

Dynamics of Dyads in Social Networks: Assortative, Relational, and Proximity Mechanisms

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Abstract

Embeddedness in social networks is increasingly seen as a root cause of human achievement, social stratification, and actor behavior. In this article, we review sociological research that examines the processes through which dyadic ties form, persist, and dissolve. Three sociological mechanisms are overviewed: assortative mechanisms that draw attention to the role of actors' attributes, relational mechanisms that emphasize the influence of existing relationships and network positions, and proximity mechanisms that focus on the social organization of interaction.

INTRODUCTION

If research activity and impact are indicators of scientific value, the capital of social network research has risen rapidly. Taking a census of all papers published in the top two sociology journals as defined by ISI's journal impact factor, the *American Journal of Sociology* (AJS) and the *American Sociological Review* (ASR), there has been a 20-year increase in the share of papers that list "networks" as a keyword. In 1980, 1990, 2000, and 2005, the share of papers on networks was 1.2%, 2.2%, 7.8%, and 11.6%. Further, **Figure 1** shows the increasing citation impact of network papers. The ranking of the 15 most cited papers in AJS and ASR by citations per year indicates that 10 out of 30 are network papers. Network papers account for 5 of the top 20 papers published in the *Administrative Science Quarterly* (ASQ) (**Figure 1** inset). In physics and communications, network research has achieved similar prominence (Monge & Contractor 2003; Barabási 2008, 2009; Newman 2008).

One impetus behind this explosion of work is the increasing number of stratification variables across persons, firms, and institutions that are now understood to be influenced by networks. Disciplines that once focused on individual attributes to explain behavior now see embeddedness in networks as a determinant of job attainment and advancement, creativity, obesity, mortality, neighborhood cohesion, political mobilization, state formation, markets, prices, digital ties, and the competitiveness of firms and states (Granovetter 2005). As this emergent body of research establishes the importance of networks as determinants of actors' behavior and outcomes, understanding the antecedents of social networks has become an increasingly important area of inquiry. Conceptualizations of networks as static substrata of social interaction are giving way to an image of networks as continuously evolving over time. In creating, maintaining, and dissolving social ties, people, groups, and organizations are continuously altering their networks and the networks of those around them.

This review examines journal articles that explain how social networks evolve over time. As an orienting principle, we cover research that examines network change at the level of the network dyad. We focus on research that explicates the existence, creation, persistence, and dissolution of social relationships among social actors and the implications that these processes have on the evolution of networks over time. For readers less acquainted with network research, we begin with a brief clarification of terminology (see also Wasserman & Faust 1992). A social network can be said to exist wherever distinct social actors (also called nodes) are connected by more or less persistent ties (or relationships). Both actors and ties can be represented by a variety of different constructs and can consequently span levels of analysis ranging from friendships among individuals to interorganizational ties between firms to commercial trade between states. Ties connecting actors can be valued, indicating stronger or weaker connections (such as friendships and best friendships), or binary, simply indicating the presence or absence of a tie. Ties can also be directed (one person chooses another as a friend, who may or may not choose him back) or undirected. Moreover, actors can simultaneously be connected by several different relations. Schoolchildren can be connected by relations of friendship, trust, or animosity, each of which may inform different aspects of a student's social world. In practice, most research within the social sciences—and by extension most of the research in this review—has focused on single-relation, binary networks.

A TYPOLOGY OF MECHANISMS OF CHANGE IN SOCIAL NETWORKS

We identify three perspectives on network change—each deriving its origins from a unique sociological lineage: (a) assortative perspectives that emphasize compatibilities and complementarities between actors' attributes; (b) relational perspectives that draw on the structuralist assumption that trust, information, and

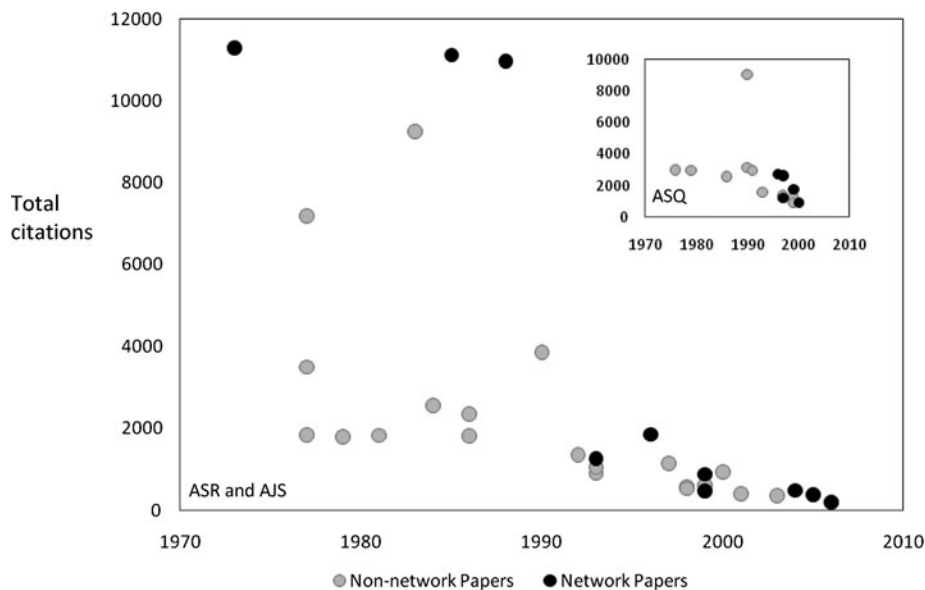


Figure 1

The increasing role of network papers in sociology journals, 1970–present. Note: The plot shows the fifteenth most highly cited papers according to the number of citations gained per year in the *American Journal of Sociology* and *American Sociological Review* (*Administrative Science Quarterly*, inset) from 1970 to the present (source: <http://www.harzing.com>). The papers in ranked order are **Coleman (1988, 522/yr)**, **Granovetter (1985, 464/yr)**, DiMaggio & Powell (1983, 356/yr), **Granovetter (1973, 314/yr)**, Meyer & Rowan (1977, 225/yr), Massey (1990, 204/yr), **Uzzi (1996, 143/yr)**, Hannan & Freeman (1977, 110/yr), Inglehart & Baker (2000, 104/yr), Hannan & Freeman (1984, 102/yr), Swidler (1986, 102/yr), Burt (2004, 97/yr), Meyer et al. (1997, 96/yr), **Powell et al. (2005, 94/yr)**, **Gulati & Gargiulo (1999, 88/yr)**, Sewell (1992, 80/yr), **Portes & Sensenbrenner (1993, 79/yr)**, Snow et al. (1986, 79/yr), Williamson (1981, 66/yr), Pickering (1993, 66/yr), **McPherson et al. (2006, 63/yr)**, Sampson et al. (1999, 62/yr), Cohen & Felson (1979, 60/yr), McCarthy & Zald (1977, 58/yr), Orloff (1993, 56/yr), Barro & McCleary (2003, 59/yr), Korpi & Palme (1998, 52/yr), Budig & England (2001, 51/yr), Duncun et al. (1998, 49/yr), and **Uzzi (1999, 47/yr)**. The papers in ranked order for ASQ are Cohen & Levinthal (1990, 476/yr), **Uzzi (1997, 221/yr)**, **Powell et al. (1996, 209/yr)**, **Hansen (1999, 178/yr)**, Henderson & Clark (1990, 166/yr), Williamson (1991, 166/yr), Abrahamson & Fairchild (1999, 127/yr), Brown & Eisenhardt (1997, 119/yr), Tushman & Anderson (1986, 113/yr), **Ahuja (2000, 106/yr)**, **Burt (1997, 104/yr)**, Weick & Roberts (1993, 100/yr), Karasek (1979, 99/yr), Edmondson (1999, 95/yr), and Weick (1976, 91/yr). Papers coded as network papers are in **bold**.

introductions are conferred through actors' positions in existing social networks; and (c) proximity perspectives that focus on the organization of social interaction in time and space. This rubric places mechanisms into buckets that are categorically distinct yet intimately interwoven in the evolution of real social networks. For example, people may preferentially create social networks that correspond to their political beliefs but also position themselves into associations and contexts that are populated with people who have similar

political preferences (Huckfeldt & Sprague 1987). Independently, each perspective has revealed empirical regularities that often generalize across contexts, actors, and ties, giving rise to interesting self-similar patterns across interpersonal, interfirm, and even interstate research. However, owing to different theoretical foundations and explanatory variables, research in each stream has tended to occur in isolation. We articulate and review progress in each area, but we also point future research toward a more robust integration.

ASSORTATIVE MECHANISMS

Assortative mechanisms speculate that the creation, persistence, and dissolution of social relationships are all outcomes that rely on the compatibility and complementarity of actors' attributes. Thus, assortative hypotheses are generally pair-level associations between actors' similarities or dissimilarities and their consequent propensity to form connections. Lazarsfeld & Merton's (1954) analysis of friendship selection among adults coined the term homophily to refer to "a tendency for friendships to form between those who are alike in some designated respect" (p. 23) and gave birth to a rich tradition of research that has investigated the tendency toward assortativity in a variety of social contexts and relations. A more recent trend has begun to note that outright similarity in actors' attributes may not characterize social connections and that in some instances actors may seek a balance between similarity on some dimensions and differentiation, or heterophily, on others. Recent studies have also extended the assortative perspective to explain the evolution of ties between firms as well as between individuals. In each instance, the driver of network change is thought to be an interaction of actors' attributes that collectively compels them to create, maintain, or dissolve relationships.

Dynamics of Homophily

In a landmark review of more than 100 sociological studies, McPherson et al. (2001) found that people display a strong tendency toward homophily—the greater the similarity between two individuals the more likely they are to establish a connection. Homophily's potency as a social mechanism lies in its apparent universality. Similarities in the human attributes of potential alters, such as age, gender, religion, ethnicity, values, intelligence, and education, appear to characterize the formation and dissolution of connections as varied as online chats, best friendships, and marriage.

Homophily appears to strongly affect attachment because people expect a priori that

self-similar alters are more likely to accept them (Ely 1995, Ibarra 1995), to be trustworthy (Allen & Wilder 1979, Lincoln & Miller 1979), and to hold beliefs that affirm their own (Byrne & Wong 1962, Stein et al. 1965, Rokeach & Mezei 1966, Stein 1966, Allen & Wilder 1979), thereby mitigating the potential conflicts, misunderstandings, and monitoring costs that come with making connections. As a result, these benefits appear to increase with the strength of the relationship. Thus, homophily more strongly affects attachment in intimate relations (Burgess & Wallin 1943, Blackwell & Lichter 2004, Qian & Lichter 2007) and close friendships than in casual ties. For example, Van Duijn et al. (2003) found that gender homophily was positively associated with the formation of "real friends" but not "friendly" or "neutral" relations. Similarly, Leenders (1997, p. 149) concluded that gender homophily was "profoundly predominant in 'best friend' networks, but loses much of [its] importance when 'friends' are also considered."

Although innumerable attributes may impart a homophily bias, it is a rare attribute that has the strongest influence on attachment. Mehra et al. (1998, p. 443) asked 159 MBA students to identify other students they "considered especially similar to themselves" or "considered to be personal friends." Controlling for the baseline availability of similar others, minorities ($t = -2.03$, $df = 19.5$, $p < 0.05$) and women ($t = 3.82$, $df = 157$, $p < 0.001$) identified more strongly with homophilous others than did members of the majority categories (whites and men) and were also more likely to name self-similar others as personal friends. Mehra et al. reason that rare attributes are more likely to be salient to individuals and consequently central to their self-identity: "[T]wo African Americans in a crowd of whites will tend to notice and identify with each other because of their common race; however, when in a group of other African Americans, the same two people are unlikely to notice or identify with each other" (Mehra et al. 1998, p. 442). In this way, rare attributes strongly impact attachment.

If people are more likely to create social ties with self-similar others, there is also evidence that they are more likely to maintain homophilous relationships than they are to maintain heterophilous ones. Lazarsfeld & Merton's (1954) work on homophily posited that heterophilous relationships would be more likely to break apart as differences in opinions and beliefs led to interpersonal conflict. One area where this hypothesis has been tested is in research on the dissolution of romantic relationships. Felmlee et al. (1990) found that the hazard rate for detachment of interracial romantic relationships was more than three times higher than that exhibited by racially homophilous couples (antilog coef = 3.06, $p < 0.10$), and several studies within family relations have noted a higher divorce rate among racially heterophilous individuals (Heaton 2002, Bratter & King 2008). In the context of friendships, tendencies toward homophily may similarly be reflected in the dissolution of heterophilous ties—Mollica et al. (2003) examined the friendship network of graduate students and found that homophilous friendships were significantly more likely to persist more than three and a half months than were heterophilous ones (see also Hallinan & Williams 1987). Here again, the relative rarity of the attribute moderated the effect of homophily: more than 95% of Hispanic-Hispanic ties persisted, compared with 65% for white-white (the majority race in that school) ties.

Importantly, homophily shapes attachment even in contexts where diversity is explicitly valued and encouraged. In the friendship network of 114 newly admitted MBA students in a large U.S. university, Mollica et al. (2003) found that six weeks into a two-year program students had a high degree of racial homophily in their personal friendship networks—a bias that persisted more than 14 weeks despite the promotion of diversity by school administrators and the assignment of students into heterogeneous classes and teams. Ingram & Morris (2007) used electronic global positioning devices to monitor the relationships during an MBA mixer, which was aimed at helping MBA students form new

ties with students with different characteristics and backgrounds. In spite of attendees' declarations of wanting to meet new and different people, they found that students were more likely to engage with a group of people in which at least one other person in the group was of the same race or of the same approximate physical attractiveness. Similarly, Ruef et al. (2003) found that the composition of new business start-ups is driven by similarity in gender, ethnicity, and occupation rather than by functional diversification.

The role of digitally mediated relationships is an important new area of research on assortativity, homophily, and network building. These relationships form or are maintained through instant messaging, blogs, online-community membership, or email, rather than face-to-face contact, which can potentially mask visible characteristics of potential contacts (Adamic & Adar 2003, Eagle et al. 2007). One recent study, impressive for its ability to record the empirical patterns of vast numbers of people on a planetary scale, was conducted by Leskovec & Horvitz (2007). They examined the global communication network of Microsoft Messenger instant-message communications and found that, among 30 billion online conversations between approximately 240 million individuals, people tended to communicate more with others with similar ages, languages, and locations. A study on the determinants of messaging on an online dating Web site found that similarity in daters' physical attractiveness, smoking habits, education level, religion, and race all predicted the frequency of attempts to initiate a romantic relationship (Fiore & Donath 2005).

Digitally mediated contexts of social interaction such as Web sites and online communities may also impart a homophily bias in people's social choices by selectively exposing people to self-similar others. Participation in online communities requires regular access to a personal computer—a prerequisite that biases communities toward higher-income strata. Differences in the demographic makeup of online communities may similarly affect the availability of

contacts in different groups. Hargittai (2007) found that Hispanic students were significantly less likely to use the online networking site Facebook and much more likely to use MySpace, whereas the opposite was true for white and Asian students. This suggests that online networking sites might further contribute to homophily by organizing persons into groups of self-similar individuals. Surprisingly, in cyberspace, where individuals have a greater sense of anonymity, homophily appears to shape social connections.

Dynamics of Heterophily

Although persons appear to form ties according to the homophily principle, it is also self-evident that diverse network relationships exist: “[t]he simple facts of the matter are that when society confronts difficult problems—putting people on the moon, curing diseases, designing new products, crafting changes in the tax code—we create teams of diverse people” (Page 2007, p. 322). In some cases, diversity might be mandated—boards of directors of large companies must represent dissimilar functional specializations (e.g., law, science, or nonprofit) or connections to diverse financial or political resources (Westphal & Milton 2000, Mizruchi 2004). However, heterophilous ties are also formed voluntarily. Research on collaboration networks is one area that explores the increasing role of heterophily. Collaboration networks are ubiquitous and occur whenever people work together in teams—directors on a board, actors on a cast, writers on a movie, and so forth. In this work, the diversity of social ties can be inferred from coauthorship on the same articles (Newman 2001d, Moody 2004, Guimera et al. 2005, Wuchty et al. 2007, Jones et al. 2008), codirectorships on the same board (Davis et al. 2003, Westphal & Stern 2007), coperformance in the same artistic production (Watts 1999, Uzzi & Spiro 2005, Uzzi 2008), and so on.

Research on teams in which dyads are nested within larger group structures suggests that people are likely to collaborate with others who possess qualities, skills, and know-how that

are complementary to their own and relevant to solving a particular problem or objective. With regard to teams in science, Moody (2004, p. 217) remarked, “in high-growth, fast changing specialties, we would expect to see more coauthorship because it is easier to bring in a new author than it is to learn new material oneself.” Indeed, Moody (2004) found that researchers who publish quantitative work, which requires specialization in theory and methodology, are more than five times more likely to have coauthored a paper than someone who has not published quantitative work. Examining the formation of task-related ties—asking for assistance or support from a colleague—in three different organizations, Casciaro & Lobo (2008) found that a key fact of organizational life is that people seek out others whom they believe to have valuable and complementary task-related skills. Page (2007) found that in science the trend toward heterophilous ties has been increasing over time. He reported that the first ten Nobel Prizes in Physics were shared by 14 individuals, whereas the last ten have been shared by 27, a twofold increase in collaboration. This pattern has also been found in chemistry and sociology (Moody 2004) and in pre-publication teams that form to submit grants (Cummings & Kiesler 2005). In collaborations of creative and economic production, connections can be valuable or sought after precisely because they connect people with different and complementarity attributes, qualities, and capabilities (Lin et al. 1981, Lin 1999).

Alliance research—in which actors are organizations and ties are formal or informal collaborative arrangements between firms—has perhaps examined the role of heterophily in network formation most fully. It has become conventional wisdom that network ties are formed with dissimilar rather than similar collaborators. Powell et al. (2005) examined the determinants of attachment among universities, venture capital firms, public research organizations, and large pharmaceutical firms during the first ten years of the biotechnology field. They note that in this field “[n]o single organization [had] been able to internally

master and control all the competencies required to develop a new medicine,” which may have led organizations to form collaborative relationships with firms that were distinct from them in activity specialization. Research on investment banks’ tie formation (Eccles & Crane 1988; Podolny 1993, 1994) has found that diversity is actively pursued. Chung et al. (2000) concluded that banks preferentially attached to other banks that (a) specialized in selling stock to different types of investors than themselves, (b) were located in different geographic areas, and (c) specialized in stock offerings of companies in different industries. Similar preferences for heterophilous partners in interorganizational relations have been found for industry niche (Gulati 1995, Chung et al. 2000), strategic grouping (Nohria & Garcia-pont 1991), venture syndicates (Sorenson & Stuart 2008), and organizational size (Shipilov et al. 2006). Compared with interpersonal ties, interorganizational links may be more prone to heterophily because the trust orientation of homophily between individuals may be functionally substituted by contracts between organizations, and the desire for expressive benefits found in interpersonal networks may be absent in firm-to-firm relationships (Granovetter 1985). One study of task-related ties found that organizational members seek out contacts they believe to have complementary and relevant skills, but only if they perceive those people as being enjoyable to work with (Casciaro & Lobo 2008).

One indication of the instrumental nature of heterogeneous relationships is that collaborative ties between actors with complementary attributes are often short term and oriented toward the completion of a project or goal. “Connections are often forged with a specific goal in mind, such as taking a company public or selling and distributing a new medicine. Once the task is completed, the relationship is ended and successful collaborators depart gracefully” (Powell et al. 2005, p. 1138).

The increasing dominance of diverse teams and repeated heterophilous ties suggest that more research may be needed on what Blau (1974) called multiform heterogeneity.

Multiform heterogeneity means that network ties may be between individuals who are simultaneously similar and different, sharing similarities on some dimensions and differences on others. It may ultimately be an oversimplification to refer to a relationship as homophilous or heterophilous, as few individuals do not differ in at least some dimensions and match in at least a few others (Blau 1974, p. 622). An important question is whether attachment is encouraged by homogeneity across numerous dimensions (McPherson & Ranger-Moore 1991) or by a balance between similarity on some, such as race and gender, but differences on others, such as skill, knowledge, or connections. At least some early research supports the latter position. Casciaro & Lobo’s (2008) field research suggests that people preferentially collaborate with others who have complementary specializations but similar demographic traits that facilitate communication and trust. Organizations, too, appear to seek a balance between similarity on some dimensions, such as status (Podolny 1993), and dissimilarity on others, such as industry niche (Gulati 1995, Chung et al. 2000), strategic grouping (Nohria & Garcia-Pont 1991), geographic location (Gulati & Gargiulo 1999, Chung et al. 2000), size (Shipilov et al. 2006), or embedded versus arm’s-length ties (Lazerson 1995; Uzzi 1996, 1997). Future research that evaluates the choices and balance of homophily and heterophily is needed to understand the conditions under which one process or the other dominates and the balance that is struck in different social settings.

RELATIONAL MECHANISMS

Drawing on a different theoretical heritage, a second perspective places importance on direct and indirect connections linking individuals. This perspective is sometimes referred to as a “within-the-network” approach, as the focal predictor of network change is hypothesized to be the shape and structure of the network in a prior time period (Stuart & Sorenson 2007, p. 220). Arising out of Simmel’s notion of the triad, the classic relational hypothesis is of

network closure—the proposition that actors separated by one intermediary are the most likely to become connected in subsequent time periods (Simmel 1908 [1950], Davis et al. 1971). Recent work has expanded relational perspectives to emphasize the role of prior direct ties (Baker 1990, Gulati 1995, Guimera et al. 2005), indirect connections through numerous third parties (Newman 2001a, Kossinets & Watts 2006), and prior network degree centrality (Newman 2002, Uzzi 2008). Each mechanism originates from the structuralist assumption that the selection of relationships, the maintenance of existing ones, and the dissolution of old ones are conditioned by trust, information, and opportunities for interaction that are structured by the network.

Dynamics of Reciprocity

In cases in which ties are meaningfully directional—one actor chooses another who may or may not also choose them—an important relational mechanism is the tendency toward reciprocity. That is, the bestowing of a friendship from i to j tends to be quickly followed by a reciprocal offering of a friendship from j to i . Consequently, an important predictor of tie formation from one individual, i , to another, j , is whether or not j previously had a directed tie with i . Reciprocity appears to occur for several reasons. In interpersonal relationships, one-way ties are likely to become reciprocal because people tend to like others who like them (Newcomb 1956, Backman & Secord 1959, Sprecher 1998, Montoya & Insko 2008). Similarly, reciprocation relative to a first advance of friendship decreases the chance of being rebuffed (Goffman 1963).

Early evidence for the temporal development of reciprocity in friendship networks comes from grade-school data (Sørensen & Hallinan 1977, Eder & Hallinan 1978, Hallinan 1978, Tuma & Hallinan 1979, Runger & Wasserman 1980, Hallinan & Williams 1989, Doreian et al. 1996). Hallinan (1978) measured the friendship networks of fourth and sixth grade students at five elementary schools

in the Midwestern United States at seven points in time. She found that the most likely new friendship to be created was the reciprocation of an extended friendship from another student. Using the same data, Runger & Wasserman (1980) showed that students were between three and nine times more likely to create a new friendship with another student in the future if that student had already selected them. Analyzing longitudinal networks of friendship formation among 17 formerly unacquainted college students, Doreian et al. (1996) found that one of the fastest structural tendencies in a developing network was a bias toward reciprocated relationships. In another analysis on newcomer networks, Mollica et al. (2003) measured the friendship network of 114 MBA students six weeks after matriculation into a graduate program and three and a half months later. They found that just six weeks after students had met, the level of reciprocity in their friendship network was much higher than chance levels; approximately 37% of friendships were reciprocated. The reciprocation of extended friendships continued over the following eight weeks such that 52% of ties were reciprocated by the end of the observation period.

However, reciprocity in social networks does not occur solely because people reciprocate offered relationships. It also occurs as actors withdraw unreciprocated ones. Hallinan (1978) reported an interesting pattern in the evolution of friendship networks. She found that while one-way friendships were significantly more likely than null relationships to blossom into reciprocated ties, they also had a high base rate of dissolution. One-way friendships were approximately two times more likely to entirely dissolve than they were to be reciprocated. This suggests that although a one-way tie can make a reciprocal tie more likely to arise relative to a nonexistent relationship, one-way friendships are fundamentally short-lived if they fail to become reciprocal. Several factors have been identified as potential causes of the fragility of one-way ties. If a one-way tie is not reciprocated relatively quickly, independent of its potential value, it can evoke

embarrassment (Goffman 1963), distress, or mutual discomfiture (Heider 1958). Moreover, in an influential paper on the development of status hierarchies, Gould (2002, p. 1151) comments “[s]omeone who pays less attention to you than you pay to her implicitly asserts that she is superior to you in status. If you do not respond by withdrawing your attention, you have implicitly agreed.” In this way, extending a tie to someone who does not reciprocate may signify deference to another person’s higher status. Friendships in Hallinan’s schools were consistent with this hypothesis. Students were roughly half as likely to withdraw a reciprocated friendship as they were to withdraw an unreciprocated one (Runger & Wasserman 1980). Mollica et al.’s (2003) MBA study also showed that students were significantly more likely to maintain reciprocated friendships more than three and a half months than they were to maintain unreciprocated ones.

Thus, reciprocity is associated with stability. Over time, unreciprocated ties are inherently unstable, either becoming reciprocated or withdrawn. A relatively open area of inquiry is to understand why some ties are reciprocated and others are not. For example, are high-status individuals the recipients of many one-way ties, only a few of which they reciprocate? Are homophilous ties less or more likely to be reciprocated given their frequency? Do certain contexts promote reciprocation while others are characterized by many failed one-way ties?

Dynamics of Repetition

In relationships that can be ongoing in time, an important relational property is the frequency of repetition. Repeated ties figure prominently in the networks literature in many types of ties, both social and economic. In addition to being a measure of the strength of a relationship, repetition is also taken as an indicator of trust (Gulati & Gargiulo 1999, Uzzi & Lancaster 2004) and social embeddedness in economic exchange (Uzzi 1996). The frequency of a repeated tie has also been correlated with altruism, joint problem solving, and information

exchange (Uzzi 1996, 1997); deals in exchanges (DiMaggio & Louch 1998, Uzzi 1999); prices (Uzzi & Lancaster 2004); and collusion (Ingram & Roberts 2000).

Uzzi & Spiro’s (2005) work on the career histories of about 5000 artists who made Broadway musicals between 1900 and 1995 and the evolution of their network provides evidence of the tendency toward repeat relationships over time. Uzzi & Spiro (2005) showed that over time collaborators show a significant propensity to work with persons with whom they have worked in the past. Guimera et al. (2005) used agent-based simulations to show that the network structure of four scientific disciplines—astronomy, ecology, economic, and psychology—exhibited similarly high rates of repeated ties. Disaggregating the coauthorship networks in these fields over the top seven journals in each field, the authors were able to compare the rates of repeated ties across these diverse networks. They showed that the rate of repeated ties varied from about 50% to approximately 99%, which suggests that repeated ties are common and, for some networks, are the norm.

Even in markets where relationships are frequently thought of as being arm’s-length, one-shot engagements, we find relatively high rates of repeated, reciprocal ties. Baker (1990) looked at the relationships between large corporations and their investment banks with an eye to how many banks they maintain relationships with and the repetition of dyadic financial relationships. He showed that corporations tend to have ongoing relationships with a core set of financial partners, adding others on an ad-hoc basis for special deals. This condition is also found between investment banks (Podolny 1994) and large law firms and their client corporations (Uzzi & Lancaster 2004). Uzzi (1996) showed that in the competitive markets of the apparel industry, many contractors concentrate their relationships with certain manufacturers—establishing ongoing, repeat relationships—and those contractors who fail to establish these embedded ties tend to fail at greater rates, suggesting that the orientation

toward repetition is important to the functioning of the network and the actors embedded within it. Thus, in networks of economic exchange and friendship, the ties that exist at one point in time are likely to be repeated in the future.

Dynamics of Clustering and Closure

In comparing networks as diverse as biological food webs to the World Wide Web to interlocking corporate directorates, Newman & Park (2003) found that a characteristic that distinguishes social networks from biological and technological networks is clustering, a condition originally proposed by Simmel (1908 [1950]). Clustering means that social networks tend to have a high density of closed triads, or, colloquially, people tend to become friends with the friends of their friends. In their respective networks, corporate board members (Davis et al. 2003), Hollywood movie actors (Watts 1999), Broadway musical artists (Uzzi & Spiro 2005), inventors (Fleming et al. 2007), scientists (Newman 2001b), lawyers (Lazega & Pattison 1999), and organizations, tied together through alliances (Kogut & Walker 2001, Baum et al. 2003), all tend to be connected to other actors who are themselves connected.

Several rationales have been proposed to explain the almost universal observation that social networks exhibit nontrivial clustering. Granovetter (1973, p. 1362) suggested that people are inclined to create ties with the friends of their friends (or the business associates of their business associates, etc.) because people who spend time with a common third are likely to incidentally encounter each other, even if they are not explicitly introduced (cf. Feld 1997). Others have noted that sharing a third party provides information about potential connections through referrals and gossip and that this information eases the process of developing a new tie by decreasing the uncertainty and risk of a new connection (Burt & Knez 1995). In this respect, proximity in a social network is correlated with increased information about the trustworthiness of a potential contact. "Better

than the statement that someone is known to be reliable is information from a trusted informant that he has dealt with that individual and found him so," remarked Granovetter (1985, p. 490). Finally, research on social capital has noted that embeddedness among third parties can also promote collectively oriented norms, thereby minimizing opportunism (Coleman 1990; Granovetter 1985; Uzzi 1997, p. 48) and mitigating conflict (Simmel 1908 [1950], p. 135; Portes & Sensenbrenner 1993; Krackhardt & Handcock 2008).

A measurable implication of these processes on network dynamics is that open triads tend to close over time. In one of the first empirical studies on the closure process, Hammer (1980) examined longitudinal data of interpersonal interaction in three settings: a neighborhood church, a coffeehouse, and a textile factory. In each network, ties between individuals were measured by observing interactions over a period of time (ranging from one month for the coffeehouse and church to six months for the textile plant). A tie was said to exist if people were observed interacting (usually conversing) with one another. Providing early support for the closure process, Hammer found that in all three settings pairs of unacquainted individuals were significantly more likely to begin interacting if they had a common acquaintance. This early study alluded to the generality of the closure mechanism; Hammer's church and coffeehouse were located in Manhattan, the textile factory in Africa.

The closure hypothesis of social attachment has been further corroborated by recent studies that have vastly increased the size and scope of research through the use of digital communication data. Kossinets & Watts (2006) tracked the emails of 45,553 students, faculty, and staff at a large research university over an academic year with the goal of identifying factors that predicted communication between individuals. One of the predominant influences on social attachment that they uncovered was Simmel's triadic closure. Having a mutual contact dramatically increased the tendency for two formerly unconnected students to begin communicating

via email: Among students who did not share a common class—and were therefore less likely to incidentally meet—having a mutual contact increased the probability of communication by a staggering 140 times. Even students who sat in a class together were three times more likely to begin communicating with each other via email if they both emailed a common third individual. Sharing common third parties has also been found to influence the formation of new collaborative ties between researchers. Newman (2001d) examined the structure of scientific collaboration networks of more than 1.6 million researchers in biology, physics, medicine, and computer science between 1995 and 1999. Two scientists were considered to have a tie if they had coauthored a paper together. He found a similar result—across each discipline, two scientists had a 30% or greater probability of collaborating if they had both collaborated with a common third researcher.

The effect of sharing mutual acquaintances on attachment appears to be additive—each additional mutual acquaintance shared by an unconnected dyad additionally increases the likelihood that they will become connected. Hammer (1980) found that in each of her analyzed settings having two shared acquaintances increased the probability that a pair of individuals would create a tie above and beyond the probability observed for people who shared only one. Newman (2001a) provides compelling evidence for additivity in closure. He examined the scientific collaborations catalogued in the National Institute of Health's Medline® database, a network containing more than 1.6 million researchers in biology and medicine, and found that two researchers who shared one prior collaborator were 40 times more likely to collaborate than were researchers who did not share any collaborators. Sharing two, three, four, and five prior collaborators increased the probability of collaboration by 100, 140, 170, and 200 times, respectively, than the probability experienced by researchers with no prior common collaborators. Thus, scientists' current relationships powerfully affected their selection of future collaborators.

Clustering occurs even between individuals who are separated by more than a single intermediary. In a social network, the distance from one actor, i , to another, j , is denoted d_{ij} and represents the length of the shortest path between i and j .¹ Individuals who are not connected themselves, but who are connected to a common third actor, are separated by a distance of 2, people separated by two acquaintances have a distance of 3, and so on. Research has found that shorter network distances are correlated with increased tendencies toward connections. Early evidence can again be found in Hammer's (1980) analysis of interaction networks. She found that the network distance between two people at one point in time was negatively related with the probability of a tie being created between them in a subsequent time period. Patrons of the coffeehouse, employees in the African textile factory, and churchgoers who shared a contact ($d_{ij} = 2$) were significantly more likely to begin conversing during the observation period than were individuals separated by two intermediaries ($d_{ij} = 3$). Kossinets & Watts's (2006) study on the creation of email communication ties similarly found that network distance at one point in time is negatively related to the probability of attachment: Among students who were not currently in a class together, dyads separated by two intermediaries ($d_{ij} = 3$) were approximately 30 times less likely to initiate a new tie than were individuals separated by only one ($d_{ij} = 2$). Given evidence that on average people are regularly linked by a short "6 degrees of separation" (Milgram 1967, Leskovec & Horvitz 2007), it is likely that the effect of network distance on attachment decays rapidly as people become separated by more and more intermediaries. Thus, mutual acquaintances and proximity within a social network have notable effects on social attachment: In many networks, new ties are more likely to be formed between people who are not

¹This definition of distance is made more nuanced by considerations of valued ties, or of the directionality of ties, which we do not here include (see Wasserman & Faust 1992, chapter 4.3–4.5, for more on these considerations).

only close in a network, but are close through numerous independent intermediaries.

Ties that connect people who share several common alters are said to be structurally embedded and are not only more likely to arise in a social network, but are also more likely to withstand the test of time. In one study, Martin & Yeung (2006) looked at the relationships between members of 60 voluntary communes to see what factors predicted the survival of interpersonal relationships between 1974 and 1986. Even though all ties examined were between people who had once lived together and consequently had relatively strong social ties, people with mutual acquaintances were more likely to stay in touch for more than 12 years and exhibited more frequent interaction. Burt (2000) used survival analysis to examine the hazard rate of business relationship decay among 345 bankers during a four-year period. At the end of each year, bankers were asked to identify individuals with whom they had “frequent and substantial business contact in the preceding year.” Bankers experienced a high degree of turnover in their year-to-year business networks. On average, less than 35% of the ties they had in a given year were still extant the following year. Even in this rapidly evolving context of strong and weak ties, Burt found that ties that were embedded in triads were slower to decay than were nonembedded ones ($p < 0.001$). An apparent paradox is that ties bridging distant parts of social networks—connections that are disproportionately important for global connectivity, information flow, and human achievement—are not only the least likely to be created in the first place, but are also the most likely to decay over time.

It might therefore be expected that social networks close over time, continuously becoming more clustered. Yet networks can both open and close. Using a complete population data set of about 5000 creative artists who cocreated the hundreds of Broadway musicals that appeared between 1877 and 1995, Uzzi & Spiro (2005) and Uzzi (2008) studied the changing properties of small world networks with a focus on the temporal formation and distribution of closed

triads, or clustering, in the network. Using the clustering coefficient ratio, a variable that measures the ratio of actual clustering to that expected by the random creation of links in a network of the same size, they found that this network increased and decreased in clustering over time in a punctuated way. Clustering decreased after a shock perturbed the network. For example, the clustering coefficient of the network sometimes dropped as much as 30% after large shocks such as the Great Depression, the rise of movies and television, and the AIDS epidemic. This suggests that large upheavals in a network or shocks that change the environmental or market conditions within which a network is embedded may lead to the breakdown of clusters and a consequent decrease in the clustering coefficient ratio. Perhaps shocks weaken common ties to the same third party or make interaction with a common third party less predictable (Uzzi & Spiro 2005).

Not all social networks exhibit clustering. In fact some social networks exhibit the opposite tendency. Networks that have few, if any, closed cycles may exist where closure is normatively prohibited or logistically impossible. Kinship networks where ties represent genealogical descent are an obvious example of taboo norms against closure. More sociologically interesting examples can be found in romantic dating networks, which have implications for the spread of ideas, infectious diseases, and new practices. Bearman et al. (2004) examined the romantic and sexual networks of more than 800 high school students in a midsize Midwestern town. Conspicuously absent from the network was the existence of many closed triads or cycles of length 4. Bearman et al. speculated that such short cycles do not frequently occur because of a social prohibition against dating the former lover of your current lover’s ex-lover, and because the closure of triads would require a high rate of same-sex unions. Consequently, even in Hollywood, where revolving door romances among the stars could increase the likelihood of closure, closed triads, or cycles of length 4, are unlikely. Independent of their personal attractiveness

(or not), Billy Bob Thornton is unlikely to date Jennifer Aniston because their exes, Angelina Jolie and Brad Pitt, became a couple first.

Dynamics of Degree

In the 1920s and 1930s, Moreno (1934) sketched the social networks of prisoners at Sing Sing prison and schoolchildren at the Hudson School for girls in upstate New York, thus giving birth to the sociogram (Moreno 1934). Reflecting on these first sociograms, Moreno and a collaborator, Jennings (1943), discovered that some individuals tended to be at the center of their networks (stars) while others remained on the periphery (isolates). This realization gave rise to the concept of network centrality. It has since developed into a myriad of related measures that capture different aspects of an actor's connectedness and status, including betweenness, closeness, degree, prestige, fitness, attractiveness, rank, and brokerage (Borgatti & Everett 2006). Most work finds a positive association between an actor being in a central position in the network and that actor's goal achievement, including creativity (Burt 2004, Uzzi & Spiro 2005), job attainment (Granovetter 1973), professional advancement (Brass 1984; Burt 1992, 2004), political influence (Fernandez & Gould 1994), prestige (Burris 2004), rate of alliance formation (Powell et al. 2005), and dissolution (Saavedra et al. 2008).

In addition to shaping outcomes, centrality has important effects on the evolution of actors' social networks. Degree centrality—the number of ties that an actor possesses—has received particular attention (Zeleny 1940, Katz 1953, Price 1976, Freeman 1979, Friedkin 1991, Marsden 2002). In many social networks, researchers have found that most actors have only a few ties, while a small number have extraordinarily many (Borgatti & Everett 1999, Albert & Barabási 2002). An analysis of the online friendships of 4.2 million people on Facebook found that a few individuals had more than 10,000 friends, more than 55 times as many as the average user's 180 (Golder et al. 2006). Liljeros

et al. (2001) found that degree centrality is similarly skewed in sexual contact networks, where some superconnector actors acquire as many as 1000 partners. Davis et al. (2003) examined the network of corporate board memberships in the United States between 1982 and 2001 and found that the average director had ties to 16 other directors, but a few were connected to as many as 100. Similar patterns exist in the rap music industry cosinger network (Smith 2006), the Hollywood movie coappearance network (Barabási & Albert 1999), and numerous coauthorship networks in academia (Price 1965; Newman 2001c,d; Jeong et al. 2003; cf. Moody 2004; Guimera et al. 2005; Wuchty et al. 2007).

One reason social networks develop such a high variance in actors' degree centrality is that the number of ties an actor possesses (degree) affects processes of attachment. One prominent model, termed preferential attachment, posits that the rate at which actors acquire new ties is a function of the number of ties they currently have (Price 1976, Barabási & Albert 1999). Implications of preferential attachment echo Merton's (1968) "Matthew Effect." Social connections tend to accrue to those who already have them, the consequence of which is that small differences in actor centrality compound over time into a distinct cumulative advantage.

Preferential attachment purportedly occurs because actors looking for new connections use an actor's degree as a proxy for his or her fitness. In this way, the deceptively simple process has significant ramifications for acquiring and reinforcing centrality because it suggests that central actors benefit from a rich-get-richer phenomenon of cumulative advantage. In a paper that examined this process across varied types of social networks, Jeong et al. (2003) explored (a) the coauthorship network in the neuroscience field, (b) the citation network of papers published in *Physical Review Letters*, and (c) the Hollywood cocast actor network from 1892–1999. They found that neuroscientists, Hollywood actors, and physicists who had relatively more links than their respective peers tended to attach to other actors at a higher rate than

did their less connected counterparts. Newman (2001a) similarly found that researchers in physics and biology who already had a large number of collaborators were more likely to accumulate new collaborators in the future. In a first empirical test of the preferential attachment model that used a specially designed methodology for testing preferential attachment (Clauset et al. 2009), Uzzi (2008) showed that the creative artists who made Broadway musicals acquired new ties in proportion to the number of ties they already possessed.

The relationship between centrality and tie accumulation is likely to be diminished by factors that moderate an actor's resources for tie acquisition or maintenance such as time, money, or even natural aging. In many contexts, highly connected actors may accumulate new ties up to a carrying capacity, after which they cease to acquire more (Amaral et al. 2000, Guimera et al. 2005, Uzzi & Spiro 2005). As a result, networks of relationships that require significant investments of time, such as friendship networks (Amaral et al. 2000, Newman et al. 2001), interorganizational collaboration networks (Kogut et al. 2007), and corporate board membership networks (Newman et al. 2002, Davis et al. 2003, Conyon & Muldoon 2006), have less extreme differences between the most and least central actors than do networks of relationships where increasing one's degree requires only a small cost, or one-time cost, such as Facebook friends or networks of sexual contacts (Liljeros et al. 2001). Research on interfirm networks has found that the influence of degree centrality on attachment can also be minimized by other factors that are stronger proxies for fitness. For example, Powell et al.'s (2005) analysis of the interorganizational collaboration networks found that in many cases firms exhibited a preference for novelty over preferential attachment—with well-established, highly connected firms collaborating with younger, less-connected organizations. Kogut et al. (2007) examined the emergence of the U.S. venture capital syndication network and found that new entrant firms sometimes entered the network with more

cutting-edge knowledge and consequently surpassed some incumbent firms in the number of partners they accumulated. Whether a preference for novelty may similarly enable some individuals—for example, rising stars—to surpass incumbents in the extent of their connectedness is a relatively unexplored area.

Not only are high-degree actors more likely to form attachments than noncentral actors, but they are also more likely to form attachments with each other—popular actors attach to other popular actors, whereas lower-degree actors tend to attach to other low-degree actors. In a study on the bases of community power in a Midwestern U.S. town, Perrucci & Pilisuk (1970) identified the individuals who had the most ties to different organizations and constituencies. They encountered an interesting result: Among eight of the elite individuals who had ties to multiple organizations within the community of 50,000 people, 53 of 56 possible social ties existed. In other words, each of the eight elite individuals named nearly all of the other eight as people they saw socially. This finding supported assortativity among elite actors, but also strongly suggested that the most well-connected individuals in the community preferred to attach to other well-connected individuals. Recently, Conyon & Muldoon (2006) collected data on corporate directorships at 1733 unique firms in the United States, Germany, and the United Kingdom. Despite the different regulatory environments characterizing each locale, they found that in each case directors who sit on a lot of boards tend to do so with other high-degree directors. In a provocative paper, Newman (2002) compared five different social networks—including coauthorship networks and a network of corporate directors—to six biological and technological networks and found that only social networks exhibited a tendency for the most connected actors to connect among themselves. In his study of the Broadway musical industry, Uzzi (2008) found that this tendency occurs at the interteam level as well (where teams are the nodes and ties between teams are made by a shared teammate)—production teams that are highly

central are more likely to connect to other central teams.

A literature is emerging on degree centrality and detachment. Baker et al. (1998) studied the longevity and detachment of large companies' links with their advertising agencies circa 1985–1987. They argued that conditions affecting breakup were due to competitive, market, and institutional forces that could be measured as network variables. Their work indicated that a company's degree, as measured by the number of ad agencies it employed, was positively related to the probability of breakup of the firm-agency relationship. Their rationale for preferential detachment is that firms that employed a large number of advertising agencies had an increased variety and availability of alternatives to any one focal agency. Thus, echoing processes of attachment, detachment can be affected by actors' degree. However, Saavedra et al. (2008) found that detachment is not the reverse process of attachment. Using 20 years of data on the exchanges between manufacturers and contractors in the New York City garment industry, they found that even though firms form ties through preferential attachment, the links between the highest- and lowest-degree nodes have the lowest probability of breakup. Their explanation is that in the preferential attachment model a node's degree is a stand-in for its true fitness because direct performance data are costly to gather before the relationship is made. By contrast, during breakup there is already a link in place, which enables the quality of the relationship to be judged based on first-hand accounts and a history of past interactions. Saavedra et al. (2008, p. 16470) conclude that a preference to maintain connections between high- and low-degree actors results in "a remarkably robust topology," as these connections preserve the global connectivity of a network even when undergoing severe decline.

PROXIMITY MECHANISMS

Whereas assortative mechanisms are derived from information on actors' attributes, and relational mechanisms originate from information

about actors' relationships, proximity mechanisms put the source of network change at the level of actors' social and cultural environments. The most elementary proximity hypothesis is that interaction increases with geographic/physical propinquity. Being proximate is thought to encourage chance encounters and opportunities for interaction, which can lead to the formation of new relationships and the maintenance of existing ones. More complex conjectures can be drawn from the heterogeneous organization of social activities into foci that bring actors together and occasion the formation of positive sentiment, opportunities for interaction, shared goals, and cultural norms of sociability.

Dynamics of Proximity and Social Foci

"Cupid may have wings, but apparently they are not adapted for long flights," remarked Bossard (1932, p. 222) after examining the physical distances between 10,000 applicants for marriage licenses in Philadelphia. More than one in six couples filing for a marriage license had previously lived within a single city block of each other, providing early evidence for the important role of proximity on social attachment. Using electronic footprint data, recent studies have found additional evidence for the large impact of proximity on attachment. A study of email networks among Dartmouth students found that sharing a dormitory increased the volume of emails sent by two times, living on the same floor by another two times, and sharing a room by a further three times (Marmaros & Sacerdote 2006). Within a large multidivisional company, Kleinbaum et al. (2008) show that individuals who are in the same business unit, subfunction, and office location communicate in emails, calendar meetings, and teleconferences approximately 1000 times more than do pairs of employees that do not share any of those categories. At the planetary scale, Leskovec & Horvitz (2007) showed that the frequency and duration of 1.8 billion instant-message conversations between 180 million people worldwide decreased as geographic distance increased. Even when digital

communication can make the world flat and in one electrifying moment “end the tyranny of distance” (to paraphrase Samuel Morse), people still tend to connect to those comparatively few others who are spatially proximate.

Proximity similarly influences the persistence of social ties by moderating the effort required to maintain relationships. Martin & Yeung’s (2006) analysis on the determinants of tie persistence of former residents of voluntary communes found that geographic proximity was a significant predictor of detachment; people were much more likely to remain friends over a 12-year period if they were geographically close. In an analysis of the evolution of 66 high school graduates’ personal networks over a 6-year period, Bidart & Lavenu (2005) similarly found that changes in geographic location resulted in the loss of significant portions of people’s networks. They note that some individuals lost as much as one-third of their old personal networks as they transitioned to a new location (pp. 365–68). Proximity may have increased importance during later periods of people’s lives when they are less mobile. For example, Ikkink & van Tilburg (1999) found that distance was negatively related to the longevity of older adults’ social-support ties, and Fischer (1982) showed that age was associated with social networks that were more geographically constrained.

The idea of proximity may involve but is not defined by geographic closeness (Gieryn 2000). Rather, social interaction is organized into foci such as “social, psychological, legal, or physical entit[ies] around which joint activities are organized” (Feld 1981, p. 1016). The notion of social foci draws attention to collectivities such as workplaces, clubs, groups, and associations to which individuals can belong and that cannot be defined in terms of physical geography alone (Feld 1981, Grossetti 2005). Sharing foci of activity affects attachment above and beyond physical proximity, as common interest in an activity may emphasize members’ shared interests instead of their discordant ones (Uzzi & Dunlap 2005), downplay status or role discrepancies (Moody 2001), and bring people

together in mutually rewarding situations that promote positive sentiment (Homans 1961; Feld 1981, p. 1017). Moreover, foci such as neighborhoods, communities, and organizations may develop cultures that further induce the creation of social relationships (Entwisle et al. 2007). If networks are the fabric of interpersonal interaction, social foci are the looms in which they are woven.

Kono et al. (1998) examined the influence of social foci and geographic proximity on firms’ choices of corporate board members. They found that firms were more likely to share corporate board members (referred to as a corporate interlock; see Mizruchi 1996) if those firms had headquarters in proximate locations. However, upon closer inspection, Kono et al. (1998) found that membership in exclusive upper-class clubs in the same city as the headquarters was the actual driver of board interlocks. These clubs were important social foci that enabled interaction between elites who then shaped interfirm ties. More broadly, several studies have documented the influence that the foci of shared workplaces play in fostering social ties. Kossinets & Watts’s (2006) analysis of the formation of email communication ties found that a significant predictor of tie formation was whether or not students were in a class together. Golder et al. (2006) recently looked at 284 million Facebook messages sent by 4.2 million students at 496 different universities and found that nearly 60% of all messages were exchanged by students at the same university.

Given advances in technologies that facilitate communication, geographically dispersed social foci may be playing a more important role in organizing attachments while geography is playing a less important role. Jones et al. (2008) examined all the collaborations among U.S. scientists worldwide from 1975 to 2005 for 650 U.S. research universities. They calculated the fraction of work published by scientists as sole authors, coauthors in teams with other scientists from their home or nearby universities, and coauthors in teams with other scientists at other universities at a distance. Their work showed

that in all areas of science the greatest growth rate in collaborations is in university collaborations at a distance. In social science, for example, multiuniversity collaborations made up about 40% of all team collaborations in 2005. The fraction of collaborations of coauthored work done with researchers from their home or nearby universities was also 40%. These findings allude to the possibility that shared foci such as academic associations, conferences, and consortia oriented around academic disciplines and research areas may increasingly bring together researchers from geographically distinct locales. As technological advances in communication proliferate, the effect of distance on attachment may increasingly be supplanted by the influence of shared foci that supersede the confines of geographic propinquity (Wellman 1979, 1996; Hampton & Wellman 2001).

Similar to how changes in geographic distance influenced detachment, the loss of shared foci induces the breaking apart of network ties. Bidart & Lavenu's (2005, p. 361) study of network evolution found that when transitioning from school to work, young people "lost their schoolmates in a fairly extreme way. . . . They had relatively extensive networks, which underwent a major replacement of ties at the time of their entry into working life." Nevertheless, "[a] relation may last longer than the circle [foci], which made its initial construction possible. We maintain relations with former school or university companions, former colleagues, and former activists in political parties long since disappeared" (Grossetti 2005, p. 292). Relationships that carry over from prior foci play an additionally important role of connecting the different social groups and communities to which people belong. Ties formed during university years may have a large impact on the social capital of graduates throughout their careers, as Cohen et al. (2008) recently showed with regard to the role of MBA alma mater and access to private information in the stock market.

What is much less understood in this literature is an understanding of the aspects of foci of activity that lead to strong tendencies toward social connections—i.e., a theory of why some

foci encourage connections and others do not. In his study of New York City child care centers, Small (2009) has begun to address this. He found that mothers often expanded their network through relationships developed at the centers; however, the extent of network development was strongly influenced by institutional practices at the centers. He found that people were more likely to form ties when "they have opportunities to interact, when they do so frequently, when they are focused on some activity, when they are not competitors, and when they have reason to cooperate" (p. 15). This corroborates experimental findings that suggest that perceptions of group belongingness, positive affective sentiments, and emotional reactions are greatest when activities are characterized by highly interdependent activities and feelings of shared responsibility (Lawler et al. 2008). There is still much opportunity for future research in this area. Do shared activities that focus on small group interaction, such as four-person bridge teams (to allude to the famous shared activity that created a connection, valued at \$45 billion, between William Gates and Warren Buffet), or large group activities, such as soccer or basketball, have a greater impact on the formation of network attachments? Do activities that have some gradation of winning or losing versus noncompetitive interaction (e.g., a book club) impact the creation of ties differently? How do activities that highlight a core aspect of personal commonality, such as a shared passion for the environment, help create connections between people who are otherwise nonhomophilous or distantly linked through common third parties?

CONCLUSION

Homans (1961, p. 1) commented that social behavior is a "familiar chaos," in that "[n]othing is more familiar to men than their ordinary, everyday social behavior," yet much of social interaction still appears chaotic. Change in social networks is a familiar chaos. Although there are few social phenomena more elementary than the creation and dissolution of relationships,

these processes are driven by sometimes complex mechanisms and generate networks that have profound implications for human achievement, beliefs, and outcomes. Researchers have historically approached this familiar chaos in three ways: one focusing on actors' attributes, another on their relationships, and a third on proximity. Each approach has yielded robust and often generalizable findings. However, these theoretical streams have also tended to progress in relative isolation—favoring their own theoretical foundations and explanatory variables. Further integration stands to benefit network research in at least three ways: (a) by explicating causal mechanisms, (b) by exploring interactions between mechanisms, and (c) by evaluating the changing role of different mechanisms as networks emerge and evolve.

Disambiguating causal relationships in the dynamics of relationship formation and dissolution remains an elusive goal. Perpetually threatening the validity of each perspective covered in this review is the possibility that its findings are epiphenomenal to the operation of the others. For example, Feld (1982) argues that proponents of homophily significantly overestimate actors' preferences to interact with self-similar others by neglecting to account for people's self-selection into contexts that bring together disproportionately homophilous actors. Indeed, a recent analysis by Kossinets & Watts (2009) found precisely this effect—in their study, college students with similar gender, age, majors, academic years, and foreign/domestic status tend to take classes together, where they find occasion to create social ties. Thus, observed biases toward interaction with self-similar others are largely the result of prior selection into contexts of homophilous actors. Similar alternative explanations for clustering have also been proposed (e.g., Feld 1981). Future research that simultaneously accounts for mechanisms in each perspective may further untangle these theoretically elusive questions.

A second promising avenue for future research is to explore interactions between assortative, relational, and proximity mechanisms. One extant stream of research that

brings together assortative and relational mechanisms explores the different networking tendencies of men and women. For example, Eder & Hallinan (1978) found that male and female schoolchildren demonstrate different solutions to having a friend that is not friends with their friends—boys were more likely to add relationships to embed the isolated individual, whereas girls were more likely to delete a relationship to entrench their existing friendship clique. Conversely, Plickert et al. (2007) found that women are more likely than men to reciprocate some relationships and, further, that reciprocity is more likely between individuals that are spatially proximate. Future studies may further explore interactions between assortative, relational, and proximity mechanisms by (a) evaluating whether closure is more likely between individuals who share social foci or share attributes, or by (b) testing whether homophily is greater (or lesser) within social foci or whether homophily still matters between people who share friends.

Finally, it is relatively unknown whether different mechanisms play greater or lesser roles as networks evolve. One area where this is especially apparent is in the genesis of social networks. Critiques of relational mechanisms have noted that an emphasis on prior network structure unavoidably begs the question: Where does the network come from in the first place (Podolny & Page 1998; Stuart & Sorenson 2007, p. 220)? Given the importance of prior connections on informing actors about potential friends and colleagues, people in emerging networks may rely on other avenues of information gathering—such as homophily and social proximity—to initially find new friends and colleagues, and only later rely on networks to facilitate the formation of relationships. This suggests that as networks evolve so too do the rules that govern their evolution (Rivera & Uzzi 2009). In the face of this complexity, what is clear is that understanding these contingent effects of network dynamics promises that future work will develop a greater understanding of the changing networks in which we are all embedded.

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