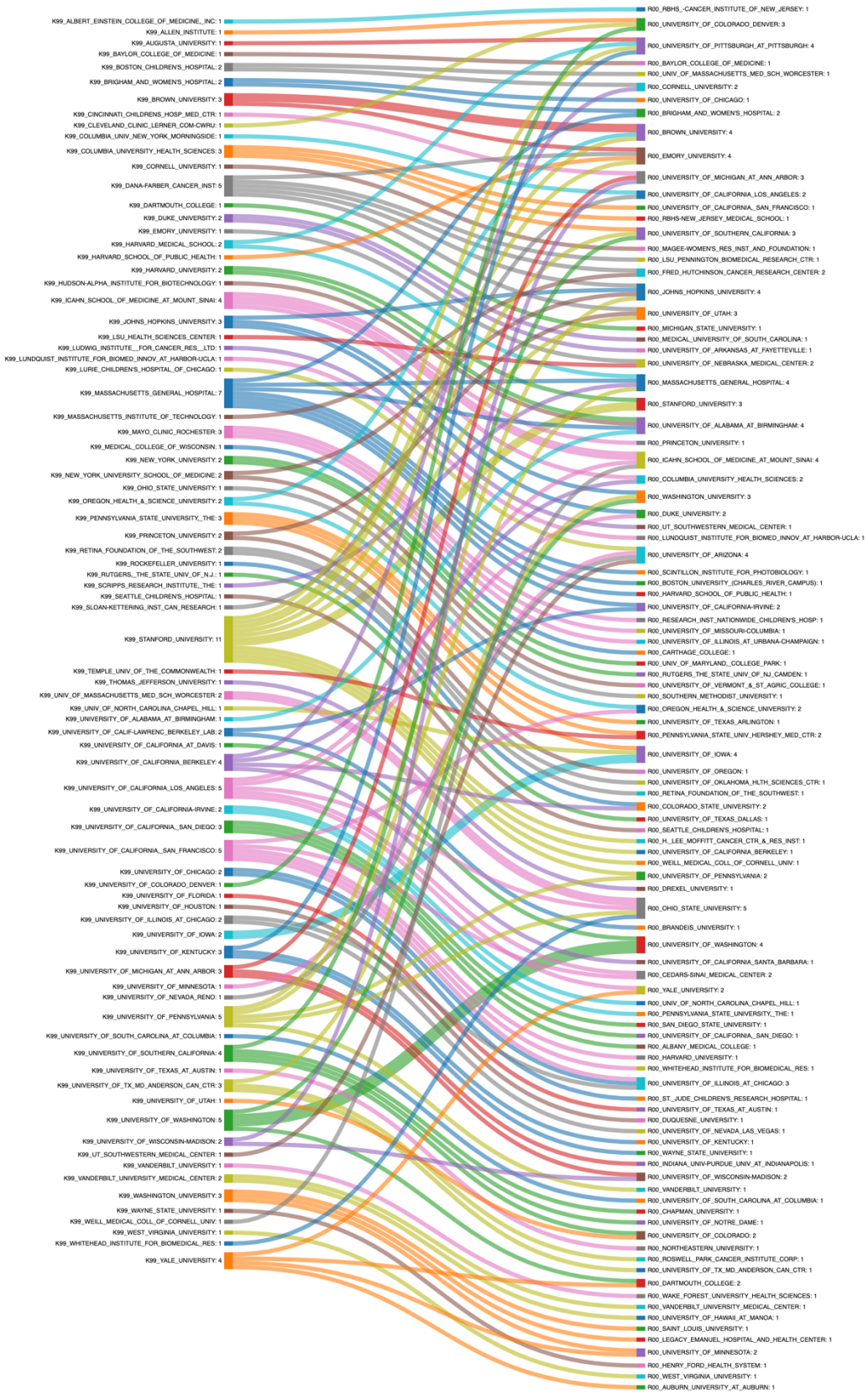
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K99_EMORY_UNIVERSITY: 1
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R00_COLUMBIA_UNIVERSITY_HEALTH_SCIENCES: 2
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R00_CARTHAGE_COLLEGE: 1
R00_UNIV_OF_MARYLAND__COLLEGE_PARK: 1
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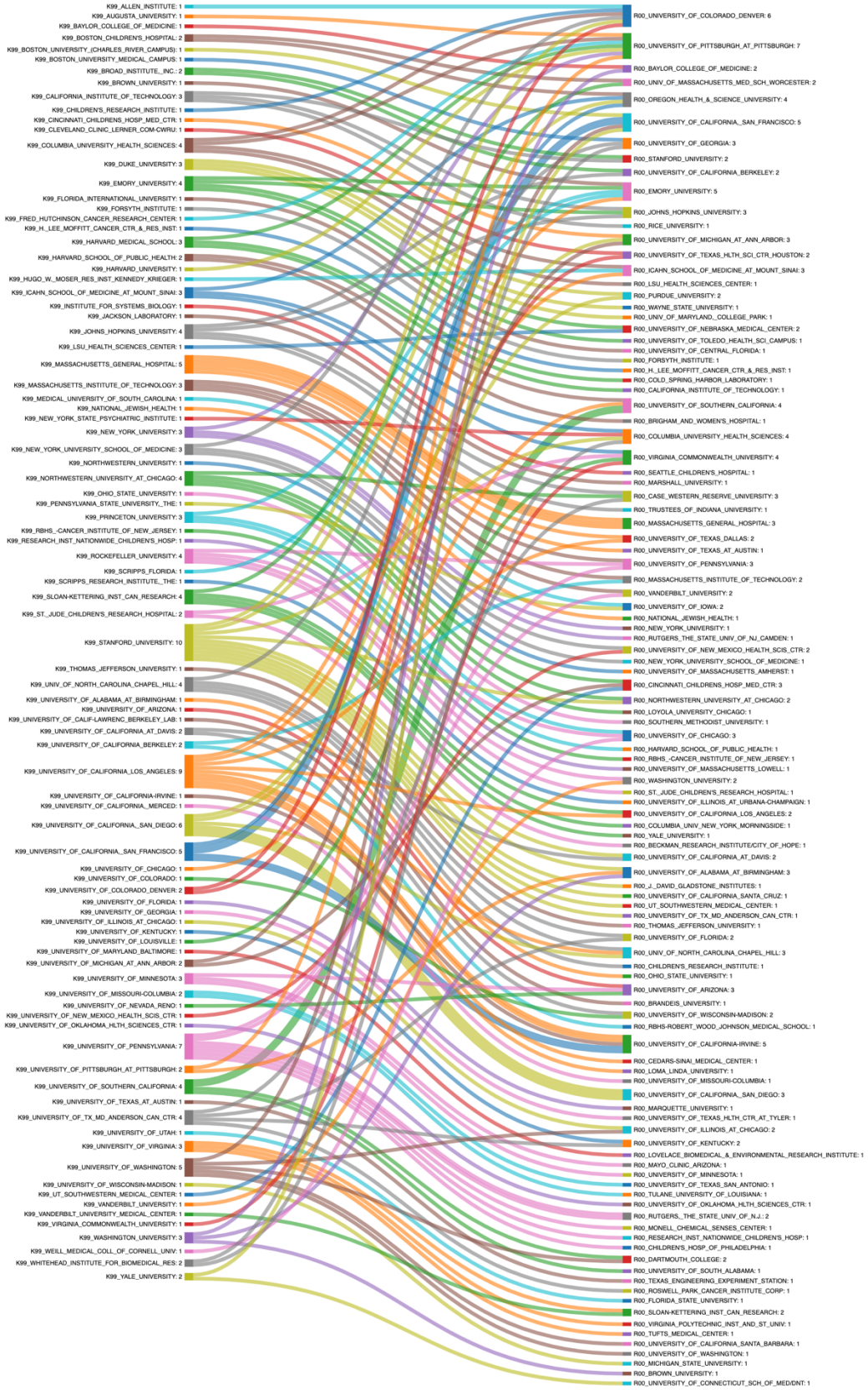
352 M 2019-2020



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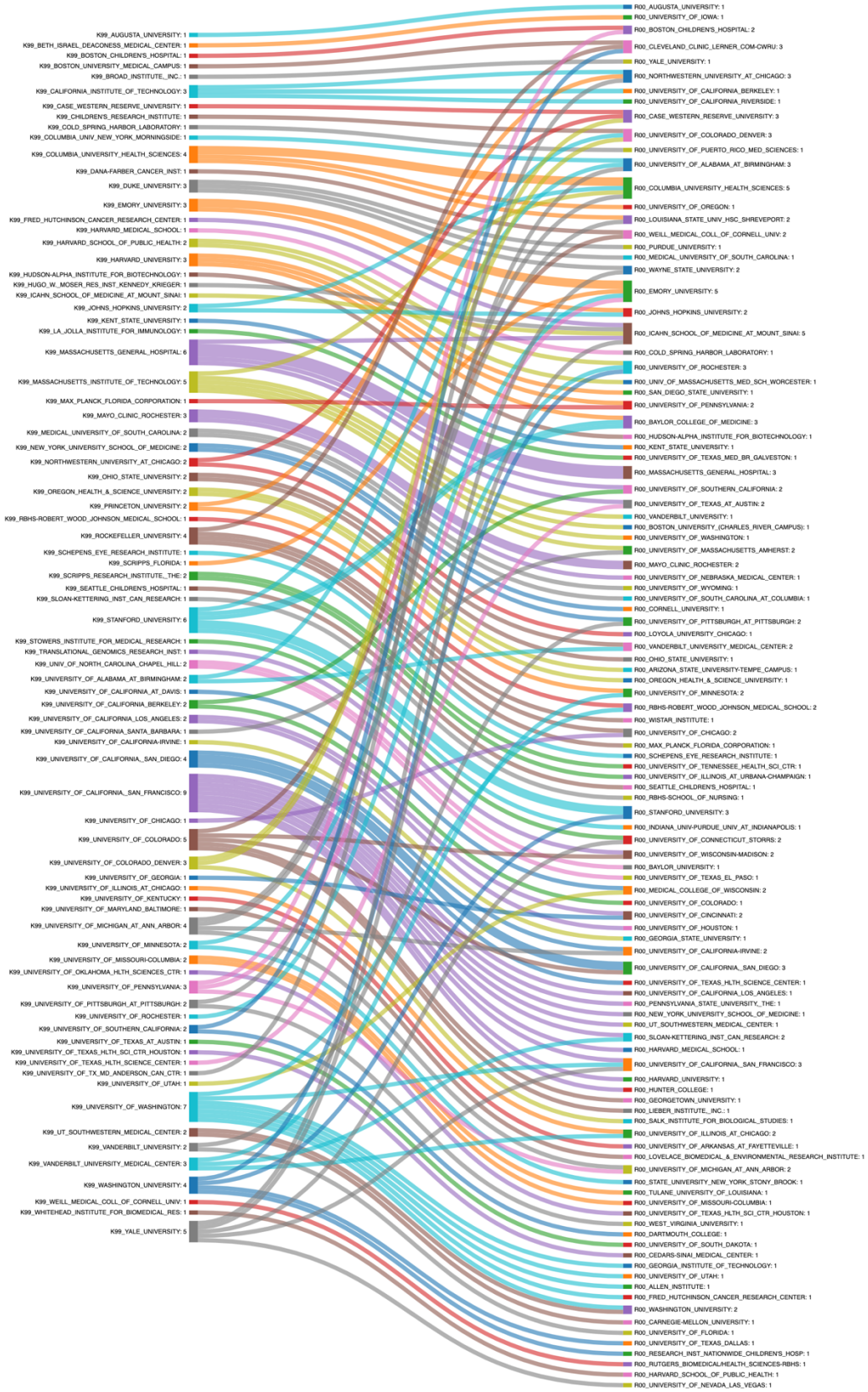

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356 O 2021-2022

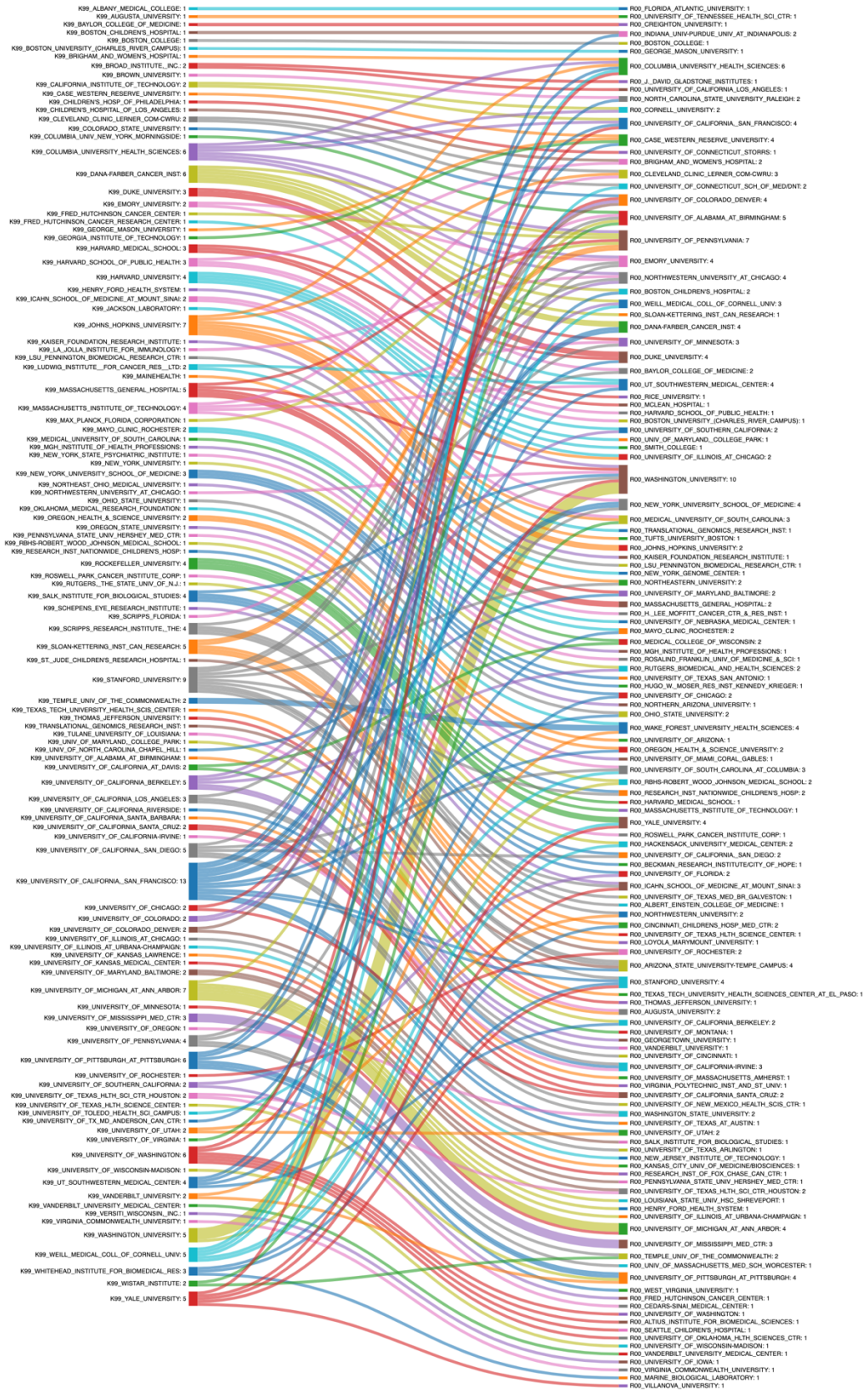

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Figure 5: A-O) Sankey diagrams of each cycle from 2007-2008 through 2021-2022 showing each successful K99 to R00 award transfer with the K99 institution on the left and R00 institution on the right.

References

1) Fernandes JD, Sarabipour S, Smith CT, Niemi NM, Jadavji NM, Kozik AJ, Holehouse AS, Pejaver V, Symmons O, Bisson Filho AW, Haage A. A survey-based analysis of the academic job market. Elife. 2020 Jun 12;9:e54097. doi: 10.7554/eLife.54097. PMID: 32530420; PMCID: PMC7360372.
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3) NIH Report. Success Rates. https://report.nih.gov/funding/nih-budget-and-spending-data-past-fiscal-years/success-rates. Accessed 1/26/2023.
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