Minds to Medical

Networks of Knowledge: How to Find Them, and Utilize Them

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Science is not a solitary pursuit. The more complex and distributed knowledge becomes, the more we need others to help us make sense of it. The greater the volume of information, the more we need others to point us toward what to pay attention to.

Medical research is exploding – both humans and machines are processing health and disease data looking for patterns that will reveal new ways to heal. Medical knowledge is no longer found just in the usual places amongst the usual suspects. Key findings and productive collaborations are emerging from many institutions, in many cities and in many countries. The United States is no longer the only location of cutting edge research and its translation into medical practice.

How do we determine where innovative thinking and research is happening? A common way used to be to look at who is getting the big grants to investigate big health issues. That still works, partially, but grants are often constrained by old rules and geographic/institutional boundaries. We are also aware that some investigators are better at getting grants than getting breakthroughs. Total dollars spent does not equal total benefit. Another way to filter out who is influential in a research field is to look at publications. After all, "publish or perish" is still the mantra throughout academia. Maybe a person's publication *h-index*[1] is a better indicator of their place in the research ecosystem?

We propose a third option – the researcher's location in the network of other researchers as determined by his/her collaborations with various colleagues. Those "in the thick of things" in their particular field of study will hear of, and understand, what is new, innovative, and possible, before others who are not at a good crossroads of information

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[1] Hirsch JE (2005), "An index to quantify an individual's scientific research output" PNAS vol. 102 no. 46 16569–16572

flows and knowledge exchanges. It turns out that the "golden rule" of real estate – *location, location, location* – also applies to human networks[2]. In real estate the physical location of your home or office is important – geography and distance matter. In human networks, what matters is your *social distanc*e, not your physical distance. Are you connected to the right people? Do you work with people that matter? With people that have non-redundant sources of knowledge and wisdom? Are you in an echo chamber of common thinking or at the intersection of knowledge clusters where innovations via cross-fertilization may happen?

We look at a key area of medical research – translational medicine – and how it is developing around the world, and how the hospitals, universities and research centers in Cleveland, Ohio are participating in this fast-growing field in medical research. Who are the key translational medicine researchers – according to the above three measures (grants, publications, network location)? Where are the doctors and scientists located – both geographically and in the networks of knowledge exchange? How are Cleveland and its researchers and institutions positioned in this burgeoning field? What can Cleveland institutions and researchers do to improve their *location* in the networks that matter?

The first step to improving your network is to "know your network." Just like a doctor will use x-rays and cat-scans to look inside a patient's body to understand their ailment, so we will map out the clusters and connections amongst translational medicine researchers. Once you "know your network", you can take action on/in the network. You can "navigate the network" because now you have a road map – you know where to go for what. You can also "knead the network" – excite a portion of the network to take action on a threat or opportunity. Finally, and most importantly, you can "knit the network" – make new connections between individuals and groups that need to exchange knowledge or translate understanding to move everyone forward with new discoveries or better implementation

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[2] Krebs VE (2003), "Power in Networks" http://orgnet.com/PowerInNetworks.pdf

of current knowledge. *Connect the unconnected where it makes sense for new opportunities and learning.*

Translational medicine, also known as, *translational research*, is a popular field of exploration. We looked at data from the last 5 years (2012-2016) in both grant activity and publications. We suggest combining grant history, publication history, and social network analysis[3] to reveal the star researchers and their clusters of collaboration in this field of interest. Grant history is obtained from the StarMetrics database looking at both National Institutes of Health (NIH) and National Science Foundation (NSF) grants in the field of translational medicine over the period of 2012 through 2016. Publication data was obtained from the PubMed database – National Library of Medicine supported by the NIH. The data from these two sources was combined to form the nodes and links of the translational medicine network, which was then processed by social network analysis (SNA) software[4]. From this resultant network of knowledge we were able to determine the researchers who were best located in the network – which were at the intersection of information flows, knowledge exchanges, and conversations of what's new/important/changing.

After looking at our two databases, we were surprised at the volume of data we found around translational medicine. We had an initial network of over 68,000 researchers and over 1,000,000 collaborations between them. Some doctors and scientists collaborated on only one study, while others collaborated numerous times. Those that collaborated numerous times did not always collaborate with the same others. Collaborations were often a mixture of old partners and new partners – and usually the better mix of old and new, the better results[5].

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[3] Wasserman S, and Faust K (1994), *Social Network Analysis: Methods and Applications,* Cambridge University Press, New York, NY 1994.
[4] http://orgnet.com/software.html
[5] Uzzi B and Jarrett S. "Collaboration and Creativity: The Small World Problem," American Journal of Sociology, Sept 2005, 111:447-504.

Collaboration Maps

We searched StarMetrics and PubMed for the phrase "translational research" and found many people and publications that linked to that phrase. Below we see the all of the data we found – over 68,000 researchers and over 1 million links amongst them. The first two diagrams below are often called "hairballs" because of their shape and massive set of links. Figure 1 shows some of the key Cleveland researchers in the hairball of data. Those affiliated with CWRU are in red, while blue nodes represent those affiliated with Cleveland Clinic. There are also a few small green nodes in that mass of data; they represent some of the other medical institutions in Cleveland such as the Veteran's Administration Hospital and MetroHealth. Node size in Figure 1 shows the number of NSH/NIH grants received by the researchers of the time period of 2012-2016.
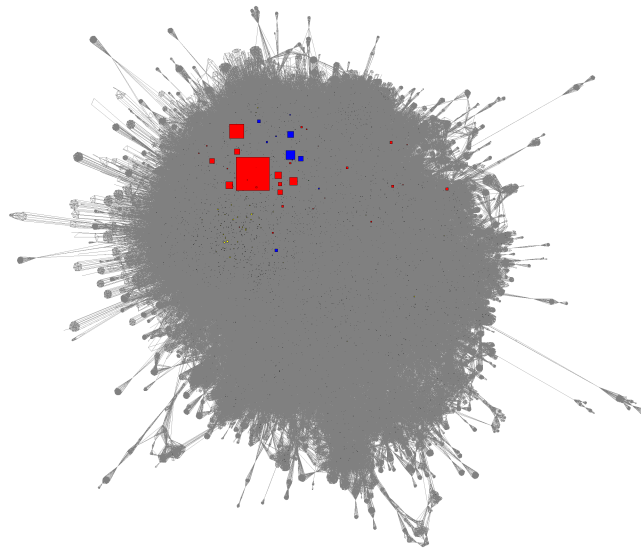
Figure 1 – Cleveland Grant Recipients in "translational research" ecosystem

Other locations around the world also have prominent researchers who have strands to "translational research". Figure 2 shows researchers who have published often in the field. The number of publications that touch this research field determines node size. Yellow nodes represent researchers outside of the Cleveland area. We notice a dense
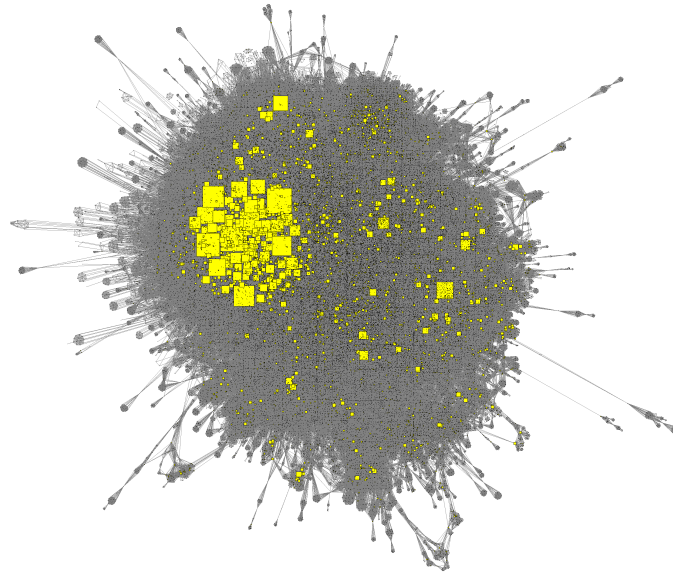
Figure 3 – Strong ties and emergent communities in the field of translational research

Figure 3 begins to reveal the many sub-networks (sub-communities) within the larger translational research community. Researchers from Cleveland are obviously out-numbered and populate the periphery[6] of the network. Those groups of frequent publishers who often work together populate the core of the network. Who is in this dense community of colleagues, and where do they reside in the world?

We zoom in on the core[7] of the network and examine who these researchers are. Figure 4 shows us the core of the translational research publishing community. Examining the author names, and their affiliated institutions we see that the core of this network is in China, or contains researchers who initially studied in China. Unfortunately the names of many of the authors are very similar so it is difficult to put them each with their respective

[6] Krebs VE (2005), Building Adaptive Communities through Network Weaving
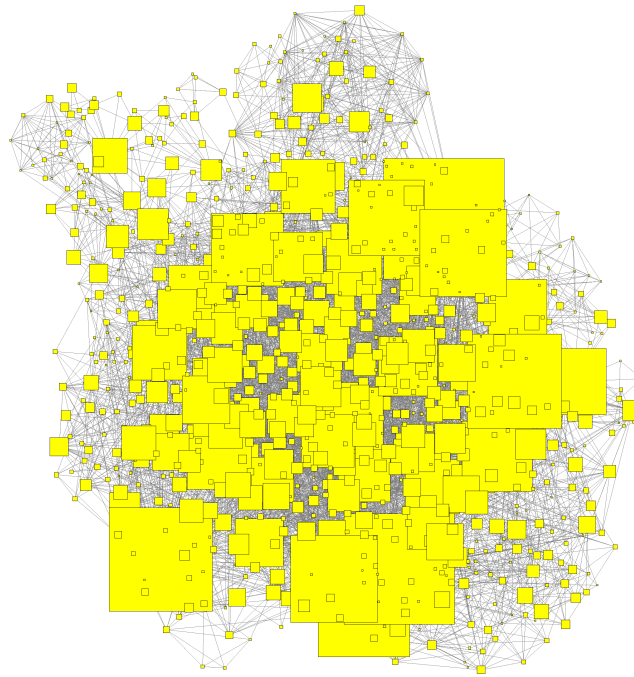*Nonprofit Quarterly* vol. 12 (Winter 2005): 66-72.

[7] Ibid

institution. Examining the core data with PubMed finds a preponderance of these authors associated with a university, hospital or research center in China.

Figure 4 – Network Core in the field of translational research

The number of publications one writes is not the only indicator of one's influence or level of respect in their knowledge community. Where they are located in the knowledge network also matters[8]. We go back to our network of strong tie clusters that we looked at in Figure 3. Now we will look at the network measure of integration for each researcher – how well are they connected to other prestigious/influential researchers? This measure helps us evaluate the network of flows that a researcher is embedded in. Those who are connected to others, who are also well connected, will be exposed not only to more

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[8] Burt, RS, "Structural holes and good ideas", *American journal of sociology*, Volume 110.2 (2004): 349-399.

knowledge, viewpoints, opinions and experiences, but also to a greater variety of them from a diverse set of sources. Figure 5 shows us who is best integrated in the information flows and knowledge exchanges in translational research. Unfortunately, no one from Cleveland is in the thick of things, but they do have connections to (have collaborated with) those that are central to the network.

Figure 5 – Network metrics of key researchers

The two red nodes to the left of the center/core are prominent researchers at CWRU. They are have collaborated together, but not significantly. Zooming into the network deeper we look at the "network neighborhood" around these two CWRU researchers. How are they connected to others at CWRU, or CCF? How are they connected to the key nodes in the core of the network? Figure 6 shows us the network neighborhood of these two researchers. They connect to many researchers outside of Cleveland. The largest nodes on the right side of the diagram represent some of researchers in the core of the network we saw in Figure 4.

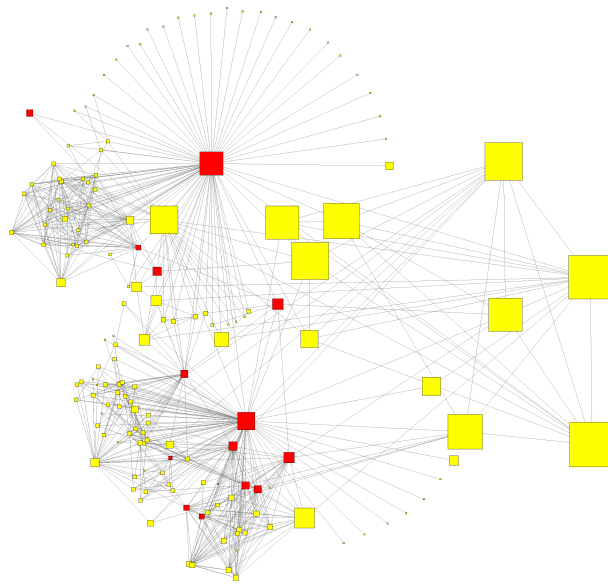**Figure 6 – Cleveland researchers connecting to researchers in network core**

It is good that some of Cleveland's top researchers have good connections outside of Cleveland. But how are Cleveland's researchers connected to each other? Is Cleveland a siloed medical research community? Or do researchers from the major institutions work together across boundaries? Figure 7 shows us the collaborations between major medical institutions in Cleveland. We see collaborations within CWRU and a few within CCF and CCLCM, but nothing between the two major medical institutions. The two connected green nodes are from the VA hospital.
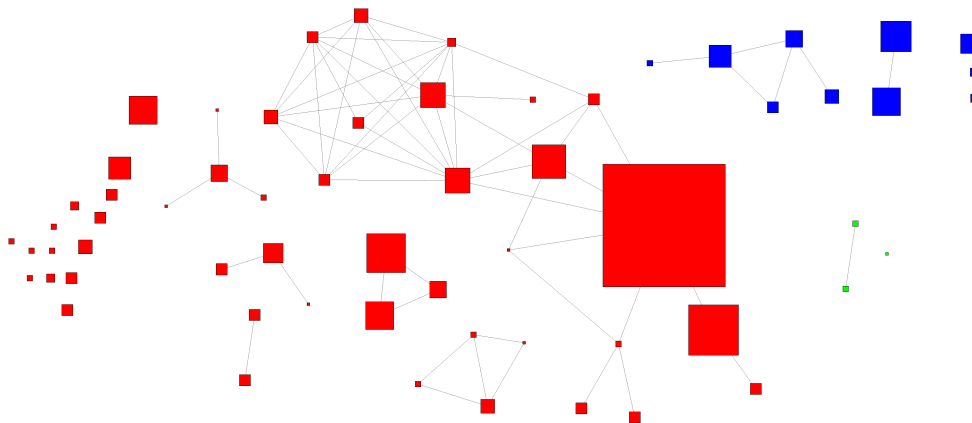
In Figure 7 we have set the bar *high* for what a connection is – we are looking at strong ties, those researchers who have collaborated together over time. The number of Grants they have recently received from NIH and NSF sizes the nodes in the Figure 7.

**Figure 7 – Frequent Collaborations between researchers in Cleveland**

If we lowered the bar, for what a connection is, we would see a few more collaborations between CWRU and CCF, mostly via CCLCM. Figure 8 shows a link between two researchers if they have collaborated on one (1) project or more together. One collaboration is usually not enough to set up a trusted relationship between two professionals, but it is a start.
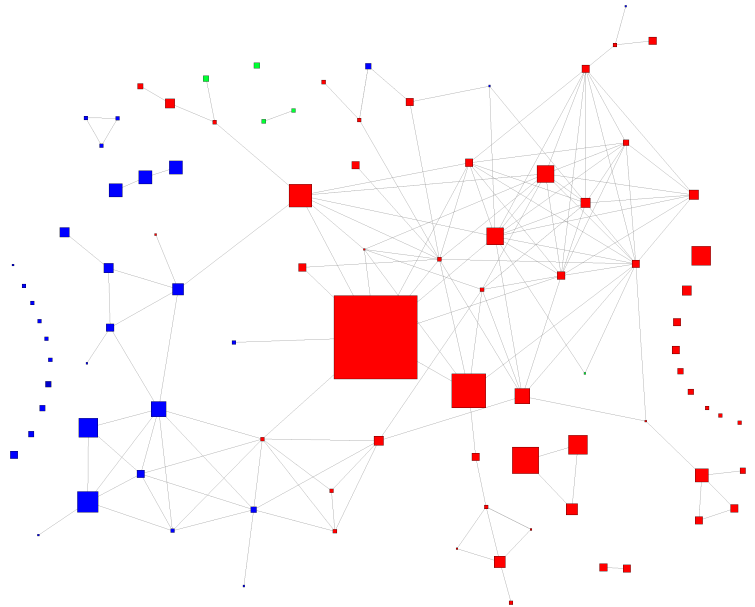
Figure 8 – Cleveland researchers who have collaborated at least once.

The node size in Figure 8 again designates the number of grants that researchers have received in the last 5 years. To improve this network, we need to understand the connectivity of the network – the "as is" picture/x-ray. Who is well positioned in the network to make connections between the various institutions? Who is in position to be a bridge builder? Who has the potential to be a connector within Cleveland's research community?

To find network connectors we run another network metric called betweenness[9]. Instead of using the academic term we will just call it *connector* – it reveals nodes that can connect those that are not connected. This does not infer that everyone should be connected to everyone else. It does reveal those in the network that are best located to build bridges, or translate between groups, emergent communities, or clusters. Figure 9 shows both the

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[9] Freeman, LC, "Centrality in social networks conceptual clarification." *Social Networks* 1.3 (1979): 215-239.

strong and weak ties in the Cleveland translational research community – which researchers have at least one project together. These may be paths to start building roads or bridges between communities that need to communicate and collaborate. The node size in Figure 9 designates *potential to be a connecto*r of others. This node size does not have any relation to number of grants or number of publications – it is purely a connecting position in the network. A *connector* does not need to be the top subject matter expert(SME), s/he just needs to be aware of *who knows who* and *who knows what.*
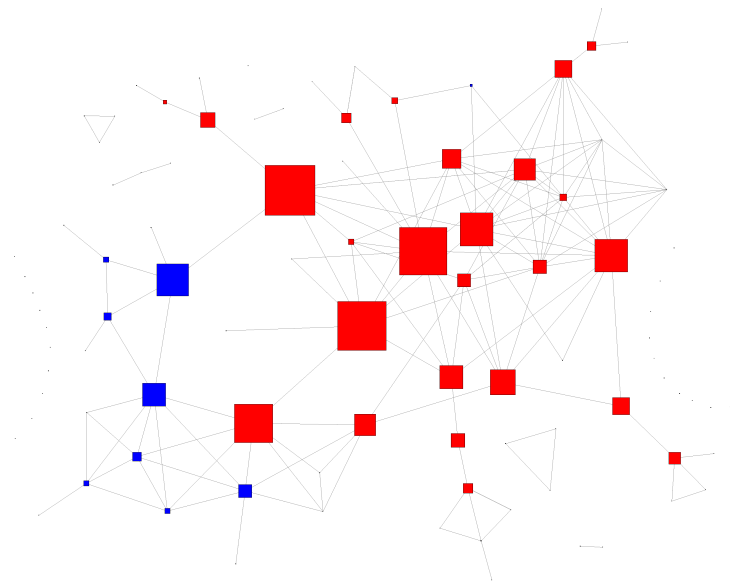
Figure 9 – Cleveland researchers who may be connectors or bridge-builders.

From our findings it seems that the "translational research" community in Cleveland should have two goals.

1. Continue improving internal research community connections
2. Seek out new and interesting external connections to other related research groups

Both sets of new collaborations will mix people and ideas that may be new to each other and may lead to both serendipitous and intentional discoveries. Innovation happens at the

intersections of knowledge communities. Intersections where new, yet overlapping, information and knowledge can mix to take the next step forward on what is known and what is possible.

For future studies like these, I recommend picking a more focused field of research to examine. "Translation research" is a broad topic and therefore we probably looked at many researchers that were at best tangentially included in this ecosystem. Picking a detailed topic will make it easier to decide who is in and who is not – allowing us to see more clearly defined borders of each knowledge community. Yet, as with any human community or network there are no perfectly clear boundaries between who belongs where. Human knowledge and social networks have fuzzy boundaries. Scientists belong to many overlapping communities. However a sharper focus will improve future studies of this kind.