4

Network Theory

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This chapter is about *network theory*, which in general usage can refer to several different kinds of ideas. For example, both a theory of *tie formation* and a theory of the advantages of *social capital* could be considered network theory. In the tie formation case, network properties serve as the dependent variable, and the theory concerns the antecedents of network phenomena. In the social capital case, the network construct is the independent variable, and the theory considers the consequences of network phenomena. We distinguish between the two kinds of theory by referring to the first (on antecedents) as *theory of networks* and the second (on consequences) as *network theory*.[1] The focus of this chapter is on network theory, which we define as the proposed processes and mechanisms that relate network properties to outcomes of interest.

One approach to writing a chapter on network theory is to simply review the network literature and note that so-and-so argued that network variable X leads to Y while someone else argued that network variable Z leads to W. The problem with this is that theory is more than a system of interrelated variables—it is the reason the variables are related. Theory describes the unseen mechanism that generates an outcome from initial conditions. Our approach, therefore, is to examine well-known network theories and extract the underlying principles or mechanisms they propose. We think of these mechanisms as elemental theoretical memes that are combined in various ways to generate theory. We hope this approach will help identify commonalities across different research efforts and provide conceptual tools for creating new theory.

We start the chapter with detailed accounts of a few well-known network theories that serve as prototypes. We then abstract an underlying generic theory that we call the *network flow model* (where networks are seen as systems of pipes through which information flows), which we argue underlies much of network thinking. As part of this, we introduce a typology of dyadic states and events. Next, we consider examples of network theorizing that stem from a different underlying model, which we call the *network architecture model* (where networks are seen as systems of girders that create structures of dependencies). The two models are then discussed in the light of a typology of network research traditions. We conclude with some general observations about the state of network theorizing.

EXAMPLES OF NETWORK THEORIZING

We start with a detailed account of Granovetter's (1973) strength of weak ties (SWT) theory, using new terminology that facilitates comparison with other theories. Conveniently, the theory is organized as a set of explicit premises and conclusions, as shown in Figure 4.1. The first premise of the theory is that the stronger[2] the tie between two people, the more likely that their social worlds will overlap—that they will have ties with the same third parties, a kind of transitivity.

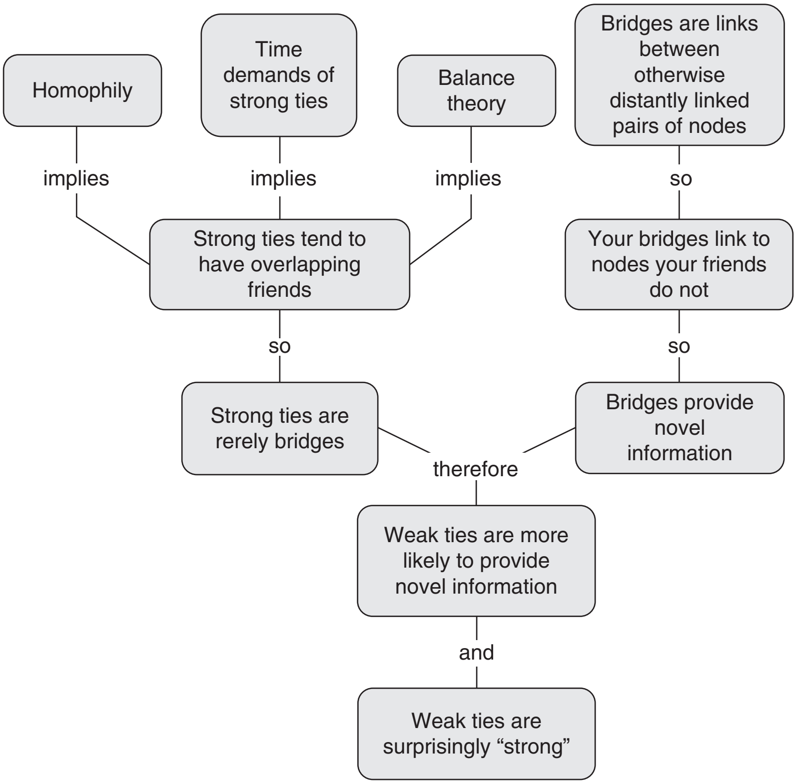

Figure 4.1 Granovetter’s (1973) strength of weak ties theory

For example, if A is married to B, and B is close friends with C, the chances are that A and C will at least be acquaintances (see Figure 4.2). The reason for this, Granovetter argues, is that the underlying causes of tie formation have this kind of transitivity built into them. For example, people tend to be *homophilous*, meaning that they have stronger ties with people who are similar to themselves (Lazarsfeld and Merton, 1954; McPherson et al., 2001). Homophily is weakly transitive because if A is similar to B, and B is similar to C, then A and C are likely to share some similarity as well. To the extent ties are caused by similarity, this will induce weak transitivity in the tie structure as well.

Another argument is based on balance or cognitive dissonance theory (Heider, 1958; Cartwright and Harary, 1956; Newcomb, 1961; J. Davis, 1967). If A likes B, and B likes C, A would like to like C as well to avoid dissonance.

The second premise of SWT is that bridging ties are a potential source of novel ideas. A bridging tie is a tie that links a person to people who are not connected to their other friends.[3] The idea is that from a bridging tie a person can hear things that are not already circulating among their other friends. In Figure 4.3, A’s tie with G is a bridging tie.[4]

Putting the two premises together, Granovetter reasoned that strong ties are unlikely to be the

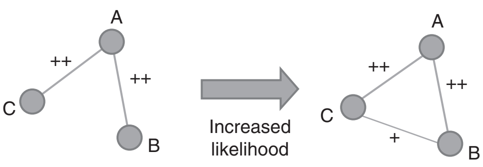

Figure 4.2 One premise of Granovetter’s (1973) SWT theory

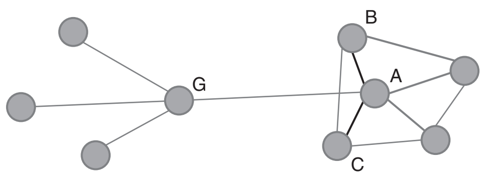

Figure 4.3 Bridging tie from A to G. Removing the tie disconnects the network

sources of novel information. The reason is as follows. First, bridging ties are unlikely to be strong. According to premise 1, if A and G have a strong tie, then G should have at least a weak tie to A's other strong friends. But if this is true, then the tie between A and G cannot be a bridge, since this would imply the existence of many short paths from A to G via their common acquaintances. Therefore, only weak ties can be bridges. Since bridges are the sources of novel information, and only weak ties are bridges, it is the weak ties that are the best potential sources of novel information.[5]

Granovetter uses this theory to explain why people often get or at least hear about jobs through acquaintances rather than close friends. In this sense, the theory is one of individual social capital, where people with more weak ties (i.e., more social capital) are more successful.

Granovetter also applies the theory at the group level, arguing that communities with many strong ties have pockets of strong local cohesion but weak global cohesion. In contrast, communities with many weak ties have weak local cohesion but strong global cohesion. He illustrates the idea in a case study of Boston in which the city assimilated one adjacent community (the West End) but failed to assimilate another (Charlestown). According to Granovetter, Charlestown had more weak ties, which facilitated community-level organizing. The traditional ethnic West End was a bedroom community in which people worked elsewhere; it was fragmented into distinct clusters of very dense strong ties, lacking bridging weak ties. In contrast, Charlestown residents worked in the community and had more opportunities to rub elbows. Thus, a community's diffuse weak-tie structure constitutes group-level social capital that enables the group to work together to achieve goals, such as mobilizing resources and organizing community action to respond to an outside threat.

Another well-known network theory is Burt's (1992) structural holes theory of social capital. Burt argues that if we compare nodes A and B in Figure 4.4, the shape of A's ego network is likely to afford A more novel information than B's ego network does for B. Both have the same number of ties, and we can stipulate that they are of the same strength. But because B's contacts are connected with each other, the information B gets from, say, X may well be the same information B gets from Y. In contrast, A's three ties connect A to three pockets of the network, who may know different things. A's ties connect to three different pools of information (represented by circles in Figure 4.4), while B's ties connect to just one pool. Burt argued that, as a result, A is likely to receive more nonredundant information at any given time than B, which can then be exploited to do a better job or to be the source of "new" ideas.

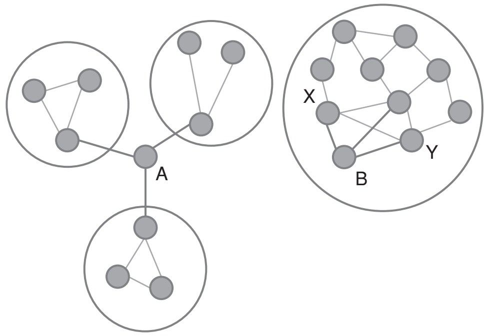

Figure 4.4 Node A has more structural holes than B

Burt's theory may look different from Granovetter's, but the differences are largely in language and focus. In Burt's language, A has more structural holes than B, which means A has more nonredundant ties. In Granovetter's language, A has more bridges than B. But whether we call them nonredundant ties or bridges, the concept is the same, and so are the consequences: more novel information.

Where Granovetter and Burt differ is that Granovetter further argues that a tie's strength determines whether it will serve as a bridge. Burt does not disagree and even provides empirical evidence that bridging ties are weaker in that they are more subject to decay (Burt, 1992, 2002). However, Burt sees tie strength as a mere "correlate" of the underlying principle, which is nonredundancy (1992: 27). Thus, the difference is between preferring the distal cause (strength of ties), as Granovetter does, and the proximal cause (bridging ties), as Burt does. The first yields an appealingly ironic and counterintuitive story line, while the second "captures the causal agent directly and thus provides a stronger foundation for theory" (Burt, 1992: 28). But it is all based on the same underlying model of how networks work, a model that we shall argue underpins a great deal of network theory.

The superficial differences and underlying similarity of weak tie and structural hole theories recall the apparent contradiction between Burt's structural hole argument and Coleman's closure theory of social capital. Burt (1992) argues that communication between an ego's two alters doesn't just reduce information, it constrains ego's behavior. For example, if the alters share information about their interactions with ego, then ego cannot tell substantially different stories to each party, constraining ego's behavior and reducing ego's social capital. In contrast, Coleman (1988) argues that the connections among ego's alters enable the alters to work together to help ego, increasing ego's social capital.

For example, a child benefits from having parents, teachers, neighborhood adults, and so on communicate with each other because this way they can ensure that the child does his homework, avoids danger, etc. But as Burt (2005) points out, the conflict between these views is more apparent than real, as both assume that ties among the child's alters constrain that child. The difference is simply that in Coleman's educational setting, constraint is good, and in Burt's corporate setting, constraint is typically bad. It is really only the (unwise) value-loadedness of the social capital concept that creates contradiction.

Another well-known area of network theorizing is small-world theory. In the 1950s and 1960s, a stream of mathematical research sought to explain coincidences of mutual acquaintanceship (de Sola Pool and Kochen, 1978[6]; Rapoport and Horvath, 1961). The basic thrust of the research was to show that societies were probably much more close-knit than popularly believed. A field experiment by Milgram (1967; Travers and Milgram, 1969) supported this theory, finding that paths linking random Americans were incredibly short. Restarting this stream of research 20 years later, Watts and Strogatz (1998) asked how human networks could have such short average distances, given that human networks were so clustered, a property that was known to lengthen network distances (Rapoport and Horvath, 1961). The answer, Watts and Strogatz showed, was simple: adding even a small number of random ties to a heavily clustered network could radically reduce distances among nodes. The reason was that many of these random ties would be between clusters, which is to say, they were bridges.

Integrating network yheories: the network flow model

In our view, small-world (SW) theory, structural hole (SH) theory, Coleman social capital (CSC) theory, and SWT theory are all elaborations—in different directions and for different purposes—of the same theory. In this section, we deconstruct this theory into three layers: a deep layer that defines the rules of a theoretical universe within which to work, a middle layer that consists of a theorem derived from the rules of the universe, and a surface layer that connects to the variables associated with a specific empirical setting. Together, these create the theory of which SW, SWT, SH and CSC are all different views. We then show how other theorems or derivations from the same set of underlying rules generate different (but not incompatible) theories.

The deep layer consists of a very simple model of how social systems work, which is essentially that they are networks through which information (or any resource) flows from node to node along paths consisting of ties interlocked through shared endpoints. The element of network paths is important. Paths simultaneously imply both connection and disconnection, with the length of paths indicating the degree of disconnection. We refer to this model as the network flow model, and we conceive of it as a platform for theorizing.

We limit the network flow model to "true" flows in the sense that what arrives at the other end is the same as when it started. Whatever flows through the network may be damaged or changed en route, but it remains basically the same thing. If it starts as gossip, it arrives as gossip, even if the details have changed. The distinction we are making is with a more general sense of flow such as a chain of causality, where, for example, someone misses an appointment and sets off a chain of events that culminate in a civil war. We regard this more general sense of flow as constituting a different model.

The middle layer consists of a bit of reasoning that says that transitivity (closure; clusteredness) slows network flows by increasing path lengths. This reasoning is effectively a theorem derived from the underlying flow model. Because all of the elements of the theorem are drawn from the network flow model, the theorem can be proved (or disproved) mathematically and can be explored via simulation. The network flow model is a closed world in which all the rules are known. Theory, at this level, consists of taking constructs defined on the underlying model (such as betweenness centrality) and relating them to outcomes in the same universe (such as frequency and time of first arrival of something flowing through the network).

The surface layer can be seen as a "personalization" of the theory that ornaments the basic theory with variables drawn from the immediate empirical context and which serve as an interface to general social theory. For example, Granovetter decorates the theory at one end by adding strength of tie as an antecedent to transitivity. Burt decorates the theory at the other end by connecting information flows to personal creativity and producing value. Travers and Milgram suggest that upper-class people are more likely to be key nodes.

The transitivity theorem is just one of many we can derive from the underlying flow model to yield new theory. For example, a different theorem is that, ceteris paribus, nodes with more ties have greater exposure to (i.e., more chances of receiving) whatever is flowing through a network (Freeman, 1979; Borgatti, 1995, 2005). Depending on the flow's usefulness, this should mean better outcomes for nodes with more ties.[7]

We can also reason that it matters how well connected a node's contacts (Bonacich, 1972) are.

A node with five contacts that have no other contacts has little exposure to information flowing through the network. A node whose five contacts are the most central nodes in the network will have great exposure. For example, in a sexual network, many nodes can be monogamous, but their risk of catching a sexually transmitted disease will vary based on how well "connected" their partner has recently been.

If the connectedness of an ego's alters matters, so could other characteristics, including nonstructural attributes, such as wealth, power, or expertise. Being connected to powerful and wealthy people may present more opportunities than being connected to an equal number of people without such resources. This is the basis of Lin's (1982) social resource theory (see also Snijders, 1999), another branch of social capital research.

If we assume that the time it takes for information to move along a network path is proportional to the length of the path, another obvious theorem is that nodes that are closest to all others should, on average, receive flows more quickly (Freeman, 1979; Borgatti, 1995, 2005). When it is beneficial to receive flows before others do (e.g., information on organizational events), nodes with greater overall closeness should perform better.

A well-known theoretical proposition is that nodes positioned along the only or best paths between others may be able to benefit by controlling, filtering, or coloring the flow, as well as charging rents for passing along the flow (Freeman, 1977).

Finally, we can theorize that nodes located in the same general areas (e.g., connected to the same nodes; Lorrain and White, 1971) will tend to hear the same things and therefore have equal access to opportunities provided by network flows (Burt, 1976).

There are many other basic theoretical propositions found in the literature that can be derived from the basic network flow model. The main point is that the network flow model provides a conceptual universe within which we can conceptualize properties (such as clusteredness or centrality) and relate them to other properties (such as probabilities of receiving something flowing through the system). These properties are widely misperceived as elements of methodology (i.e., "measures") that are unconnected to theory, when in fact they are derivations of a model and exist only in the context of a theoretical process.[8]

RELATIONAL STATES AND EVENTS IN THE NETWORK FLOW MODEL

Theories derived from the network flow model distinguish between two kinds of relational or

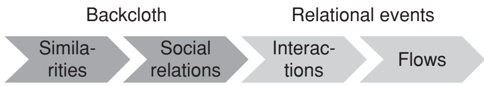

Figure 4.5 Types of dyadic phenomena

dyadic phenomena, which Atkin (1974, 1977) referred to as *backcloth* and *traffic*. The backcloth consists of an underlying infrastructure that enables and constrains the traffic, and the traffic consists of what flows through the network, such as information. For example, in SWT theory, social ties such as acquaintanceships serve as potential conduits for information.

A more elaborate set of distinctions is illustrated in Figure 4.5, which divides dyadic phenomena into four basic categories: similarities, social relations, interactions, and flows.[9]

The *similarities* category refers to physical proximity, co-membership in social categories, and sharing of behaviors, attitudes, and beliefs. Generally, we do not see these items as social ties, but we do often see them as increasing the probabilities of certain relations and dyadic events. For example, in an organizational setting, Allen (1977) found that communication tends to increase as a function of spatial proximity.

The *social relations* category refers to the classic kinds of social ties that are ubiquitous in network theorizing. We distinguish between two types of social relations: role-based and cognitive/affective. *Role-based* includes kinships and role relations such as *boss of*, *teacher of*, and *friend of*. We use the term *role-based* because these relations are usually institutionalized into rights and obligations, and are linguistically identified as, for example, *friend*, *boss*, or *uncle*. Many are also symmetric or skew-symmetric, such that if A is a friend of B, then B is a friend of A, and if A is the teacher of B, then B is the student of A. Another characteristic of role-based relations is that they are in a weak sense public and objective—a researcher can ask a third party whether two people are friends or have a teacher/student relationship and not receive an automatic "how should I know?" reaction.

The second type of social relation consists of perceptions and attitudes about specific others, such as *knowing*, *liking*, or *disliking*. These evaluations are widely considered private, idiosyncratic, and invisible. They can easily be nonsymmetric: A likes B, but the reverse may or may not be true.

The *interactions* category refers to discrete and separate events that may occur frequently but then stop, such as *talking with*, *fighting with*, or *having lunch with*.

Finally, the *flows* category includes things such as resources, information, and diseases that move from node to node. They may transfer (being only at one place at a time) and duplicate (as in information). Flows matter in most network theories but are generally assumed immeasurable in practice.

In Atkin's view, the four dyadic phenomena all serve as the backcloth for the phenomena to their right. Hence, physical proximity can facilitate the development of certain relationships, and certain relationships permit certain interactions; these in turn provide the vehicle for transmissions or flows. However, it is also clear that phenomena on the right can transform the phenomena on the left, so that people with certain relationships (e.g., spouses) tend to move closer together, and certain interactions (e.g., sex) can change or institutionalize relationships.

Theory based on the network flow model focuses on either social relations or interactions, using these ties to define the network backcloth, which then determines flows. Interactions are transitory, so theory built on them typically conceptualizes them as cumulative and repeated over time, describing them as *recurrent*, *patterned*, or *relatively stable*. In effect, this relation converts into an underlying social relation that is ongoing across interaction episodes.

We emphasize three points based on this discussion. First, much of the flow model exists because we do not measure flows directly.[10] Hence we build theory that links the observable network of social relations to these latent flows. If the flows were directly measurable, we would not need to infer that nodes with more structural holes (or weak ties) would receive more information: we would simply measure the information they got.

Second, much of network flow theory depends on the relative permanence of ties. For example, consider a node that profits from being the broker between otherwise unconnected nodes. This works only if the spanned nodes cannot simply create a tie with each other at will. If a direct tie can always be formed, the importance of paths through a network vanishes, as does the importance of structure in general.

Third, when researching the exploitation of network position by nodes, it is problematic to measure relational *events* such as interactions and flows rather than relational states, because power use can change the event network. For example, if a node tries to extract rents for being between two others, the others may choose a different path (Ryall and Sorenson, 2007; Reagans and Zuckerman, 2008). So the event network we see is not the potential structure defined by underlying relations, but an actualized instance that could change at any time and therefore does not tell us what other paths might have been possible.

THE NETWORK ARCHITECTURE MODEL

As noted earlier, the network flow model is based on what we termed *true* flows of resources, which travel along network paths and are acquired by the nodes encountered along the way, either as capital or as a trait. However, not all network theorizing derives from this underlying model. Consider the image of an entrepreneur usually presented in social resource theory (Lin, 1982, 1999a, 1999b). To be successful, the entrepreneur needs help: rich friends can contribute capital, or experienced friends can convey key knowledge, but often no resources are actually transferred to ego. For example, a legislator can favor a developer by pushing through a bill that allows the developer to utilize previously off-limits land. A judge can decide a case for a friend's benefit. The benefits are real, but contrary to the network flow model, the legislator's and the judge's powers are not transferred to the developer. Rather, work is done on behalf of another, as described by principal/agent theory (Rees, 1985; Eisenhardt, 1989), and this constitutes a different mechanism for achievement.

A similar situation is seen in transactional knowledge theory (Hollingshead, 1998; Argote, 1999; Moreland, 1999), where organizations are seen as distributed knowledge systems in which different bits of the organization's knowledge store are held in different heads. While it is known who knows what, the knowledge can be utilized. However, the knowledge in a node's head may not be actually transferred when it is used. For example, a chemist is tapped to solve a problem involving stereo isomers. The chemist's knowledge of chemistry is not likely to be transferred to others on the project team who may not have a chemistry background. In fact, if the knowledge were transferable, the organization would cease to be a distributed knowledge system, and every member would be a prodigious polymath. Rather, the chemist works in concert with the team or its leader.[11]

These examples imply a mechanism of node success that is slightly different from the procurement of resources through network paths, as in the network flow model. Instead, it is a virtual procurement because instead of transferring their resources, an ego's alters act on behalf of or in concert with ego. Another way to think about this is that the alters act as an extension of ego, together forming a larger, more capable, entity. The nodes act as one, and this coordination not only harnesses the powers of all the nodes but also means that the individual nodes cannot be used against each other. This is the principle behind unions, co-ops, and other collectivities that prevent negotiation with each member individually. The key here is that ties are serving as bonds that bind the nodes together (whether through solidarity or authority), creating a common fate.

We argue that this mechanism is different enough from that of the network flow model to constitute a different model, which we term the *network architecture model*. In defining a separate model that does not include the term "flow," we do not imply that, in the architecture model, information does not flow. To coordinate actions, nodes may well communicate. However, two points should be kept in mind. First, communication is not the only way to achieve coordination (Thompson, 1967). Second, communication, even if plentiful, plays a role in the network architecture model that is different from its role in the network flow model. In the network flow model, it is the value of the flow itself that generates outcomes for the ego that receives it. A manager receives gossip about a failing project and takes steps to disassociate herself from it. In the architecture model, it is the alignment between nodes produced by the flow that yields the outcome.

The case of authority relations—bureaucracy's backbone—is instructive. The "reports to" ties serve as conduits for information flow (e.g., orders going down; reports going up), but this differs from the network flow model both because simply receiving an order is not enriching, and orders are not (usually) repeated down the line, as on a ship. Rather, the orders from A to B are different from those from B to C. Communication is involved, but the coordination, not the message, is the mechanism.

Finally, consider *network exchange theory*, which we regard as the analogue to SWT theory in providing a clear example of a distinctive kind of network theorizing. In the experimental exchange tradition of social network analysis (Cook et al., 1983; Markovsky et al., 1988), researchers have volunteers bargain with each other to distribute points between them, with the goal of amassing as many points as possible across a series of rounds. The participants are placed in a network designed by the experimenters and can negotiate only with people they have been given links to. In each round of the game, participants must divide 24 points with someone they have a tie to. Initially, they tend to make even trades of 12 and 12. Over time, however, those in certain network positions are able to command more favorable terms, such as 13–11, 14–10, and eventually, 23–1. For example, in Figure 4.6a, node X accumulates the most points.

Initially, centrality was thought to be the underlying principle (Cook et al., 1983). However, it was soon discovered that in the network shown in Figure 4.6b, the most central node had no power. Instead, the Zs had the power. The reason was simple: even though X has as many potential trading partners as the Zs, the Zs each have a partner (a Y) that is in a very weak position, whereas X

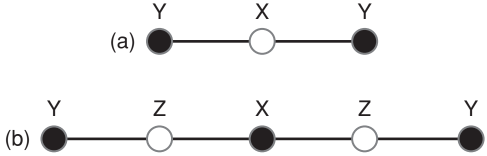

Figure 4.6 Two experimental exchange networks. Light-colored nodes have more power (Allen, Thomas J., *Managing the Flow of Technology*, figure, page 239, © 1977 Massachusetts Institute of Technology, by permission of The MIT Press)

has only powerful partners to trade with. Why are the Ys weak? Because whenever their Z makes a deal with someone else, the Y is excluded from that particular round. The Ys depend on the Zs because they lack alternatives. But it is not simply the number of alternatives that matters, because X has just as many alternatives as the Zs. Ultimately, a node's bargaining position is a consequence not only of its alternatives, but also the (lack of) alternatives of its alternatives, which in turn are determined by their own alternatives, virtually ad infinitum.

Note a number of interesting points about the exchange situation. First, while nodes interact and accumulate resources, resources (i.e., points) do not travel along paths of the network; the rules of the game prevent it. This is why centrality measures are useless in predicting outcomes of this experiment—centrality is a construct of the network flow model, and there are no flows here. But even without flows, paths do matter here. For example, adding a node linked to any of the Ys in Figure 4.6b would tend to change X's fortunes considerably. It is, if not a flow, a propagation effect in which being adjacent to a weak node makes a node strong, which in turn weakens others that the node is connected to, which strengthens still others and so on through the network (Bonacich, 1987). Perhaps a better term than *propagation* would be *autocorrelation*, meaning that a node's state is affected by the states of the nodes it is connected to, but not necessarily in the simple manner proposed by the network flow model, in which a node always comes to have the same thing its environment has.[12] Rather, it is more like adaptation, such that nodes react to their environments rather than acquire them.

Network exchange theory may be seen as a special case of network role theory (Borgatti and Everett, 1992b). If we examine a network such as shown in Figure 4.7, it is apparent that nodes *b*, *g*, *d*, and *i* are structurally similar to each other, even if they are not particularly close to each other. Indeed, suppose one were to remove the labels on all nodes in Figure 4.7, pick up the diagram, flip it

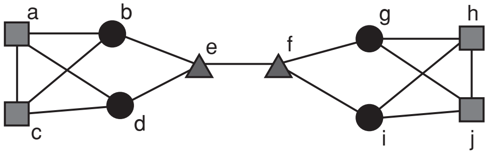

Figure 4.7 Shapes identify nodes that are structurally isomorphic

around on both its vertical and horizontal axes, and then put it back down on the page. Could one reassign the labels correctly? Clearly one could not mistake *b* for *e*, because *b* has a pair of friends (*a* and *c*) who are friends with each other, while none of *e*'s friends are friends with each other. We would also not confuse *b* for *a*, because among *a*'s friends, not one but two pairs are friends with each other. But we could not tell the difference between *b* and *d*, nor *g* and *i*. Similarly, *a*, *c*, *h*, and *j* are indistinguishable from each other, as are *e* and *f;* within each of these sets, the nodes are structurally isomorphic.

In a sense, the network in Figure 4.7 has an underlying structure in which the 10 different nodes reduce to just three classes of nodes that share certain characteristic relations with each other. The pattern of relations among classes is shown in Figure 4.8, which presents a reduced model (a *blockmodel* in the language of White et al., 1976) of the network in Figure 4.7. The pattern is that square nodes (the class containing *a*, *c*, *h*, *j*) have ties to both circle nodes and other square nodes; triangle nodes have ties with themselves and with circle nodes; circle nodes connect square nodes to triangle nodes and have no ties among themselves.

In effect, the three classes of nodes play three different structural roles and have three different social environments, and these differences imply different consequences for the nodes occupying those positions. Indeed, returning to experimental exchange networks, Borgatti and Everett (1992a) showed that all experimental results to date confirm that nodes playing the same structural roles obtain the same results, within bounds of statistical variation.

In discussing the flow and architecture models, it is tempting to argue that they rest on two different metaphorical understandings of ties. In the flow model, ties are pipes (or roads, or circuits) through which things flow (the traffic, the current). In the architecture model, the ties are bonds, ligatures, girders, or bones that bind the network together, creating a structure (like a skeleton) around which the rest of the social system is draped. The bonds serve as the elemental units of structure.

This pipes-and-bonds distinction is not unhelpful, but it is also not quite right. As we have tried to point out, both models typically involve flows of some kind at the dyadic level. It is the style and function of these flows that is different.

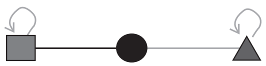

Figure 4.8 Blockmodel of network in Figure 4.7

GOALS OF NETWORK THEORY

For simplicity of exposition, our discussion of the network flow and architecture models has focused on explaining differences in node (or group) success with respect to performance or rewards. This value-loaded focus is drawn from the *social capital* research tradition, which investigates the benefits of (or aspects of) network position for individuals and groups.

However, social capital is not the only theoretical perspective in the field. The *social homogeneity* perspective seeks network-theoretic explanations for why some nodes share traits with certain others, particularly with respect to behaviors (such as adoption of innovation), beliefs, and attitudes (Borgatti and Foster, 2003).[13]

The network flow model and the architecture model are used in both social capital and social homogeneity studies, providing competing explanations for the same outcomes. Figure 4.9, drawn from Borgatti and Foster (2003), summarizes this discussion as a simple 2-by-2 cross-classification. The rows correspond to the fundamental models and therefore basic explanatory modes. The columns correspond to research traditions, based on their generic goals of explaining variance in performance or similarity of traits. The cells of the table identify specific mechanisms used in each context. We regard these elemental mechanisms as part of the vocabulary of social network theory. We discuss each quadrant in turn.[14]

Underlying model	Social capital	Social homogeneity
Network flow model	Capitalization	Contagion
Network architecture model	Coordination	Adaptation

Figure 4.9 Network functions (mechanisms) by model and research tradition

The top-left quadrant, which uses the network flow model to understand success, is one of the most developed, particularly in organizational research. The key concept is *capitalization*, meaning that nodes acquire ideas, resources, and opportunities through their ties, and this process either directly increases their human capital or increases their ability to exploit their human capital, which in turn contributes to their success in terms of performance and rewards. The capitalization process is evident in work on social support (e.g., Wellman and Wortley, 1990), status attainment (Lin, 1999a), job search information and job-getting (Granovetter, 1973, 1974), knowledge (Borgatti and Cross, 2003; Bouty, 2000), creativity (Perry-Smith and Shalley, 2003; Burt, 2004), mobility (Boxman et al., 1991; Burt, 1997; Seibert et al., 2001), power (Brass, 1984; Kilduff and Krackhardt, 1994), leadership (Brass and Krackhardt, 1999; Pastor et al., 2002), performance (Baldwin et al., 1997; Mehra et al., 2001), and entrepreneurship (Renzulli et al., 2000).[15] The capitalization mechanism can also be seen in group-level research, such as in the work of Bavelas (1950) and Leavitt (1951), showing that communication networks with short distances from each node to a central node (an "information integrator") were better able to solve puzzles involving pooling of information.

The bottom-left quadrant, labeled *coordination*, uses the architectural model to provide an alternative set of explanations for node (or group) success. In this model, networks provide benefits because they can coordinate or "virtually agglomerate" multiple nodes in order to bring all their resources to bear in a coordinated fashion (and avoid being divided and conquered). Different network structures, in combination with contextual rules of the game, create different dependencies and possibilities for coordination (Markovsky et al., 1988; Cook et al., 1983). Work based on these mechanisms includes Burt's (1992) work on the control benefits of structural holes, research on "network organizations" (Miles and Snow, 1986; Powell, 1990; Snow et al., 1992; Jones et al., 1997), research on compliance with norms (Roethlisberger and Dickson, 1939; Mayhew, 1980; Kiuru et al., 2009), and work on the in- and out-groups of leaders (Sparrowe and Liden, 1997). Other work in this tradition is the literature on transactional memory systems (Hollingshead, 1998; Moreland, 1999; Rulke and Galaskiewicz, 2000), in which an individual or group benefits from the knowledge of others without necessarily acquiring that knowledge themselves. At the group level, we have already mentioned Granovetter's (1973) account of communities' differential ability to fight off incorporation by a neighboring city, thanks to having a network structure that facilitated community-wide collaboration.

The top-right quadrant, *contagion*, is the basis for most diffusion research. The basic idea is that nodes essentially become their environments through a process of contamination/infection/staining[16] so that one's location in a network has much to do with one's acquired traits. Both the coordination quadrant and the capitalization mechanisms are about processes in which nodes acquire something flowing through network paths. The difference is that in one case the nodes acquire capital, while in the other they acquire traits.

Network research based on the contagion mechanism includes Coleman, Katz, and Menzel's (1966) classic study, which argued that informal discussions among physicians created behavioral contagion with respect to adopting tetracycline, as well as the study by Davis (1991) arguing that the now-standard corporate practice of "poison pills" spread through corporate board interlocks. The contagion mechanism has been used to explain similarity in job decisions (Kilduff, 1990), the adoption of organizational structures and strategies (DiMaggio and Powell, 1983; Geletkanycz and Hambrick, 1997), disease and immunity outcomes (Morris, 1993; Cohen et al., 1997), decisions to smoke (Christakis and Fowler, 2008), similarity of attitudes and beliefs (Harrison and Carroll, 2002; Sanders and Hoekstra, 1998; Molina, 1995), and the production of consensus through social influence (Friedkin and Johnsen, 1999).

It should be noted that each of these general processes, such as contagion, can be broken down further into micro-mechanisms at the dyadic level. For example, DiMaggio and Powell (1983) discussed *mimetic processes*, in which a firm actively imitates another firm in its environment, and *coercive processes*, where a trait is imposed on a firm, as when a large customer imposes a certain accounting system on a supplier. Within each of these micro-mechanisms we can continue to add detail, such as noting that the likelihood of mimetic processes increases with uncertainty and the need for legitimacy (DiMaggio and Powell, 1983; Galaskiewicz and Wasserman, 1989; Haunschild and Miner, 1997). However, this kind of theorizing belongs to the interface layer discussed earlier and is outside the scope of this chapter.

Finally, the bottom-right quadrant, *adaptation*, uses the architecture model to provide an alternative to network flows for explaining homogeneity. Instead of a node acquiring what is flowing through the network, as in contagion, the node responds or adapts to a set of environmental dependencies. Social homogeneity is explained by the architecture model as *convergent evolution*, similar to the evolutionary process that results in sharks and dolphins having similar shapes. For example, two nodes that are both central in the advice networks of their respective firms may come to have a similar distaste for the phone, because it so often brings more work. Similarly, in structural role theory, nodes are seen as similar if they have ties to similar others, which is to say they have similar environments.

The adaptation mechanism has been used to explain similarity in attitudes (Erickson, 1988), organizational behaviors (Galaskiewicz and Burt, 1991; Haunschild and Miner, 1997; Galaskiewicz and Wasserman, 1989), and organizational isomorphism (DiMaggio, 1986).

DISCUSSION

A frequent confusion about network research has to do with where theory ends and methodology begins. Network analysis is exemplary in the social sciences in basing its theorizing on a fundamental construct—the network—that is both emically meaningful and fully mathematical. Fitted with some fundamental processes, such as flows of resources through paths, the network model is extremely fertile in that it so easily generates distinctive research questions—such as, how does it affect a node to be along the only path between two sets of others?

Furthermore, the "mathematicity" of the network construct means that such research questions are almost automatically expressible in terms of mathematical properties of the network (such as betweenness), and usually are. This makes research questions in the network field highly amenable to empirical, mathematical, and simulation-based exploration. But it also generates an image problem because the same formula that defines the theoretical network property of, say, betweenness, also enables us to measure it in an empirical dataset. Therefore, it appears to be "just" methodology. Yet concepts like centrality are not only theoretical constructs, they embody a basic model of how social systems work.

Confusion also exists regarding what a network is. In our view, at least two fundamental conceptualizations define networks: *nominalist* and *realist* conceptualizations, echoing a well-known distinction by Laumann, Marsden, and Prensky (1989) with regard to data collection. The concept of networks implicit in this chapter and in most academic research has been the nominalist view, which sees networks principally as models rather than things "out there." For a nominalist, a network is defined by choosing a tie, such as friendship, to examine among a set of nodes. So when a nominalist speaks of *multiple networks*, the nominalist is considering different kinds of ties simultaneously, such as a friendship network together with an advice network, both defined on the same set of nodes. For a nominalist, networks can be disconnected, and indeed the degree of connectedness is just another property of networks that can be theorized about.

In contrast, in the realist perspective (which is often found in applied work), networks are defined as a set of interconnected nodes, which by definition cannot be disconnected. A realist considers multiple networks to mean multiple groups. Indeed, the realist conception of a network tends to be a replacement for or variant of the concept of sociological group. This is especially evident in popular culture, where public entities that would once have been named the "Preservation Society" or "Lexington Trade Association" would today be called the "Preservation Network" and "Lexington Trade Network." Similarly, we speak of terrorist networks rather than terrorist organizations, and medical insurance companies identify doctors as either in- or out-of-network.

In academic work in the realist tradition, *network* typically connotes a group that has more lateral than vertical ties, relies on social or informal ties to achieve coordination, and consists of relatively empowered or autonomous members, whether they are employees in a firm or organizations in a so-called network organization.

A consequence of having these different views is confusion about meaningful research questions. For example, although we have not discussed theories of networks, a reasonable research question for a realist is, "What conditions will cause a network to emerge?" For the nominalist, this question is awkward because networks arise when you define them, even if they are empty of ties. It is not the network that emerges, but rather ties (or, more usefully, it is that properties of the network structure change over time). Similarly, a meaningful methodological question for a realist is, "What are the best relations to ask about in a survey to tap into the network?" For a nominalist, each question corresponds to a different network, and which question is asked depends on the research question. But for the realist, an underlying reality can be detected by well-chosen questions, much like a psychometric scale. Confusion also lies in the concept of a node "belonging to multiple networks." For a realist, this really means that the node belongs to multiple groups. For a nominalist, it is an odd concept—at best it could mean that the node is not an isolate in several different networks defined by different social relations.

A final confusion has to do with the multiple levels of analysis possible in network research and how this relates to traditional micro/macro distinctions. At the lowest level is the dyad. Research at this level is concerned with whether one kind of tie influences another. For example, in economic sociology, a fundamental proposition is that economic transactions are embedded in social relationships (Granovetter, 1985). In knowledge management, Borgatti and Cross (2003) suggested that in order for X to seek information from Y, certain relational conditions must be present.

At the next level is the node. This is the level that receives the most attention in the literature, and it is readily accessible to researchers outside the network tradition. Most of the work reviewed in this chapter is at the node level, such as when the number of structural holes a node possesses is related to the node's performance.

The highest level is the network as a whole.[17] Theorizing at this level is concerned with the consequences for the network of properties of the network's *internal structure*. For example, Johnson, Boster, and Palinkas (2003) argued that work teams with core/periphery structures would have higher morale than teams divided into potentially warring factions. Thus, a property of network structure, core/peripheriness, is related to a network outcome—morale. The network level of analysis should not be confused with whether the nodes themselves consist of collectivities. For example, suppose our nodes are firms, and we theorize that more central firms in an inter-firm alliance network are more profitable. This is a node-level analysis, not a network-level analysis. In contrast, if we theorize that the shape of the alliance network in an industry affects the profitability of the industry as a whole (and we compare across several industries), this is a network-level analysis. Similarly, a study of how the network structure of top management teams affects their performance is also a network-level study.

CONCLUSION

In this chapter, we have sought to explain network theory, and to do so in a way that would facilitate generating new theory. Our approach has been to analyze a few representative network theories and extract from them generic mechanisms or modes of explanation. In so doing, we found it convenient to deconstruct network theories into "layers," where the deepest layer consists of a general model of how things work. This is a model of a system, not of any particular outcome. On top of that are the theorems or propositions that we can derive from the underlying model. The final layer is the interface layer, which connects the network constructs to the concepts of specific research domains.

We argue that two underlying models are in evidence in network theorizing, which we refer to as the network flow model and the network architecture model. The flow model views a social system as a system of nodes interconnected by paths (the backcloth), which carry information or other resources (the traffic). Theories based on the flow model define properties of the backcloth structure and relate these to flow outcomes, such as frequency and time of arrival of something flowing through the network, which are then related to more general outcomes such as status attainment. The architecture model sees network ties as creating structures of interdependency and coordination. Theories based on this model explain how the pattern of interconnections interacts with contextual rules to generate outcomes such as power.

Drawing on Borgatti and Foster (2003), we note that network theorizing can be seen as answering two basic types of research questions, namely why some nodes or groups achieve more (the social capital tradition), and why some nodes or networks are more similar to each other (the social homogeneity tradition). Combining this distinction based on types of outcomes with the distinction between the two explanatory models yields a four-cell cross-classification in which each cell corresponds to a different generic mechanism for explaining outcomes (Figure 4.9): the capitalization mechanism is used to explain success as a function of receiving useful flows through the network; the coordination mechanism explains success via virtually merging with others and preventing adversaries from coordinating with each other; the contagion mechanism explains observed similarity as a function of direct influence or diffusion; and the adaptation mechanism explains similarity as resulting from adaptation to similar social environments.

Our objective has been to analyze network theory into theoretical building blocks that make it easier to create new theory as needed. We hope this will help stem the flow of "cookie-cutter" studies that copy the variables of classic studies but miss the logic of how network properties generate outcomes.

NOTES

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1 In this terminology, a theory of endogenous network evolution, in which both independent and dependent variables are network properties, would be called a network theory of networks. A psychological theory of tie formation (e.g., homophily) would be labeled a theory of networks, but not a network theory of networks.

2 While Granovetter (1973: 1361) provides a definition of strength of tie, it is useful to realize that any definition of tie strength that preserves the first premise can be used (Freeman, 1979).

3 More technically, a bridge is a tie between A and B, which, if removed, would leave a very long path (if any at all) connecting A to B. A bridge is a shortcut.

4 The second premise was "in the air" when Granovetter was writing. Rapoport and Horvath (1961), in particular, explored this concept in depth.

5 Note that there is no claim that all weak ties are sources of novel information—just the ones that happen to be bridges. Granovetter's point is simply that it is weak ties rather than strong ties that are more likely to be bridges.

6 Original paper written in 1958 and well circulated for 20 years before publication in 1978 in the inaugural issue of *Social Networks.*

7 Similarly, a well-connected node has many opportunities to expose others to what it carries, whether an idea or a disease.

8 Indeed, Borgatti (2005) showed that the well-known formulas for closeness and betweenness centrality give the expected values of key network outcomes (such as frequency and time of arrival) under specific models of flow. They are not generic measures or techniques such as regression, which can be divorced from an underlying model of how things work. Rather, they are rooted in specific network theories of how social systems work.

9 It is useful to note that the two categories on the left make up relational phenomena that, while they exist, exist continuously, like states. The phenomena on the right tend to be transitory and discrete, as in events.

10 This is largely for convenience. For example, it is time-consuming and therefore rare to track a specific bit of information as it moves through a gossip network. However, some settings lend themselves to observing flows, as in the movement of goods in the world economic trade network.

11 However, this is not to imply particular motives such as wanting to help, or being coerced into helping. Space limitations in this chapter prevent us from discussing the micro-theory of these exchanges.

12 We don't use the term "autocorrelation" because it refers to a statistical condition rather than a social process.

13 As Borgatti and Foster (2003) pointed out, modeling variance in outcome and homogeneity in attributes are logically two sides of the same coin but seem to constitute different literatures in the field.

14 This terminology varies slightly from Borgatti et al.'s (2009) and Marin and Wellman's in this volume. What was *transmission* in Borgatti et al. has been subdivided into *capitalization* and *contagion* here. *Binding* and *exclusion* in Borgatti et al. have been combined as *coordination* here. The mechanism of adaptation is the same in both.

15 At the empirical level, much of this work is ego-centered, and therefore might seem to ignore the network path structure that is at the heart of the network flow model. However, in much of this work, the theoretical rationale is built on whole network processes, as in the case of weak tie theory and structural hole theory.

16 We do not intend to imply that what is adopted is "bad." Any attitude, behavior, or belief can be diffused, whether it is positive, negative, or indifferent.

17 To simplify exposition, we have omitted the intermediary level of the subgroup, which shares qualities with both the node and whole network levels.

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