can they best be utilized? From time to time, we will reference classic social theorists to see to what extent social network ideas illuminate the problems that they posed. In this view, social networks are not only structural abstractions and the study of networks is not an alternative to classic ways of understanding society, but is a way of gaining greater insight into social life. Though networks also characterize the inanimate world such as electrical power grids, social networks have to be understood, to quote E. F. Schumacher (1973), "as if people mattered."

2 Basic Network Concepts, Part I

INDIVIDUAL MEMBERS OF NETWORKS

Introduction

Social network theory is one of the few theories in social science that can be applied to a variety of levels of analysis from small groups to entire global systems. The same powerful concepts work with small groups, with organizations, nations, and international systems.

Chapters 2–4 introduce elementary network concepts, the "score-card" without which you cannot distinguish the players. In addition to defining the concepts, the chapters provide some flavor of how they are used and how they are linked to basic ideas about networks. This chapter introduces concepts concerning relations between the units that comprise a network. Chapter 3 discusses concepts that describe a network as a whole. Chapter 4 addresses where to draw the line—partitioning whole networks. We begin with a definition of a simple network that connects pairs or dyads. We conclude the chapter with a discussion of triads, the most elementary network in which the structure of the network really matters. For networks, dyads and triads are the analogue of molecules. Dyads and triads will give us a handle for understanding larger networks.

With dyads or pairs we are interested in why people come together—why they form a dyad in the first place. As with all network theory, we will see that a feedback loop is at the heart of network processes. There are forces such as propinquity—for example being in the same place at the same time—that bring people together; but at the same time, the dyad creates consequences for its members and for the whole network. People who are connected with one another tend to be physically proximate. People who are near to one another also tend to share the same characteristics, values, and social statuses. This relationship is one of the reasons, for example, that desegregating neighborhoods or integrating schools can be particularly challenging. Regardless of how the connection happens, once people are linked, there is a tendency for them to acquire the same characteristics, values, or social statuses from one another. Chicken-and-egg problems abound in social network analyses.

The discussion above concerns "people," but the concepts apply to all levels of networks including groups, organizations, and even nations. Some illustrations and a few elementary propositions will be offered for each concept. Further applications of the concepts, as well as more complex concepts and propositions, will be developed in later chapters devoted to specific topics. While all the concepts have formalized means of measurement, and often several different ways to measure the same concept, the aim of this book is to develop the concept itself and show how it is applied in theoretical statements and in substantive findings. Measurement issues will be noted and referenced, but the mechanics of the analysis is mainly reserved for other literature.[1]

What Is a Network?

We begin with a more precise definition of "network": a network is a set of relationships. More formally, a network contains a set of objects (in mathematical terms, nodes) and a mapping or description of relations between the objects or nodes. The simplest network contains two objects, 1 and 2, and one relationship that links them. Nodes 1 and 2, for example, might be people, and the relationship that links them might be as simple as standing in the same room. If 1 is in the same room as 2, then 2 is in the same room as 1.[2] The relationship is in figure 2.1a is not directional.

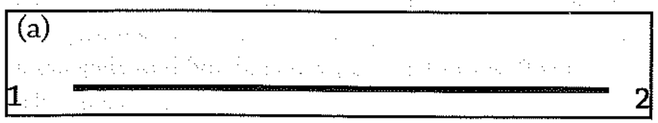

FIGURE 2.1A Simple Relationship

There are also directional relationships (figure 2.1.b) such as 1 likes 2.

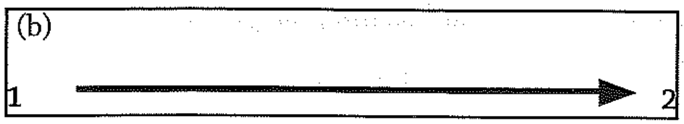

FIGURE 2.1B Directed Relationship

In this simple network of "liking," the relationship could be symmetrical.

Nodes 1 and 2 like one another, or their liking is mutual. The liking network below (figure 2.1c) is similar to the first one of standing in the same room together, but has a valence or a flow. Mutuality is a tricky matter, however, and not all that easy to achieve, so mutual networks tend to be limited. A prevalent tie between dyads is *antisymmetric*. Father and son, boss and employee are examples. The relationship is by definition different, depending on which way you look.

FIGURE 2.1C Symmetric Relationship

There need not be just one relationship mapped between nodes 1 and 2. For example, 1 and 2 might be in the same room and might also like one another. When there is more than one relationship, this is called a multiplex relationship.

Aside from their directionality, or lack of it, relationships might be more than the sharing of an attribute or being in the same place at the same time. There can be a flow between the objects or the nodes. Liking, for example, might lead to an exchange of gifts. Flows and exchanges are very important in network theory.

At one level, this list of concepts of relationships between pairs of nodes is now logically complete. But consider a network (figure 2.1d) between pairs that operates via an intermediary node. For example:

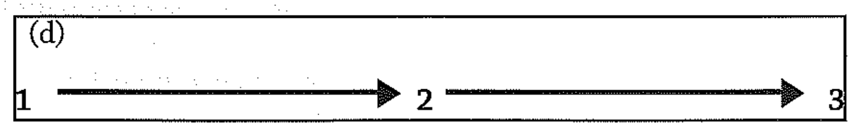

FIGURE 2.1D Relationship Through an Intermediary

Node 1 is connected to 3 via 2. The relationships shown above are directional and not reciprocal. They might be transitive or they might not be. If the relationship is transitive, it means that if 1 loves 2, then 2 also loves 3. Possible, but not likely. Transitive relationships are more common in an official hierarchy. Node 1 gives a message to 2 who forwards it to 3.

One can describe the network distance between pairs of nodes in terms of the number of steps or links between them. There are obviously two steps between 1 and 3. But if 1 also likes 3, as shown below (figure 2.1e), the network is said to be transitive or balanced and mutual and, in this case, all three nodes are directly linked.

The network depicted in figure 2.1e is a "sociogram"—a term invented by Jacob Moreno (Moreno 1953 [1934]), who is regarded by many as a key founder of modern network studies. It is also what mathematicians call a graph. There is a branch of

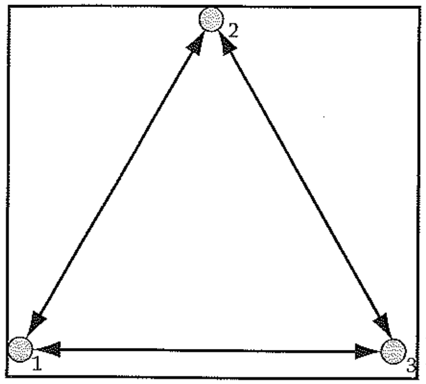

FIGURE 2.1E Sociogram of Three Nodes, All Mutually Related

mathematics, graph theory, which allows sociograms to be manipulated mathematically (Harary, Norman, and Cartwright 1965). The depiction of relationships as sociograms allowed observers almost instant insight as to what was going on in small, not overly complicated networks. The addition of graph theory to the tools for understanding networks further allowed for understanding and manipulating much larger and more complex networks. In this introduction to network theory, we will dispense with the mathematics of graph theory but will rely on its insights and findings. The simple network of three units is called a triad. This simple network turns out to be the building block of more complex relations and will be discussed at the end of this chapter.

Many network analysts, and much of the software for manipulating networks, prefer to work algebraically with networks when they are depicted and expressed as matrices. Below (table 2.1) is the same sociogram but in matrix form. In network terms, we call this an adjacency matrix because it shows who is next to whom.

The numbers, 1, 2, and 3 on the top line and the first column identify the same nodes as in figure 2.2. The number 1 on the second line indicates a connection between the nodes. Node 1 "chooses" nodes 2 and 3. Node 2 "chooses" nodes 1 and 3. Node 3 "chooses" nodes 1 and 2. The dashes indicate that in this graph or matrix, self-choice is not at play, though in some networks self-choice can be an option. For example, candidates in an election can vote for themselves.

TABLE 2.1

The Adjacency Matrix that Represents Figure 1

	1	2	3
1	-	1	1
2	1	-	1
3	1	1	-

Sociological Questions about Relationships

Though all of our examples thus far have been social, in principle, we might as well have been talking about electrical currents. There is a branch of network theory that deals with such matters, though electrical circuits tend to be considerably simpler than social networks. But consider. At each level of analysis—individual, organization, or nation-state, for example—what are the conditions that make it more or less likely that a path will exist between two nodes, that the nodes will have the same attributes, that they will be reciprocally or mutually related to one another, and that triads will be balanced? The answers lie in social theory. We now introduce some elementary hypotheses about these conditions.

Social scientists have investigated three kinds of networks: ego-centric, socio-centric, and open-system networks. Ego-centric networks are those networks that are connected with a single node or individual, for example, my good friends or all the companies that do business with Widgets, Inc. (the favorite name of organizations studied in business schools). However, a list is not necessarily a network. In popular discourse, especially when social support is discussed, any list is called a "network." It is a network in a basic sense because even if no one on the list is connected with one another, each individual is at least all connected with the person being supported. The support may include help with a job search, comfort during an illness, or a loan of money or a lawn mower. A person with a large number of good friends whom he or she can count on is commonly said to have a large "network." This network cannot be discussed in social network terms, however, unless we know whether and how these people are connected with one another.[3] It is obviously one thing to have a supportive network in which most people know one another and a very different matter if the people are unknown to one another. Ego networks and how they extend further to links beyond the starting point are discussed in the next chapter on whole networks.

Socio-centric networks are networks in a "box." Connections between children in a classroom or between executives or workers in an organization are closed system networks and the ones most often studied in terms of the fine points of network structure. These were the ones with which Moreno began his studies. Open system networks are networks in which the boundaries are not necessarily clear, for they are not in a box—for example, the elite of the United States, connections between corporations, the chain of influencers of a particular decision, or the adopters of new practices. In some ways, these are the most interesting networks. Later chapters in this book, one about the "Small World" and one about diffusion, explore these open systems in some detail.

CONNECTIONS

We now examine some of the social situations and forces that make for connections between one node (e.g., a person, an organization, a country) to another.

Propinquity

At all levels of analysis, nodes are more likely to be connected with one another, other conditions being equal, if they are geographically near to one another. Individuals are more likely to be friends if they are geographically close (Feld and Carter 1998). In a pioneering study of the propinquity effect, Festinger, Schacter, and Back (1950) demonstrated that in a new housing project for World War II veterans, persons who lived near to one another were more likely to become friends. Persons in corner housing units were more likely to be socially isolated than persons in units that lay between other units (ibid.). Further underlying the importance of location, a study of networks in the United States of people who serve together on several different corporate boards of directors (these are called "interlocking directorates") found that "[i]nterlocks are concentrated in firms headquartered in the same locale" (Kono et al. 1998). Being selected to serve on boards of directors has more to do with local upper class structure, being acquainted with people because one has run into them at the same clubs, than with simple friendship. Though some of the same network principles (in this case propinquity) apply for individual persons, corporations, or countries, how the principle plays out may differ for various levels of analysis. Trade between countries, other things being equal, is more likely if the countries have common borders. But, for example, "averaged over all EU countries, intranational trade is about ten times as high as international trade with an EU partner country of similar size and distance" (Volker 2000). Economists tend to define propinquity in terms of cost of transportation rather than the actual number of miles between nodes or sheer border crossings when tariff is not an issue (Krugman and Obstfeld 2000).[4]

Propinquity can also be more broadly defined as being in the same place at the same time. There is a distinction between co-location, which puts people simply within range of one another, and co-presence, which implies a social relationship that is within the framework of a social institution or social structure (Zhao and Elesh 2008). Common interests (e.g., music) and common arenas or foci for meeting (e.g., mothers at the playground) are another mode for drawing people together (Feld 1981; Feld and Carter 1998; Kadushin 1966). Studies of elites show that persons are more likely to have a connection, relationship, or friendship if they went to the same prep school at the same time (Domhoff 1967). Of course, these individuals may merely share an "old school" tie (they went to the same school but at different times), in which case we are talking about homophily, a different kind of propinquity.

Homophily

Homophily (from the Greek, "love of the same") is a concept introduced into social theory by Lazarsfeld and Merton (1978 [1955]) that embeds a folk proposition: "birds of a feather flock together." More formally, if two people have characteristics that match in a proportion greater than expected in the population from which they are drawn or the network of which they are a part, then they are more likely to be connected (Verbrugge 1977). The converse is also true: if two people are connected, then they are more likely to have common characteristics or attributes. There is also an implied feedback: over time, relationships tend to sort out so that they become more homophilous. I have said "people," but the homophily principle, like propinquity, applies equally to groups, organizations, countries, or other social units.

Individual-Level Homophily

At the individual level, persons are more likely to have a connection, friendship, or association, if they have common attributes (Lazarsfeld and Merton 1978 [1955]). While common norms are promoted through common attributes, so are common attributes likely when association or friendship occurs as a result of co-location and commonly situated activities (Feld and Carter 1998).

Lazarsfeld and Merton distinguished between status-homophily, which can be ascribed (e.g., age, race, sex) or acquired (e.g., marital status, education, occupation), and value-homophily (e.g., attitudes, stereotypes), which has also been termed homogeneity (Hall and Wellman 1985). Common attitudes can be based on patterns of relationships (Erickson 1988). Numerous studies have documented the tendency towards homophily in a variety of social networks (McPherson, Smith-Lovin, and Cook 2001). But a critical research and theoretical question is which characteristics, attributes, or activities are selected in a given situation to be salient candidates for homophily. For example, the extent to which the situation values "race" or defines it in terms of skin color will affect whether common characteristics such as skin color will be related to children's choice of one another as friends in a classroom situation (Hallinan 1982; Hallinan and Williams 1989). Because of the principle of homophily, social network analysis thus almost invariably involves the sociology of class, gender, ethnicity, and nationality as well as cultural values. Some of the sorting out and clustering of networks is of course the result of visible attributes, but some is the result of less visible ones. To make the less visible more visible, dating and matching services offer checklists through which they attempt to bring people together.

There are two kinds of causes of homophily. Common norms or values may bring nodes with common attributes together, or the reverse, common attributes and contacts may lead to common norms, and this holds true for both individuals and collectivities (Burt 1982, 234–238). For example, a study of adolescent girls found that students belonging to the same clique tended to have similar scores on various measures of behaviors such as binge eating, alcohol use, dietary restraint, and so on. But we do not know whether adolescent girls hang around together because they share similar habits, or they have become similar to each other while hanging around with one another (Hutchinson and Raspee 2007). In general, research on homophily investigates the conditions under which homophily is likely to occur—which factors in a social system encourage which kinds of similarities and leads to particular ties (McPherson, Smith-Lovin, and Cook 2001). This is even more complex than it seems because homophily is a process. To reiterate, if people hang out together they tend to have the same attitudes, and if they have the same attitudes, they tend to hang out together (Erickson 1988). Chicken-and-egg situations always create difficulties, and a major part of Lazarsfeld and Merton's original formulation was devoted to Lazarsfeld's essentially unsuccessful attempts to sort this out.

A second cause for homophily is structural location. Two nodes may have the same attributes because both operate in the same arena, and again, vice versa (Feld and Carter 1998). While similar pairs tend to form a relationship, the availability of similar attributes is a function of social structure. I am more likely to find people interested in solving mathematical problems in a physics class than in a class on English literature. But people drawn to mathematics are more likely to choose a physics class that an English class. By studying the email interactions, over a year, of a population of over 30,000 students and staff in a university, Kossinets and Watts (2009) were able to determine that individual preferences for like persons and common social location both produced homophily. But modest initial preferences for similar others became amplified over many email exchanges into stronger patterns of homophily; similar interests led to similar locations in which similar interests were more available. The feedback between network structure and individual preference thus becomes especially noticeable over time.

In sum, if people flock together, it appears that there are four processes involved: (1) the same kinds of people come together; (2) people influence one another and in the process become alike; (3) people can end up in the same place; (4) and once they are in the same place, the very place influences them to become alike.[5]

The principle of homophily exemplifies the tendency of social networks to be "unfair" and makes "social engineering" to counter prejudice and segregation more difficult. For example, in one study of social network engineering and race, a police academy attempted to facilitate racial integration by populating squads with a selection of recruits that reflected the demographics of the larger cohort (Conti and Doreian 2010). The academy also instituted fixed seating. As observed and surveyed over the training period, squads "worked to increase levels of social knowledge within and between races through time as well as the level of friendship at the end of the academy. The fixed seating arrangement worked in the same fashion but as a weaker force. Social knowledge and friendship were highest for pairs of recruits in the same squad and were adjacent in the fixed seating—both within and between races" (ibid., 42).

Interaction led to greater understanding, but not to a complete elimination of conflict around race: "expunging underlying attitudes regarding race is another matter. Throughout the academy, an underlying tension regarding race existed and was expressed with racist remarks (recorded as part of the ethnographic data)" (Ibid.).

Homophily and Collectivities

Hypotheses about homophily are straightforward for individual persons, but somewhat more complex when it comes to collectivities. At the organizational level, whether similarity leads to a greater likelihood of a tie depends on the kind of a connection, as well as the on the industry.

Consider Ford, Chrysler, and General Motors as having common characteristics: they are automobile manufacturers and are geographically adjacent to one another in Detroit. But common characteristics and geographic propinquity do not necessarily lead to a tie. For example, Ford does not sell cars to General Motors. On the other hand, when engineers and managers move from one company to another, a tie develops

between the automobile companies. Similarly, software firms in Silicon Valley cultivate ties to one another through their practice of regularly licensing software to one another and also exchanging personnel. Geographic co-location is of course covered under the heading of propinquity, but through the principle of "external economy," it also leads to homophily via structural co-location. External economies, as the name implies, are "the economies that a firm can obtain through the use of facilities or services 'external' to itself" (Hoover and Vernon 1962). This leads to the classic situation of "birds of a feather flocking together" to take advantage of readily available services and hence lower transaction costs.[6] The being in the same place at the same time, at once a factor in homophily also makes relations with one another easier. It is no accident that firms that compete with one another and thus have very similar attributes are also geographically close (Uzzi 1996). We will have more to say about this principle when we discuss social circles of organizations.

The corporate examples suggest that power in a relationship is not irrelevant. Given that there is a dyad formed by virtue of homophily, and that the dyad connection itself creates greater homophily, what is the role of power or mutuality in the dyad? We often observe that in any relationship at any time one of the pair has an advantage over the other. When are the relationships equal; when is there mutuality?

Dyads and Mutuality

We have seen that in directed graphs or networks, there can be four possible relationships: none at all (they are not connected), A relates to B, B relates to A, and A and B both relate to one another. We are concerned here with the fourth relationship, reciprocity or mutuality.

The concept of mutuality implies first, that relations are reciprocal, that is, they involve a give and take between the two parties; and second, that power or asymmetry in the relationship is of little or no consequence. Mutuality is strongly affected by the social and cultural structure within which the dyads are embedded. For example, in elementary school, girls are more likely to reciprocate friendship choice than are boys. Girls may be more socialized to emphasize personal relationships therefore develop more intimate friendships (Shrum, Cheek, and Hunter 1988). The doctor-patient relationship can be a close one, though guided by professional norms. But the relationship is inherently anti-symmetric. Recent developments in psychoanalysis, however, urge a more mutual relationship between therapist and patient (Mitchell 1993). The American husband-wife relationship is another one in which norms of mutuality have been changing, though to be sure women still do more housework and have greater responsibility for child rearing.

Under what conditions, in what kinds of networks, can we expect that nodes will have a mutual relationship? One can try and address this question by looking at the likelihood that a particular network or social system will be composed of more or fewer mutual relationships than one might expect at random (Mandel 2000; Wasserman and Faust 1997). Mutuality begins early in life and is a key factor in human development.

As such, mutuality is strong factor in the formation of children's friendships (Schaefer et al. 2010).

While at the level of individuals it may be difficult to sort out mutuality, at the organizational level this task may be easier. Organizations can share an attribute—two organizations that confront illegal drug problems, for example. In this respect, the police and psychiatric clinics can be said to be in the same network. Then we examine the nature of flows between them. Do the police send people to psychiatric clinics; do the clinics send people to the police? If both are true, how does this reciprocal relationship work out in practice? Is there more than one relationship between the police and psychiatric clinics? For example, do they "exchange" clients (a flow), and are they both members of the mayor's task force on fighting drug addiction (a shared connection); and if so, how does this multiplex relationship affect them? Answers to these apparently very simple questions can result in complex analyses of the roles of different organizations in dealing with drug problems. Just as a reminder, there are also relations between units larger than organizations. There is an entire branch of economics that deals with trade relations between nations (Krugman and Obstfeld 2000).[7] The advantage of organizational or national research into reciprocity is that data are from databases that trace transactions of one kind or another and hence do not suffer from people's faulty memories. For example, contrary to the theory that argues that the hierarchical structure between core and peripheral countries are becoming more and more solidified, the reciprocity between countries in the global telecom network was found to have increased between 1989 and 1999 (Monge and Matei 2004).

There are a large range of propositions and studies about pairs of relations, most of which assert that the greater the similarity of the attributes of the pairs, the greater the likelihood of there being a flow between them (see homophily, above). While this may be obvious, consider that most "coalition building" consists of creating mutual flows between pairs that do not share many attributes. There is a major movement in public health and in drug- and alcohol-addiction-prevention programs that attempts to build community coalitions in an effort to have an impact on drug and alcohol consumption. The proponents remain optimistic. Foundations and the federal government continue to fund these programs, yet careful studies show that "overall the documented research evidence for positive coalition or partnership outcomes is weak, or, in stronger language, conspicuous by its rarity" (Berkowitz 2001, 220; see also Kadushin et al. 2005). Although "obvious" to network analysts who understand that bringing pairs together in the long term when they have quite different characteristics is difficult and rare, this elementary fact of pair relationships is apparently poorly understood.

Balance and Triads

As noted, network analysis really begins with triads, for they are the beginnings of a "society" that is independent of the ties between a dyad:

> In respect to its sociological destiny...the dyadic element is much more frequently confronted with All or Nothing than is the member of the larger group. This peculiar closeness between the two is most clearly revealed if the dyad is contrasted with the triad [in Simmel's German, 'associations of three']....Where three elements, A, B, C, constitute a group, there is, in addition to the direct relationship between A and B, for instance, their indirect one, which is derived from their common relation to C....Discords between two parties which they themselves cannot remedy, are accommodated by the third or by absorption in a comprehensive whole....Yet...no matter how close a triad may be, there is always the occasion on which two of the three members regard the third as an intruder. (Simmel 1950, 135)

In Simmel's view, the third can be non-partisan and a mediator, but can also be "the Tertius Gaudens" (the third who enjoys; Simmel 1950, 154). The third can line up with one of the two others and thereby gain his or her own advantage or can act as a broker between them and make a broker's profit. This latter possibility will be taken up at greater length when we consider Burt's "structural hole" argument (Burt 1992). Simmel also observed that the most certain way of compromising a secret between two people is to add a third to the "secret."

The addition of a third member to a dyad thus, perhaps surprisingly, vastly increases the complexity of relationships and sets the stage for our examination of whole networks in the next chapter. One important set of ideas hinges on the balance between the three members of a triad and leads to the classic "Balance Hypothesis." Intuitively, just as there is the aphorism "birds of a feather flock together," there is also the saying that "a friend of my friend is a friend of mine" and "an enemy of my friend is an enemy of mine." Beyond intuition, this can be more formalized as: "In the case of three entities, a balanced state exists if all three relations are positive in all respects, or if two are negative and one is positive" (Heider 1946, 110).

For example, the earlier network illustrating a triad shows all three relationships to be positive. But if A dislikes C and B also dislikes C, then it follows by the balance hypothesis that A and B like one another. Heider further contends based on the principles of Gestalt psychology that there is a tendency over time toward balance; "[i]f a not balanced state exists, then forces towards this state will arise." And further, "[i]f a change is not possible, the state of imbalance will produce tension." Even in an apparently simple network, the minimum structure for a "society," matters can be more complicated than they seem.

Martin suggests that given two emotional states (love and hatred) and extremely rational participants, there must be strong institutional support for the balance to emerge, for the simple reason that the "laws" of balance assume a reactivity that is the opposite of what would consider rational. Take the principle, "my enemy's friend is my enemy. It is a poor sort of enemy who allows himself to be guided by this maxim" (Martin 2009, 45). Martin explains that if A and B are enemies, it is good strategy for A to try to make friends with B's friend C and all of B's friends, thus leaving B completely isolated.

Whatever the chosen strategy, triads are analogous to molecules in a periodic table of elements. While there are only a handful of elements found in nature, molecules combine to form complex chemical structures, according to certain rules (in the case of triads, rules include balance, transitivity, homophily, and circles or foci, among others): "The triad census is thus a 'periodic table of social elements' and similarly able to categorize and build social structures."[8]

There are actually 16 possible configurations of triads, as shown in figure 2.2. We offer the figure for reference because of the great amount of work than has been focused on this, the most elementary network. Most of these analyses are beyond the scope of this introduction. Still, as we shall see, there are some interesting consequences to the possible arrangements of the triads and their nested dyads. In the next chapter on whole networks, we will show how different arrangements affect the interpretation of cohesiveness in a small club.

The first character in the triad name gives the number of mutual dyads. For example, there is one in triad number 3. The second character gives the number of asymmetric dyads, for example, 1 in triad number 2. The third character gives the number of null dyads, that is, no connection between pairs, as in the very first triad in which none of

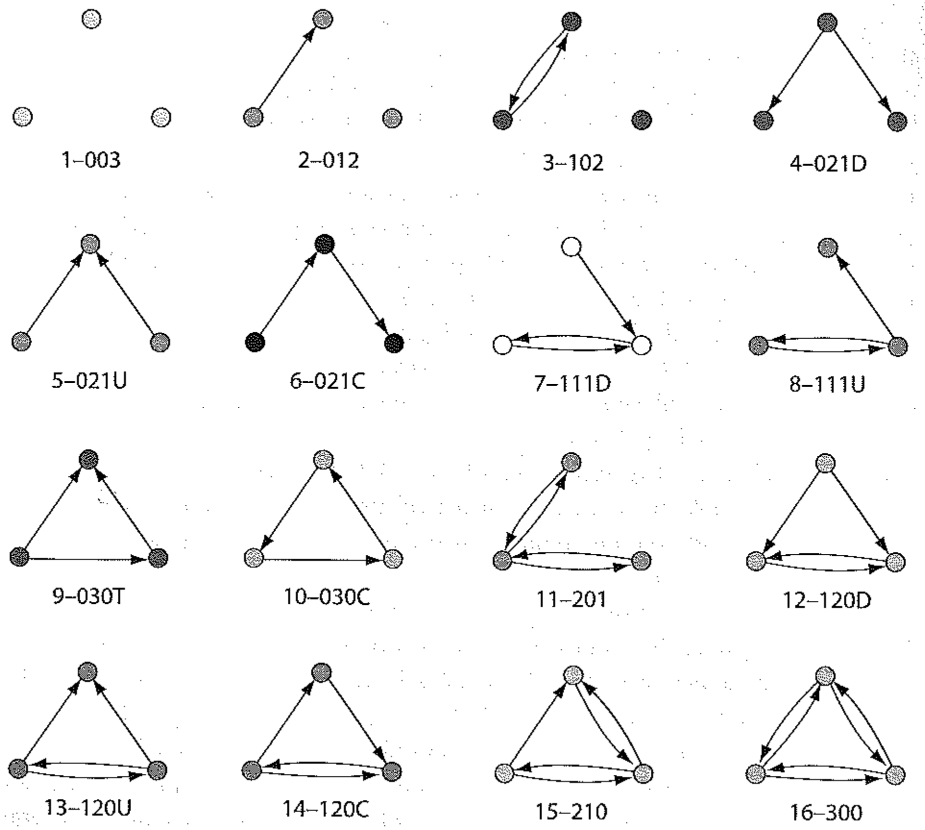

FIGURE 2.2 Sixteen Possible Configurations of Triads

the nodes is connected. The fourth character, if present, distinguishes between triads which are otherwise identical. For example, there are two 030 triads, number 9 and number 10. Number 9 is Transitive and number 10 Cyclical. Numbers 7 and 8 look alike except that in 7 the asymmetric pair has a Downward arrow or connection sign, and 8 has an Upward arrow.

The arrangements may seem obscure, but the census or count of configurations can be compared with the chance distributions of these configurations in any network and yield important insights about the network. In general, the triad census, that is, the distribution of the 16 types of triads in an actual network, the "local" processes in the network, has been very useful in evaluating theories about the global attributes of the entire network, especially since some theoretical structures of a network may be contradicted by the distribution of the triad types in a particular network. A network of interpersonal choices must have only certain kinds of triads. From the balance hypothesis, it follows that friends are likely to agree about a third party—if one of them likes a third party, both will like that person. And close friends agree more strongly about a third party than friends who are not particularly close. Configurations (numbers 7 and 8) that conform to this hypothesis should be statistically more frequent in a social network than configurations that do not. This balance tends to be supported in a wide variety of social networks in which the nodes are people (Wasserman and Faust , 596). International alliances also seem to follow the hypothesis (Antal, Krapivsky, and Redner 2006).Another property of triads related to the balance hypothesis is transitivity: if actor P chooses actor O, and actor O chooses actor X, then P is likely to choose X. For example, triad number 9 contains one transitive relationship, triad 12 contains two, and triad 16 contains six transitive relationships. In contrast, triad 6 is intransitive. Statistical tests "are very supportive of the proposition that interpersonal choices tend to be transitive" (Wasserman and Faust ,598). Intransitive triads are very rare.

Nonetheless, balance is only one theory about choice in a network and does have its limitations by postulating rigorous rules for relations that in messy social life do not always hold.[9] Homophily and its extensions are another cause of connections and, though related to balance, homophily takes account of the social and cultural structures in which a network is embedded. Social circles and foci of activities (see earlier discussion) are other reasons for relationships.

While the distribution of triads seems at first to be a limited idea, the prevalence of different combinations of triads can reveal a great deal about the entire network. We shall see in chapter 5 how transitivity defines the boundaries of a small group. Indeed, the plan of this book follows the heuristic that networks are built up from smaller components.[10] There is a class of network models that utilize the dependence of types of dyads and triads on various attributes of the actors within the network that are extremely useful in shedding light on the social processes within these networks, though work in this field is just beginning to receive wide application (Robins and Pattison 2005; Snijders, van de Bunt, and Steglich 2010; Wasserman and Robins 2005). We observed previously that tendencies toward reciprocity start early. So too do transitivity and balance. In the same study of preschoolers and social networks cited earlier, "children were more likely to select others as play partners when those ties increased the number of transitive patterns in the network" and "[t]hroughout the year, children became increasingly likely to form relationships with the friends of current friends"(Schaefer et al., 67).

Where We Are Now

We began with some simple definitions. A network is a set of nodes and a map showing the relationships between the nodes. The simplest network is a dyad. Relationships in a dyad can be undirected, mutual, or directed. When there is more than one relationship between a pair, such as coworkers and friends, it is called multiplex. Relationships are transitive when what holds for A to B, also holds for B to C. Triads begin to introduce a true social system. Finally, a description of social networks does more than merely list friends or supporters but rather reveals the extent of connections between them.

Socially interesting aspects of networks occur when homophily and propinquity are introduced. Sure, "birds of a feather flock together" but how this phenomenon occurs for individuals and for collectivities and under what circumstances forms the basis of social analysis, whether the subject be friendship patterns, corporate overlap, or international trade. Especially interesting is sorting out feedback and "chicken-and-egg" issues. People become more similar when they hang out together; but they hang out together in the first place because they are similar.

While there are major tendencies for balance in triads, other principles may also be at play. Groups and individuals may strategize to avoid the consequences of balance and try to make friends with enemies. People come together in different foci or social circles in which not everyone is symmetrically related to the others and yet they are a relatively cohesive unit.

Although triads are perhaps the analogue of molecules for networks, there is an even smaller unit—the dyad. Whole networks consist of many dyads—the basic building block of networks with which we began. Each connected triad is, as we have seen, composed of three dyads—within the pair the choices or connections are either reciprocated or not. A further fundamental aspect of a whole network is centrality or popularity. Then there is the density of the whole network: the number of direct connections or ties that exist, divided by the number of possible direct ties. Size is always important. Small groups tend to have high density, whereas large networks, though connected, tend to have low density. The email network of a university may connect all the students and faculty, but most of these are not directly connected so the email network is relatively sparse and has low density. This is typical of large networks. The distribution of reciprocated or unreciprocated dyads, centrality, and overall network density may account for most of the variance in the distribution of triads in human sociability networks (Faust 2007). This brings us directly to a more detailed discussion of whole networks in the next chapter.

3 Basic Network Concepts, Part II

WHOLE SOCIAL NETWORKS

IN THE PREVIOUS section, some basic concepts were introduced about nodes and the relations between pairs and triads. Key concepts that informed the discussion were homophily (the tendency of pairs of nodes to share the same characteristics) and balance (the tendency of the third in a triad to share or have a characteristic that complements the other two). Important as these ideas are, the essence of social network theory and analysis lies in a consideration of an entire network, to which we now turn.

A sociogram, the graph or diagram of a whole network, examples of which were shown in the first chapter, is one way to understand an entire network. As Yogi Berra reputedly said, "You can observe a lot by watching." However, sociograms that contain more than ten nodes are hard to grasp and subject to different interpretations depending on who is "watching." Analytic concepts and methods that account for the entire network and describe and summarize various aspects of it are necessary. *Distributions* of network properties are the first set of key descriptors and include the number of dyads and triads in the network. Other distributions discussed in this chapter include: *Density*, the number of connections contained within the network, and its opposite, *Structural Holes*, a category concerned with the lack of connections. A related concept, *Strength of Weak Ties*, hypothesizes that important things flow from people with whom one has limited connections. *Popularity and Centrality* demonstrate that some nodes have more connections than others and those connections serve as links to other nodes. Other distributions describe the *Distance* across the network between nodes. The radius of distances from any given node is an important descriptor. In terms of people, those nodes