Scaling Laws and University Organization

Allan C. Dobbins, Ph.D.
Department of Biomedical Engineering
adobbins@uab.edu 934-5529

Summary

Is a university more like a business corporation or a city? Specifically, we are interested in how the key attributes of a university – how its capacity for innovation and its educational quality scale with size. Cities tend to be more innovative as they grow larger, while corporations become less so. Cities tend to be long-lived, while corporations are short-lived. The purpose of this proposal is to evaluate organizational aspects of the university from an abstract, network modeling point of view, and ask if it has characteristics more like a business corporation (increasingly bureaucratic with increasing scale), how can it be made more like a city with (increasingly innovative with increasing scale). The analyses will lead to specific outcomes for the organization of UAB, an institution devoted to becoming both an outstanding educator and creator of knowledge. If UAB can succeed in becoming a research institution of the first rank, the benefits to the people of Alabama are manifold.

Background

Kleiber's law is an empirical relationship stating that basic metabolic rate scales as the ¾ power of body mass in animals. About twenty years ago, Geoffrey West and colleagues developed a principled theoretical account of why this relationship holds across a wide range of groups and sizes. They propose that the reason is that organisms seek to minimize the total hydrodynamic resistance of their circulatory systems and this is achieved via a fractal (self-similar) network (West et al, 1997). John Allman and colleagues have shown that brain size exhibits the same scaling law with body size. In addition, large-brained animals live longer. Groups of animals that are well off the standard curve relating body mass to longevity -- large-brained animals such as cetaceans and primates – are correspondingly long-lived. Robin Dunbar has shown that primate brain size is related to the size of the social group of the species – leading to the social brain hypothesis (Barton and Dunbar, 1997).

More recently, West and colleagues have turned their attention to scaling laws beyond the individual biological organism, collecting massive amounts of data to evaluate how energetic and sociological characteristics vary with the size of the city. Many energetic variables e.g. per capita energy use exhibit a sublinear scaling law with city size (e.g. exponent: ~0.85) showing economies of scale. On the other hand, variables that might be associated with the size of social networks e.g. innovation as measured by patents per capita, scale superlinearly (e.g. exponent: ~1.15). If this is generally true, then the biggest cities with their high density of highly educated people own the future. However, while this may be true in an average sense, is it necessarily true? For example, Silicon Valley consists of a collection of small to medium sized cities south of San Francisco. Yet, it has been responsible for a substantial fraction of the invention of the technological future beginning when William Hewlett and David Packard graduated from Stanford University and formed Hewlett-Packard in 1947. Silicon Valley violates the supercity rule for innovation. Therefore it is critical to understand what is actually critical for a university, city or region to prosper.

As far as we know, universities have not been subjected to the data analytics that have been applied to cities. Freeman Dyson, in a review of West's book in the *New York Review* pointed out another scaling law that runs in the opposite direction. The Japanese biologist Motoo Kimura showed that the magnitude of genetic drift in a population is inversely related to the square of population. Significant innovation may be most likely in small isolated populations. Consider Silicon Valley once again. Alan Kay and his colleagues at the Xerox PARC (Palo Alto Research Center) conceived and developed the computer workstation that they desired. One day Steve Jobs was visiting and instantly knew that he had seen the future. He returned to Apple and began the Lisa project (unsuccessful) and then the Macintosh, based on the workstation he had seen at Xerox PARC. Xerox had created an isolated incubator at PARC that generated many innovations, few of which were appreciated or exploited by its giant parent corporation. In Cambridge at the Cavendish Laboratory in the 1950s, Hodgkin and Huxley in 1952 published four seminal papers that explained the generation and propagation of nerve impulses and that set the agenda for membrane biophysics for the next three decades. A year later Watson and Crick, published their model of the structure of DNA, setting off the revolution in molecular biology that continues apace today. Some years later two scientists (John Kendrew and Max Perrutz) also in the Cavendish, produced the first complete 3D structures for hemoglobin and myoglobin. Over a period of several years one not-terribly-well-funded university produced some of the most fundamental works of the mid-20th century. Other small institutions, such as Caltech and Princeton, have also had an extraordinarily high density of outstanding science. If the superlinear scaling law for innovation with size applied, this would be impossible.

It may well turn out that the critical aspect of innovation in basic science or technology is not size, but rather the structure of the network and the flows within it. Small world networks (Watts and Strogatz, 1998) have interesting properties that may be critical.

Outcomes

The goal of this proposal is to examine the structure of universities, both their scaling and network properties and attempt to identify the characteristics that are shared by especially successful institutions. In addition, we will examine the outliers --- those that are successful despite being different than the successful cohort. Emerging from this study will be principles to guide the strategic plan of the university as it attempts to evolve into a great research institution.

To evaluate the ideas that arise from this proposal, a prototype institute in a frontier research area can be developed. Following Kimura's principle, it can be small, provided it has appropriate leadership and structure. The big picture here is the possibility of transforming UAB into a leading institution of the 21st century, a time when humanity faces unprecedented challenges.

References

Allman, John M. (1999) *Evolving Brains.* W H Freeman & Co.

Barton, R. A., & Dunbar, R. I. M. (1997). Evolution of the social brain. In A. Whiten, & R. W. Byrne (Eds.), *Machiavellian intelligence II* (second ed., pp. 240–263). Cambridge, UK: Cambridge University Press.

Kleiber, M. (1932). Body size and metabolism. *Hilgardia,* **6**, 315-353.

Watts, D.J. & Strogatz, S. (1998) *Nature,* **393**: 440–442.

West, G. B., Brown, J. H. and Enquist, B. J. (1997). A general model for the origin of allometric scaling laws in biology. *Science,* **276**, 122-26.

West, G. B. (2017) Scale: The Universal Laws of Growth, Innovation, Sustainability, and the Pace of Life in Organisms, Cities, Economies and Companies. Penguin.

Potential Participants:

ACD
JMA, Caltech
FD, IAS, Princeton
SS, Cornell
GW, Santa Fe Institute
SWZ, Yale University