

THE CHARACTERISTICS OF NETWORK SCIENCE

Network science is defined not only by its subject matter, but also by its methodology. In this section we discuss the key characteristics of the approach network science adopted to understand complex systems.

INTERDISCIPLINARY NATURE

Network science offers a language through which different disciplines can seamlessly interact with each other. Indeed, cell biologists, brain scientists (Figure 1.4) and computer scientists alike are faced with the task of characterizing the wiring diagram behind their system, extracting information from incomplete and noisy datasets, and understanding their systems' robustness to failures or attacks.

To be sure, each discipline brings a different set of goals, technical details and challenges, which are important on their own. Yet, the common nature of many issues these fields struggle with has led to a cross-disciplinary fertilization of tools and ideas. For example, the concept of betweenness centrality that emerged in the social network literature in the 1970s, today plays a key role in identifying high traffic nodes on the Internet. Similarly algorithms developed by computer scientists for graph partitioning have found novel applications in identifying disease modules in medicine or detecting communities within large social networks.

EMPIRICAL, DATA DRIVEN NATURE

Several key concepts of network science have their roots in graph theory, a fertile field of mathematics. What distinguishes network science from graph theory is its empirical nature, i.e. its focus on data, function and utility. As we will see in the coming chapters, in network science we are never satisfied with developing abstract mathematical tools to describe a certain network property. Each tool we develop is tested on real data and its value is judged by the insights it offers about a system's properties and behavior.

QUANTITATIVE AND MATHEMATICAL NATURE

To contribute to the development of network science and to properly use its tools, it is essential to master the mathematical formalism behind

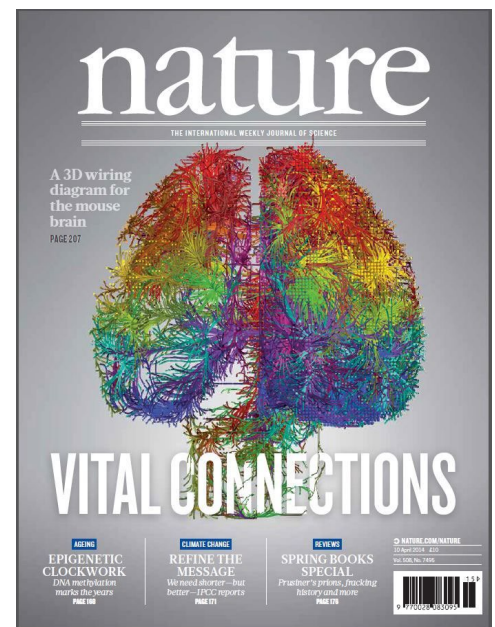


Figure 1.4
Mapping the Brain

An exploding application area for network science is brain research. The wiring diagram of a complete nervous system has long been available for *C. elegans*, a small roundworm, but neuronal connectivity data for larger animals has been missing until recently. That is changing thanks to major efforts by the scientific community to develop technologies that can map out the brain's wiring diagram. The image shows the cover of the April 10, 2014 issue of *Nature*, reporting an extensive map of the laboratory mouse [4] generated by researchers at the Allen Institute in Seattle.

it. Network science borrowed the formalism to deal with graphs from graph theory and the conceptual framework to deal with randomness and seek universal organizing principles from statistical physics. Lately, the field is benefiting from concepts borrowed from engineering, like control and information theory, allowing us to understand the control principles of networks, and from statistics, helping us extract information from incomplete and noisy datasets.

The development of network analysis software has made the tools of network science available to a wider community, even those who may not be familiar with the intellectual foundations and the full mathematical depths of the discipline. Yet, to further the field and to efficiently use its tools, we need to master its theoretical formalism.

COMPUTATIONAL NATURE

Given the size of many of the networks of practical interest, and the exceptional amount of auxiliary data behind them, network scientists are regularly confronted by a series of formidable computational challenges. Hence, the field has a strong computational character, actively borrowing from algorithms, database management and data mining. A series of software tools are available to address these computational problems, enabling practitioners with diverse computational skills to analyze the networks of interest to them.

In summary, a mastery of network science requires familiarity with each of these aspects of the field. It is their combination that offers the multi-faceted tools and perspectives necessary to understand the properties of real networks.