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Conceptualizing the Multiteam System as an Ecosystem of Networked Groups

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This chapter will consider the multiteam system (MTS) as part of a larger ecology of networked groups and individuals that the MTS acts within and that, in turn, shapes the MTS itself. The original description of the multiteam system by Mathieu, Marks, and Zaccaro (2001) treated the MTS largely as a self-contained entity composed of several interacting teams, such as firefighters, emergency medical technicians (EMTs), and the surgical and recovery teams at the hospital. According to them, the MTS has a hierarchy of goals, stretching from the overall goal of the MTS (e.g., patient survival) down to the subgoals of each of the constituent teams (e.g., extract the victim from the wreck, or transport the victim to the hospital). Task and goal interdependencies lend the MTS its coherence as a system and provide a degree of closure for the system. Mathieu et al. noted that the MTS is situated within two types of environments, the embedding organization and the external environment, both of which include other groups that the MTS must relate to. This implies the existence of a group ecology for the MTS, though Mathieu et al. did not develop this idea much further.

This chapter will undertake to develop this line of thought more fully by advancing a model of an ecology of networked groups that compete for members and for tasks. This model was originally developed to fill a gap in our knowledge of human organization. We have a great deal of theory and knowledge about individuals, dyads, and isolated small groups, on the one hand, and about large aggregates such as markets, societies, and organizations, on the other, but there is remarkably little understanding of the behavior of intermediate to large groups composed of between eight and 200 members in natural contexts. Recent developments in theory and research on small groups and networks position us to develop a theory to fill this gap. This theory, network ecosystems theory, takes the form of a dynamic evolving set of groups that exchange members as they organize around various task foci. Evolution of the network of groups is driven both by microlevel network and group processes and by macrolevel network processes.

Multiteam systems operate in group ecosystems, and although not all group ecosystems are multiteam systems, many are. Multiteam systems are composed of networks of teams that must interact with an environment that includes other teams and individuals, many of whom are at least temporarily networked with the teams that comprise the MTS. As such, the MTS can be viewed as part of a larger dynamic network that is constantly evolving and exchanging information, assistance, and other resources with other actors and groups in the network. Hence, considering MTSs in group ecologies allows us to highlight group environment interactions in a more specific way than current theories of MTSs.

This chapter will be organized as follows. First, we develop a statement of the problem that motivates network ecosystems theory and a canonical description of the group ecosystem that will serve as the reference point for development of the theory. Second, we develop the theoretical framework as a series of propositions about the network ecosystem. Following this, we discuss the MTS in the context of network ecosystems and present an example illustrating how an MTS might operate in a network ecosystem. Finally, we discuss the implications of network ecosystems theory for MTS theory and research.

THE PROBLEM

Most previous research on small groups and teams has operated under a restrictive model that treats groups as well-defined, clearly bounded entities with a stable set of members. The vast majority of experiments on groups and teams take as their unit of analysis a single, small, isolated group whose members are assigned by the researchers. Studies of workgroups and other groups in natural settings, too, overwhelmingly focus on well-bounded, relatively small and stable groups, relying on managers or members to define the groups for study, and assuming that the group remains more or less stable and well bounded throughout the study. Viewing groups in this way makes conducting research on groups straightforward, because researchers have a well-defined unit of analysis that can be observed relatively easily. It is a simple matter to videotape a five-person group gathered around a table in the experimenter's laboratory. It is straightforward to administer a survey to a well-defined work unit (e.g., a nursing unit in a hospital) and the results of the survey clearly apply to this unit.

However, groups in their actual settings are much more complex entities than the small, stable sets of people considered in most previous group research (Putnam & Stohl, 1996). Although small, insulated groups can be found in many hierarchical organizations and traditional small businesses, it is more often the case that groups and teams must coordinate with other groups, and most members of a given group belong to other groups. Consider two examples:

- A nursing floor in a hospital runs two 12-hour shifts a day with two different sets of nurses (each working 3–4 12-hour days) for each shift. Nurses during each shift work in flexible teams to coordinate care for patients; these teams reconfigure depending on the specific mix of patients and their needs. Nurses working the two shifts must coordinate patient care at the handoff time, and nurses in one set must coordinate with those in another when a new set comes on. Nurses from the floor also serve on several committees, including five who comprise a quality improvement committee whose members also include a couple of physicians and a facilitator from human resources; a patient safety committee of five nurses; and two who serve as liaisons to the General Nursing Management Committee, which sets general policy for all floors in the hospital. This hospital floor can be viewed as one large team, as four teams composed of nurses in the same shift and set, or as seven teams if the three additional committees are added. The nurses also have to coordinate on an ad hoc basis with physicians and physical therapists to deliver care, improvising small groups "on the fly."

- An emergency response management team composed of two city fire chiefs, a county fire chief, city and county police chiefs, a city manager, and the director of the local Red Cross convene in the county response center to coordinate response to a train derailment that has resulted in a chemical spill and fire. The emergency management team must gather data from multiple sources, make sense of the situation, and plan a response, including assignment of personnel to teams, task assignment, supervision of responder teams, updating plans as new information comes in, and communication with the public about the incident. As the group works, its members will reconfigure into subgroups that deal with different aspects of the situation and work out elements of response. Some members will go out into the field to supervise response teams or coordinate different teams, effectively creating multiteam complexes that greatly expand the size of the team. The operative management team will decompose, then recompose as the response unfolds. Additional members with needed expertise will be added temporarily or permanently.

These groups differ in significant ways from the simple small group that is the focus of most extant research on groups. They "burst" the boundaries of the traditional idealized small group in several respects:

- They are large and are composed of subgroups that may be functionally and hierarchically differentiated.
- Their membership shifts over time, not only as a function of turnover, but also because the shifts are necessary to enable the group to do its work. A group may have core members, but other members who join the group temporarily to advance its work must be considered to have some status in the group.
- Their boundaries are ill defined, because their work requires them to adapt rapidly to changing demands. Like the nursing floor or the emergency response team, groups are nested within other groups, and in some cases two or more groups must coordinate so closely that they seem to merge into a larger working unit.
- Some subgroups (and, in some cases, the entire large group) form for limited-term projects and go out of existence when the project is complete. Members of these project teams are drawn from a pool of available personnel.

- Different subgroups within the larger group may have different goals, agendas, or concerns and may be subject to different influences. Hence, there is a diversity of generative mechanisms in operation in the ensemble of groups. These may also shift over time as groups develop or confront different contexts.
- The members may be spread spatially and temporally so that a particular "location" (such as an office) for the group cannot be specified. Instead, the group members come together in different patterns of subgroups as they need to collaborate. These subgroups are often temporary and improvisational, but the members act as a group when they convene and then disband to rejoin the larger group.
- Context, including the demands of task and environment, and the pool of individuals who are potential members of these groups and organizations exert a strong influence on the dynamics discussed in this list. In a real sense, these systems of groups are interdependent with their context.
- Because the groups are large and spatially dispersed, contextual influences may vary within the ensemble of subgroups and individuals that makes up the large group.
- The groups often deal with highly complex problems involving a large amount of diverse information. This requires expertise beyond that of its core members and necessitates external linkages to other groups and units.

This list of properties suggests several ways in which MTSs as described by Mathieu et al. (2001) are similar to large groups. They are dynamic in terms of tasks, goals, and team structure. They are dispersed over space. They are differentiated in terms of the goals of the teams making up the MTS and in terms of how the teams operate. They are networks of groups in particular relationships of interdependence. Although not all network ecosystems are MTSs, it seems that all MTSs could be analyzed in terms of group ecosystems.

The network ecosystems model is also designed to tackle an important problem that exists in research on social networks, though in this case it is turned on its head. Most previous research on social networks has primarily focused on entire networks with much less attention accorded to subgroups or parts of networks as autonomous units, except in relation to larger network generative mechanisms that generally operate at the level of the individual member, the dyad, or at most the triad. In this research, groups are regarded as cliques within the encompassing network, and their formation and existence are explained in terms of the overall mechanisms generating the network, such as balance or exchange. Network research does not usually acknowledge that individual groups within the network may have their own local concerns or generative mechanisms that drive the group's formation and behavior, or that various groups may have different concerns or generative mechanisms. This prevents network models from capturing the internal diversity that is characteristic of the ensembles of groups just discussed.

Network ecosystems theory attempts to integrate theories of small-group behavior with theories of networks. This integration has the potential to capture the effects of network contexts on small groups and to extend the reach of theories of social networks. This would also enable us to understand and to explain the behavior of a set of critically important groups that is currently inadequately studied.

THE NETWORK ECOSYSTEM

A broader picture of groups and networks that takes their dynamic and variegated nature into account views them as part of a complex system of groups and individuals operating as an "ecosystem." A canonical description of groups in complex ecosystems constituted by networks would offer the following picture:

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> A large set of N individuals is organized into M groups that undertake long-term projects that require them to carry out various tasks (McGrath, 1984). The membership of these units shifts over time as members enter and exit them. Units themselves form, develop, and disband or decay subject to the demands of the task and other group-level processes. Within the units, members take on specialized roles and accumulate experience and skills that can be brought to bear on various tasks that the unit must carry out. Tasks vary from relatively

simple and contained ones that can be done by a single person to more complex ones that require a small group to very complex tasks that require MTSs. The members take on tasks as they arise, and at any given time there is a mix of tasks being carried out in the unit, some by individuals, some by small groups, and some, less often, by large groups or by assemblages of small groups.

Some of the groups have relatively stable membership, whereas others are crews, which have a specific set of roles that can be filled by whatever qualified personnel are available to assign to them (operating room and airline crews are examples). Still other groups are special project teams composed of members specifically assembled for a particular task. For some tasks, groups are formed that include members from multiple units. Their success in these tasks is an important determinant of the overall effectiveness of the unit in its larger project and of the units standing among other units. Effectiveness also has consequences for individual members such as learning, reputation, and morale that make them more or less fit to serve in their groups in the future (and differentially attractive as members of groups).

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The ecosystem is composed of a dynamic network of individuals and units. Units are formed by networks of individuals whose structure reflects the demands of tasks and other group dynamics such as status sorting. Multiunit structures are formed by networks of units whose structure reflects the demands of higher order or more complex tasks and intergroup dynamics. Viewed longitudinally, we would see links forming and breaking in a temporal trajectory determined by workflows, task demands, changes in task, and endogenous network processes.

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In this basic model, the MTS would be viewed as organizing itself around various tasks and forming a multilayered network of teams based on task, communication links, and authority links. The model would assume that teams are not necessarily fixed units, but may dynamically reorganize themselves, as reflected in the different kinds of interdependence discussed by Mathieu et al. (2001).

NETWORK ECOSYSTEM THEORY

The theory is stated in the form of a series of propositions that characterize the dynamics of a network ecosystem. These propositions assume that (a) the individual-level processes that generate networks and groups, (b) group-level processes, and (c) higher order endogenous network processes form a heterarchy in which each operates autonomously and in which each influences the other two. The interaction of individual-, group-, and network-level generative mechanisms, as well as the impact of exogenous structural variables such as base rates and environmental "shocks," explains the network ecosystem.

Generative Mechanisms for the Network Ecosystem

Both group-level and network-level generative mechanisms operate in the network ecosystem. The network mechanisms are primary drivers, and once groups form, they take on a life of their own and generative mechanisms at the small-group level come into play.

The network generative mechanisms include both individual-level network generative mechanisms and endogenous network–level generative mechanisms. Monge and Contractor (2003) distinguished eight families of theoretical mechanisms that explain the formation, configuration, and dynamics of networks. One important individual-level generative mechanism defined in their analysis is *homophily*, which accounts for the emergence of links on the basis of trait similarity (McPherson, Smith-Lovin, & Cook, 2001 [redacted]). A second relevant individual-level network generative mechanism is *exchange*, which explains the emergence of networks on the basis of the distribution of information and material resources among network members (Cook, 1982). People seek ties with those whose resources they need and who in turn seek resources they possess. In this view, people would join a network so that they can exchange resources they need with resources they can offer. A third mechanism at the individual level is balance, which (Heider, 1958; Holland & Leinhardt, 1975) posits a consistency toward relations. That is, individuals are more likely to create transitive ties. For example, this would predict that people are more likely to form linkages with friends of their friends.

AU: Pls. add McPherson and Smith-Lovin (1987) to the refs.

Each of these network-generative mechanisms represents individual-level motivations—toward realizing personal benefits and reducing costs, toward achieving cognitive consistency, toward finding others like oneself, toward building social capital, toward engaging in collective action, and so on—that generate and sustain network linkages. The aggregate of these individual behaviors yields the network. Most network theories, such as those that McPherson and colleagues have developed around the principle of homophily, presume that a single motivation predominates or can serve as a conduit for other motivations (e.g., homophilic bonding with others might serve one's self-interests and help to achieve balance). More complex theories such as Contractor's multitheoretical network model argue that certain sets of generative mechanisms are compatible because they function to realize higher order goals. For example, in a network dedicated to exploiting resources, the collective action, balance, and contagion generative mechanisms would work together to drive network formation and maintenance.

The other network dynamic is driven by endogenous network–level generative mechanisms. Once a network becomes a going concern, higher order connectivity among members sets in motion downward-acting generative mechanisms that are independent of individual-level and group-level generative mechanisms. There are multiple ways in which this might occur (Kontopoulos, 2006), of which two common examples will be given here. First, network-level generative mechanisms may set up a preference for certain dyadic, triadic, and group-level linkage patterns that influences lower level processes. For example, once a homophilic network attains a certain critical mass of linkages, it becomes self-sustaining in that new members and new linkages that are homophilic are preferred over those that are not. This occurs because of structural properties of the network as a whole, independent of individual-level choices. With many members interconnected by homophilic bonds, for instance, bonds of other types become "dispreferred." Forming bonds on other principles, such as connecting to someone different from oneself to build social capital, runs against current network organization, which is reinforced by the prevalence of preexisting homophilic linkages. This is a type of the autocatalysis often observed in complex systems.

Second, the higher order network may create "spatial" inhomogeneities such that individuals and groups are separated by different partitions of the network in which certain dynamics are forced on occupants. For instance, once a homophilic network is set up, different regions of the network may be reserved for different social groups (e.g., different races), in essence forcing members to leave one area of the network and enter another.

A second level of generative mechanisms in network ecosystems operates at the small-group level, in groups of three to seven (and sometimes more) members. When small, cohesive groups form in a network, they operate as a semiautonomous unit driven by their particular group dynamics. These groups are self-organizing systems within the network that are influenced by individual-level network generative mechanisms, but once they form they support independent generative mechanisms. For example, a set of individuals linking on the basis of homophily that achieves sufficient connectivity and multiplex interdependence among members to form a densely connected group is likely to develop social identity dynamics. Research on social identity in small groups suggests that in addition to sustaining and reproducing homophily as a basis for grouping, other more complex dynamics develop, including a tendency to differentiate members according to status or role within the homogeneous group (Abrams, Hogg, Hinkle, & Otten, 2005). This dynamic toward differentiation, which will be discussed in more detail under subsequent propositions, serves as an autonomous generative mechanism within the network. ~~A number of such generative mechanisms are discussed within the set of perspectives on small groups listed in the "The Network Ecosystem" section of this chapter.~~

All three generative mechanisms interact to affect individual outcomes, group formation, and network formation, maintenance, and change. They are related in a heterarchy in which each affects the others, but each also has autonomy. The relative strength of the generative mechanisms at different levels, how they relate to each other, and the impact they have on individuals, groups, and the network vary. In subsequent propositions, we discuss some ways in which they relate.

Because individual network generative mechanisms are the initial drivers of group formation, group-level generative mechanisms are initially homologous to the network generative mechanisms. The group mechanism homologous to homophily is social identity (Abrams et al., 2005). The specific social identity formulation that most closely matches the homophily principle is social categorization theory. The dynamics of social categorization—an emphasis on distinctive social categories, the valorization of one's own group compared to other groups, the stereotyping of other groups, and the development of distinctive group ideologies—offer explanations et al.'s (2001)

for the enactment of homophily at the microlevel that are consistent with McPherson's discussion. There are two homologues to exchange, group exchange (Thibaut & Kelley, 1959) and functional mechanisms in which there is a division of labor among members and member behavior functions to enable the group to achieve its goals (Hollingshead et al., 2005). Finally, balance principles operate in both networks and small groups. Taylor (1970) developed a rigorous theory of balance in small groups that can easily be linked with the balance formulations of networks that were developed in the 1970s and 1980s.

AQ: Pls. add a cite for 'McPherson's discussion' and pls. add to the refs if needed.

Interactions Among Generative Mechanisms at Different Levels

Once a network becomes a going concern, its structure at the macrolevel may autocatalyze the formation and maintenance of future links according to the individual-level generative mechanism drivers that constituted it. This counteracts the ability of competing generative mechanisms to get started to some extent. This downward influence is imperfect and does not wholly determine what happens at the individual and group levels.

The strength of the autocatalysis varies depending on the structural immediacy of the network generative mechanism and network carrying capacity. Autocatalysis is promoted by individual network generative mechanisms that have a high degree of *structural immediacy*, defined as the degree to which link generation and maintenance are based on node-to-node processes. The generative mechanism of homophily, for example, is high in structural immediacy because nodes associate based on a direct evaluation of their similarity in an immediate one-to-one fashion that results in growing networks of homophilous linkages. Other generative mechanisms with high levels of structural immediacy include contagion, simple exchange, and self-interest in market economies. Generative mechanisms lower in structural immediacy and therefore likely to result in weaker autocatalysis include balance, collective action, and generalized exchange, which all generate links based on multinodal patterns.

(Monge and Contractor, 2003)

Autocatalysis will be limited by network carrying capacity. Monge, Heiss, and Margolin (2009) argued that intra- and interorganizational communication networks have carrying capacities, that is, maximum numbers of linkages that they can sustain. It is well known that the number of potential linkages in a communication network can increase geometrically with linear increases in the number of nodes. For example, if everyone were to connect to everyone else, a network of 10 people would have 90 links, whereas a network of 11 people has the potential for 110 links. But the individuals and groups in a network have limits on their time and energy that constrain the number of actual linkages they can create and sustain to a value well below the number of potential linkages. The nearer the network gets to its network carrying capacity, the weaker the autocatalysis should be.

As the network ecosystem initially forms, individual members try to link to others based on motivators such as homophily, exchange, and balance. These represent competing "bids" for network formation. The fitness of these bids is determined by the various foci that the network is forming around (Feld, 1981) and also by exogenous shocks to the system.

Two aspects of foci can be defined, their purpose and their physical locations. Purposes for foci can be differentiated into task, social, and normative ones. Some foci attract members on the basis of the tasks they require them to do, whereas others attract members based on the need to socialize (e.g., bars or playing fields), whereas still others attract members based on normative considerations (e.g., churches or courts). To use the example of the MTS developed by Mathieu et al. (2001), when there has been a severe accident, firefighters, police, and EMTs converge on the location of the accident and each organizes around tasks, such as controlling the perimeter, keeping gawkers at a distance, putting out any fires, extracting the victims, stabilizing them on the spot, loading them into the ambulance, and transporting them to the hospital, a different location where other task foci organize the work of the surgical and recovery teams in different places within the hospital (ER, operating room, recovery room, intensive care, etc.). In this case, the foci will tend to favor network organization based on functional and exchange principles where each member gathers at the task focus that is suited to his or her skills and operating routines, which will result in a distribution of members across various locales according to task assignments. This will result in preservation of the reticulation mechanisms of exchange and homophily by profession (because firefighters, EMTs, and surgical teams are typically organized into coherent practiced units of members of a single profession).

Exogenous shocks to the system, such as a power struggle between a police commander and the fire chief who has ultimate control over the accident scene, or a sudden escalation of the emergency to a much larger disaster (e.g., the accident involved a fuel truck that suddenly exploded, razing adjacent buildings and starting fires in them), also shape the fitness of ~~reticulation drivers~~. The power struggle between police and fire chiefs would tend to favor reticulation according to homophily. On the other hand, sudden expansion of the disaster would likely favor functional division of labor, because the different professionals would have to help each other on common tasks (e.g., carrying wounded colleagues to safety).

Once groups form around a ~~reticulation driver~~, they exhibit a property of self-closure and become self-organizing systems. When small groups form self-organizing systems, they serve as powerful "amplification devices" for network generative mechanisms, because they represent densely connected regions of the network that have the potential to sustain a generative mechanism by virtue of the interdependent action systems they represent. Pressures toward conformity in small groups are powerful (and sometimes repressive) forces reinforcing homophily, because once in place these pressures tend to be self-reinforcing and self-sustaining. In the same vein, once a system has been set up, exchange in small groups creates a self-perpetuating system that rewards similarity and withholds rewards from those different from the group, thus providing another mechanism for enacting homophily and for regulating the flows of information, advice, and help among members of the network. ~~Often there are multiple homologous explanations for network generative mechanisms at the group level, which offers an explanation for the diversity of principles in network formation and maintenance.~~

Group-level processes are also complex and have their own internal dynamics that introduce additional "twists" into the network processes. These have the potential to explain network dynamics in much more detail than individual-level network generative processes allow. For example, in networks formed in terms of exchange principles, another functional theory, the collective information-sharing model (Hollingshead et al., 2005), would specify which information would be most likely to be shared with the group. This model presumes that information is distributed among members and specifies mechanisms that govern which information is most likely to be activated in the discussion; information shared by several members of the group is more likely, for example, to be contributed than is information held by only one member. Sharing of information at the group level is likely to influence group outcomes, which provide value to members in return for their exchange of information. To the extent that the members do not share information adequately and the group is less effective, other network ties are likely to be more attractive to members and the group is likely to dissolve, thus changing the overall network topology.

What determines the fitness of a given group that forms in the network ecosystem? First, the constraint of the focus determines the coherence of the group. *Constraint* refers to the degree to which the focus requires participation by members. For example, in an emergency situation, a fire in the vehicle that has victims trapped in it is strongly constraining and almost demands participation (Corman & Scott, 1994). Second the degree of activation of the focus determines whether it actually gets attention. Activation is triggered by events that make the focus salient to members. In a disaster situation in which a fire suddenly breaks out in a damaged vehicle, the focus is activated and likely to attract the group. So long as it remains activated (e.g., until the fire is put out), it is likely to retain members (Corman & Scott, 1994). Third, foci vary in strength, with some having stronger organizing properties than others. In the disaster just described, if a propane tank nearby suddenly explodes into flame, the burning vehicle becomes a much less strong attractor for group formation than the propane tank. Group performance also contributes to fitness. If the group is performing well, there are rewards for members and an incentive to stay in the group. Groups that meet their members' needs are also likely to be fitter, as their members will remain as well.

There is an interesting twist on fitness in the preceding discussion. In evolutionary theory, *fitness* is generally defined as surviving to reproduce. However, in the network ecosystem, groups come into and pass out of existence as their foci are activated and deactivated, so there is no reproduction. Instead, fitness is determined by comparative ability to cohere compared to other possible groups that might form in the space.

A complex mix of generative mechanisms operates at the group level, generative mechanisms that are often self-reinforcing and self-perpetuating due to the nature of the group system. These mechanisms can influence the formation and quality of linkages in the network and the interactions that occur in the network. From this, it follows that one or more generative mechanisms other than those engendering the encompassing network may come into operation at the group level.

For example, assume that homophily is the major organizing principle in a network. As noted, homophily at the network level is likely to engender and be generated by social identity processes at the local level. However, although social identity dynamics do create a tendency toward sorting on similarity in the network, once this has occurred, a countervailing process is likely to result. Within any group of similar people arise forces leading to differentiation; once people are comfortable that they are with "their kind" and no longer feel threatened, they begin to wish to differentiate themselves. This is reflected in the "optimal distinctiveness" model within the social identity perspective (Abrams et al., 2005) This complexity at the local level reflects the dialectic between wishing to be part of a larger collective and wishing to be independent (Smith & Berg, 1987). This countervailing process sets in motion an alternative generative mechanism that is different from that fostered by the network generative mechanism.

Networks also affect the composition of groups. People in the ecosystem are limited in terms of the time and energy they have to put into relationships of various types and also in terms of their opportunities to form linkages with others. The topology of the network determines who has open time to form new links and who is currently not available due to saturation of possible involvements or simply due to base rate demographics in the network. If, for example, most people similar to person X are already "taken" in the network, this may cause X to seek out partners on bases other than homophily. If there are only two people in the entire network with a particular skill or expertise, then the number of linkages that can form based on complementarity is necessarily limited.

Multiple Generative Mechanisms in Networks

The foregoing implies that different generative mechanisms may be in operation in the same network ecosystem. The simplest case is when the network is segmented into two or more relatively independent regions. In this case, different generative mechanisms may be in operation in different parts of the network.

A second case was implied by previous propositions: A variation may begin to take hold within a region of the network previously dominated by a particular generative mechanism. In this case, the new generative mechanism grows within the existing one, carving out its own space in the network. It could be either beneficial or a "cancer" depending on one's point of view.

It is also possible for two or more network generative mechanisms to be compatible with each other and operate simultaneously within the same network space. Contractor and colleagues (Contractor, Wasserman, & Faust, 2006) have empirically tested Meaningful Text Markup Language (MTML) predictions in over four dozen networks, using recent advances in exponential random graph-modeling techniques. Their findings across the networks indicate that the individuals' motivations to create, maintain, and dissolve ties with other individuals or knowledge repositories are a complex combination of multitheoretical motivations. No one theoretical motivation is consistently superior or inferior to others. Instead, they tend to work in ensembles.

Contractor et al. (2006) proposed that variation across networks reflects the diverse tasks that are being accomplished in these networks. The contingency framework proposes that the likelihood of a theoretical mechanism explaining the network will depend on the goals of the group. They identified five goals commonly found in the networks they investigated:

- *Exploring* refers to networks whose members are in search of new information or undiscovered resources. Theories of self-interest, cognition, and contagion are more influential in explaining networks whose goal is exploring.
- *Exploiting* refers to networks in which the major impetus is to maximize members' ability to exploit the resources that already exist in the networks. Collective action, cognition, and exchange generative mechanisms are most influential in exploiting networks.
- *Mobilizing* refers to networks whose members are trying to organize toward some collective action. Collective action, balance, and contagion are the generative mechanisms that explain these networks best.
- *Bonding* refers to networks in which the main objective is to provide social support. The generative mechanisms of balance, exchange, homophily, and proximity are more influential in the formation of networks whose goal is bonding.
- *Swarming* refers to networks where the ability to gear for a rapid response is a high priority. Collective action, cognition, and proximity best explain these networks.

Each of these goals defines configurations of compatible and complementary generative mechanisms for networks or subnetworks. Obviously, different configurations could also operate in different regions of the network, as in the first two cases discussed in this section.

Variation in the Mix of Generative Mechanisms in the Network Ecosystem

There are two major sources of variation in generative mechanisms in network ecosystems. Group-level generative mechanisms may produce variations that compete with existing generative mechanisms in the network ecosystem. The self-organizing and autonomous nature of small groups within networks gives alternative generative mechanisms a space to develop in for a time.

For a local-level generative mechanism that differs from the prevailing generative mechanism(s) at the global network level to gain a foothold depends in the first instance on the nature and robustness of local-level processes. Consider the example of optimal distinctiveness mentioned in this chapter. If the group in which this differentiation occurs is secure and free from outside threat via contact with another social group that is putatively more powerful or superior, then the differentiation will proceed apace and a differentiated social structure will develop in the group. If this differentiated structure develops complementary roles—for example, task and socioemotional leaders, procedures experts, and followers—that are rewarding to members because they help it operate more effectively and bring success (and rewards) to the group, then a competing generative mechanism of exchange may be set into motion. On the other hand, if the group is confronted by a threatening outside group, distinctiveness dynamics are likely to be dampened, whereas in-group and out-group processes that reinforce homophily are fostered. In this case, the alternative generative mechanism is not likely to develop fully or to persist. Local conditions provide the materials that enable a small fire to get started from the tinder, so to speak. Whether this fire spreads depends on selection processes in the network to be discussed in this chapter.

A second source of variation is factors exogenous to the network ecosystem. Interventions by external authorities that change assigned tasks or goals or that impose norms on the network ecosystem may give rise to variations in generative mechanisms. Each of these represents a "perturbation" in the existing network. The nature of the new task or norm may be such that it organizes members of the network system according to a generative mechanism currently in operation, but it may set up a competing generative mechanism. For example, if the emergency takes an unanticipated direction, as with the chemical explosion mentioned previously, this may also lead to wholesale reorganization of the network system. In cases where there are regular sequences or cycles of tasks, networks may undergo periodic reorganization. Organizations that must design new products and then put them into production typically require two types of networks, one densely connected and easily reconfigured for innovation, and a second that is more hierarchically and tightly configured for production (Zaltman & Duncan, 1977). In some organizations, these two networks are achieved by partitioning the organization, whereas in other smaller organizations there would be oscillations from decentralized to hierarchical networks over time.

Other exogenous factors that influence network systems include the entry of new individuals or organizations into the larger organizational set in which the network ecosystem is embedded, changes in the network's environment due to factors such as new technologies, changing legal requirements, or a financial crisis. Some of these exert continuous pressure on the network, whereas others are "shocks" to the network system, but all present opportunities for the introduction of novel generative mechanisms into the network.

Once a novel generative mechanism takes hold, it can spread to other nodes in the network, and ultimately (a) it may be extinguished by the existing dynamics; (b) it may create its own space of operation, thus partitioning the network; (c) it may enter into a commensalistic relationship with existing network mechanisms; or (d) it may outcompete existing mechanisms and take over the network.

Selection of Generative Mechanisms in the Network Ecosystem

Selection among the various generative mechanisms is influenced by six factors: (a) characteristics of the niches in the ecosystem, (b) base rates of individual role types in the network ecosystem, (c) autocatalysis, (d) dissipative structure, (e) emergence, and (f) overall network configuration.

The niches in any ecosystem of task groups correspond to *activity foci*, sites at which members assemble around a common activity or to garner resources (or both). Just as tasks can be layered—one task may be broken into subtasks, and the subtasks into component tasks, and so on—so too are foci layered. The characteristics of a task focus include the following:

- Its location: proximity to and distance from other foci
- Subtasks: foci embedded within foci (if any)
- Within-unit interdependencies: the various roles involved and how these roles relate to one another
- Between-unit interdependencies: the roles that different units within the focus undertake and how these units relate to one another; also the relationships between foci if there are multiple foci
- Task difficulty and complexity of the task and its subtasks (if any)
- The tools required

This corresponds to the multitiered task and goal hierarchies discussed by Mathieu et al. (2001) for MTS. Together these characteristics influence how reticulation of groups and the networks occurs and the particular generative mechanisms that are supported.

The foci in group ecosystems vary in terms of stability. Some are quite stable, as would be the case in a factory in which work stations are set out systematically for a continuous, stabilized workflow. Other group ecosystems may have foci that rearrange dynamically as components of the task are completed and new aspects develop. Product development departments often are organized around tasks that shift and change as the product evolves, problems emerge, and different stages of the development process unfold.

Following Thompson (1967), within-unit, between-unit, and between-foci interdependencies may be of three general types: pooled, sequential, and reciprocal. *Pooled interdependencies* are cases in which the work can be distributed to different individuals or units who work in parallel and independently and then pool their work after completing it. *Sequential interdependencies* are cases in which one person or unit finishes its work, passes it on to the next, and so on until the work is finished. *Reciprocal interdependencies* are cases in which the units must coordinate their efforts and pass the work back and forth among them, often in a very complex pattern. Types of interdependence—and combinations or sequences of them—will shape the nature of the interaction in the network and thus the selection of generative mechanisms. For instance, pooled interdependence among subtasks in a focus would encourage a sparse network by dampening the tendencies to create links based on social capital or exchange between those working on different subtasks.

A second factor influencing selection in a network ecosystem is the number of individuals capable of filling the various roles required by the task, the base rates of individuals in the population. In a day care center with 60 children and an ideal teacher–child ratio of one to six, the center can function at its best only if at least 10 teachers are in the center on any given day. If fewer teachers are available, then a network system premised on setting up quality exchanges between children and teacher may be reoriented to one in which those teachers who are thought by their colleagues to be excellent at dealing with difficult situations would be allocated additional children (a system based on cognition about the network and exchange).

A third factor that governs selection in network ecosystems is the autocatalysis discussed previously. Structural immediacy will promote autocatalysis and thus favor the selection of generative mechanisms similar to those already ascendant in the network. Autocatalysis will dampen as the network carrying capacity is approached, thus lessening selection pressure on different generative mechanisms.

A fourth factor in selection is the formation of dissipative structures. As we noted under a previous proposition, group-level processes give the variation "energy," and, if sufficiently robust, they can form a strong foundation for the persistence and spread of the generative mechanism, much as the dissipative structures described by Prigogine and colleagues are able to maintain themselves in part through the expenditure of localized energy. Certain types of network generative mechanisms may also generate the resources or energy required to sustain themselves. The self-interest, mutual interest, exchange, and coevolutionary network generative mechanisms seem particularly likely to have this characteristic, because they confer material or intangible reward on participants.

Fifth, selection is influenced by the type of emergence through which groups emerge from individual-level network processes and clusters of groups from groups. The nature of emergence shapes how well established the competing generative mechanisms are.

Kozlowski and Klein (2000) distinguished two ways in which higher level phenomena can emerge from lower level phenomena, composition and compilation. In *composition*, the higher level property emerges from the convergence of similar lower level properties that add together to yield a whole that has the same property as the sum of its parts. Homophily is one such process; lower level members and dyads choose those like themselves, and the sum of these choices yields a homophilous network. Other network generative mechanisms that seem compatible with composition are balance and contagion. When emergence occurs through compilation the lower level units have different properties, and it is the relationships among them and their complementarities that result in the emergence of the higher level property. So in exchange lower level members, dyads, and groups develop distinct competencies or resources and link to other units that have complementary ones, yielding a whole that is distinct from its parts. Other network generative mechanisms that seem to work on a complementary basis are self-interest, mutual interest, cognitive mechanisms, and collective action.

Composition occurs quicker and is more straightforward than compilation, because it operates via enlistment, that is, through individual unit changes where units are more or less independent to make changes. However, emergents based on composition are also relatively fragile, because members can be taken off or "de-enlist" one by one with little consequence for the whole emergent. *Compilation* is slower and requires more effort than composition, because members form interdependencies. Emergence thus requires coordination among lower level units. Once established, emergents based on compilation are relatively durable, precisely because they are constructed of interdependent units that mutually support one another's adherence. Members cannot leave or be taken off the assemblage without upsetting the interdependencies, so the network is likely to mobilize resistance or to rapidly seek out replacements. So the nature of emergence affects the speed with which networks organized around different generative mechanisms emerge and their durability in the face of counterpressures that might erode them. Hence, in very new networks, those formed by composition are likely to be more robust than equally new networks formed by compilation and also to find it easier to penetrate existing networks than compilation-based networks. In more established networks, however, the obverse is likely to be true: Compilation networks are more likely to be sustainable in competition with composition networks and also in competition with preexisting established networks.

Finally, the structure of the global network also influences selection. If the global network is segmented into relatively independent portions, these may support different mechanisms or configurations of mechanisms in a sort of peaceful coexistence. On the other hand, if the development of the network brings the competing generative mechanisms into contact, then one or the other is likely to spread and prevail in the network.

Different individual-level network generative mechanisms are also likely to foster overall configurations with differential selection strengths. Some of the generative mechanisms are more likely to leave "gaps" in which they do not operate strongly, enabling local variations to persist and grow. For example, balance is likely to leave gaps in the network, because balancing processes are subject to incompatibilities in relationships that "block" the balance process. Taylor (1970) noted that long cycles of relationships that must be balanced have less effect on target persons, making them less likely to change to restore balance. A network with many long and complex cycles will have weaker tendencies toward balance. Taylor also observed that there were tendencies toward unbalance in networks governed by balance, which suggests that gaps will form. In these gaps, where the impact of the generative mechanism is relatively weak, there is an opportunity for variations to take hold and spread. Homophily, on the other, hand, has a high level of structural immediacy. It is likely to be more difficult for variations to take root and spread in a network governed by homophily than in one governed by balance.

Then too, some network generative mechanisms are likely to spread variations. In a network with strong contagion processes, the behaviors, values, and attitudes underlying variations are likely to spread. Indeed, contagion can act as a mesolevel process in the respect that it enables the group-level generative mechanism to "jump" to other portions of the network. A network organized according to balance principles is also likely to propagate variations, because this generative mechanism assumes that links and nodes change in order to become more consistent.

Coevolution of Generative Mechanisms

The evolution of networks occurs during episodes, each of which consists of a period of instability and change followed by a temporary equilibrium in which the network ecosystem stabilizes. The instability represents a transition to the new stable state, which could consist of a single network governed by a uniform generative mechanism, a set of compatible generative mechanisms, or a partition of the network ecosystem into subnetworks governed by competing generative mechanisms.

The temporary equilibria vary in terms of their stability and durability. Overall, we would expect networks organized around a single generative mechanism or a set of compatible mechanisms to be more stable and durable than those in which there are two or more incompatible and competing generative mechanisms. Further, as noted previously, depending on whether they are constituted through composition or compilation, networks may vary in their robustness and durability.

The development of the network system over time occurs through a series of episodes in which the network ecosystem moves from temporary equilibrium to temporary equilibrium, shifting its mix of generative mechanisms over time. Group-level processes and exogenous factors continue to introduce variation into the network system, which destabilizes the existing equilibrium and initiates a new episode, which ends in another equilibrium.

From this, it follows that networks may reconfigure if one network generative mechanism outcompetes the prevailing mechanism. When this occurs, a new set of network influences is introduced, and this may change which generative mechanisms are able to operate at the group level. This in turn creates new possibilities for variation at the local level that then influence the global level in a continuous loop of influence.

AN ILLUSTRATION OF A MULTITEAM SYSTEM AS A NETWORK ECOLOGY

The MTS of emergency responders in Collegeville, U.S.A., offers an illustration of a network ecosystem. At the outset, the fire, police, EMT, and college police operated relatively independently of one another, as is the case in most communities. Although they were capable of coordinated response similar to that in the MTS example from Mathieu et al. (2001), which has been used throughout this chapter, their network was organized primarily by the homophily mechanism. Each profession largely kept to itself, and teams were organized separately for fire, police, EMT, and university police. Within these teams, as might be expected, social identity processes were strong and members were differentiated according to status hierarchies based on optimal distinctiveness in terms of seniority, skill, and "manliness" (Desmond, 2007). As in most towns in the state in question, if a large disaster occurred, the fire chief was authorized to take charge of the situation and exert command and control over the other units.

A major crisis occurred when a historic downtown building that was being remodeled caught on fire. It went up in flames much faster than anyone expected and burned much more fiercely, probably because some wood-refinishing supplies served as accelerants. The fire was so severe that several adjoining buildings were threatened. The fire chief coordinated the response of the Collegeville firefighters, police, and EMTs. The three groups worked in parallel and largely kept to their own tasks. In several cases, fire teams found themselves tangled with police personnel who were trying to make sure that the crowd at the scene was under control and safe, and this was the source of some friction, both at the scene and afterward in the after-action review.

Cognizant of the shortcomings of the previous response, the fire chief invited officers from the fire department, police, EMT, and college police to the yearly training offered by the state Fire Service Institute in the National Incident Management System (NIMS). This training focuses on preparing participants to fulfill the various roles involved in planning for and carrying out incident management, including those of incident commander, operations chief, safety officer, logistics chief, and communications officer. The team prepares an incident management plan, and the various officers then take charge of their sphere of duty. The incident management team is multidisciplinary, and participants may cross-train to fulfill multiple roles. Just as important as the training itself, stress Fire Service instructors, is the development of relationships and trust among participants. As one instructor commented, "We really cannot prepare them for any specific disaster, because every one is different, but we can help participants understand their roles and build relationships among them, so that when a disaster does occur, they can work together smoothly as a team."

Ranking officers from the fire department, police department, EMT services, and college police department were assigned to an incident command team and engaged in planning in response to a simulated disaster. The team used the NIMS forms to guide their work and developed an incident management plan. A fire captain served as the incident commander, an assistant police chief the operations manager, an EMT the safety officer, a college police sergeant the communications officer, and a police lieutenant the logistics officer. Because the entire team had been trained in NIMS and planning, members could take on any of these roles. The planning exercise built trust across the professions and gave them some practice in working together. The NIMS process provided a structure for the team's interaction. In this workshop, networking among participants was based on the task focus of the exercise, and members networked based on role interdependencies, rather than homophily or social identity. At the group level, team processes were driven by functional interdependencies.

When the next big disaster struck, the incident management team network formed around the task focus of planning in an incident command truck, and networking was based on functional interdependence. The action teams in the field still worked as cohesive units with their own profession (e.g., fire teams or EMT teams), but due to the planning and coordination among their supervisors, there was much less confusion and interference among the teams. In this network, the seed for functional interdependency as an organizing principle has been planted in a portion of the network, which has partitioned itself off from the rest of the network of actors who link according to the principle of homophily.

IMPLICATIONS FOR RESEARCH

Empirical research on this framework requires longitudinal designs that capture data on links among individuals in the ecosystem and also on generative mechanisms relevant to the local level, such as social identity. This research will require a large data set with multiple measures of constructs at both the network and group levels and large numbers of observations at successive time points. Fitting successive network models that change over time requires significant amounts of data.

The study of a network ecosystem requires researchers to collect network data either continuously or at regular intervals. Continuous data collection would require either automated recording of information relevant to inducing linkages or a continuous record such as video recordings of the ecosystem. Automated records of the network ecosystem could be obtained by monitoring message traffic over radio frequencies used by participants. Another way of obtaining automated records would be to access information systems that record participants' behavior. Williams, Contractor, Poole, Srivastava, and Cai (2009) described a research project that uses the databases of massive multiplayer online games to study dynamic networks that include group ecosystems. The databases record every major movement and transaction made by the players and so enable researchers to follow networks of dynamic groups over time. An additional advantage of game databases is that they preserve information about characteristics of participants (that is, of their avatar characters), task difficulty, and objectively measured outcomes and so allow discrimination between links formed on the basis of exchange, social identity, and some other network generative mechanisms.

A continuous record of the ecosystem can also be obtained by video and audio recording the ecosystem over time. This poses a challenge for data management and analysis, because network ecosystems are composed of many actors spread around a large space, unlike the nice, neat groups in labs that can be recorded with a single video camera. Recording an MTS at work requires multiple cameras and personal audio recording for each member, and might also involve other types of sensors (e.g., infrared cameras in the case of firefighters) and instruments. Managing and analyzing this massive body of data pose a major challenge. In a separate project (Poole et al., 2009), we are developing GroupScope, an observational and analytic system for large groups distributed over large physical areas. GroupScope, currently under development, uses IT to manage retrieval, annotation, and coding of large numbers of videos and audios. Developing it requires developing a suite of tools to identify automatically the best segments for human analysis, map networks from video data, and capture text from audio.

A key problem facing analysts of data gathered either automatically or through continuous recording is how to identify network connections from data that are not relational in nature. Various algorithms have been developed to extract network information from databases (see a high-level description in Williams et al., 2009). Mathur, Poole, Pena-Mora, Contractor, and Hasegawa-Johnson (2009) described an algorithm for identification of network linkages from video data. It is presently partially automated, and when fully automated should allow accurate link detection when combined with transcriptions of interactions.

In addition to records or observational data, it is also important to have subjective responses of the members of the MTS and network ecosystem. It is not practical to collect repeated measures of network ties from members. However, members can provide valuable information on why they selected partners, what the characteristics of foci are, and other information that can be used to validate measures based on records or observation.

In terms of analysis of the network data, Contractor et al. (2006) have developed procedures to test for the various generative mechanisms based on signatures of the mechanisms, particular patterns of links that signal that the operation of a specific generative mechanism. In order to test the framework, it is necessary to find ways to partition the network into portions in which different generative mechanisms prevail and to track shifts in generative mechanisms over time. ~~Contractor et al. (2007)~~ are currently working on methods suitable for undertaking these tasks. They involve (a) identification of groups from the bottom up in terms of member–member relationships, member–group relationships, and group–group relationships using group cohesiveness thresholds; and (b) tracking the movements into and out of groups via sparse matrix techniques and parallelized Markov chains.

At the group level, we must specify the particular group processes expected to be in operation, because the set of possible dynamics is much too large to inductively sort through them. This can be done deductively by specifying which group theories are likely to hold in a given context; previous research in the context of choice can provide guidance as to which group dynamics are most likely to be in play. It could also be done inductively by making an initial determination of the generative mechanisms governing the network for a portion of the longitudinal data and selecting homologous group theories. The deductive approach seems preferable, because it gives some a priori guidance as to what to measure.

DISCUSSION

In this chapter, we have discussed a theoretical framework that unifies global network theory and theories of groups, dyads, and individuals at the local level. There are at least two potential benefits of this integration. First, it provides a foundation for the study of a behavior in a class of social phenomena that has hitherto been largely neglected, the large networks of groups with membership between 7 and 200. Network systems of this type perform many important functions, and careful study of how they form, operate, and dissolve has both theoretical and practical significance, particularly for networked MTSs. For instance, we do not have good theories of what makes groups of this size effective, and study of their behavior could lead to improved understanding.

A second benefit of this integration is its potential to lead to a more general theory of group and network behavior. By conceptualizing networks as ecosystems of groups and individuals and groups as embedded within larger network ecosystems, we begin to be able to see what seem to be two disparate phenomena as part of a greater, multifaceted whole. Including local-level group dynamics as a factor in network dynamics allows us to move away from uniform, relatively simple explanations of network phenomena, and toward recognition of the complexity underlying network generative mechanisms. Including the impact of global network generative mechanisms with local group dynamics allows us to emphasize the context of the group, including its competition with other groups for members and its position in the larger network, just as bona fide group theory recommends.

A third benefit (though one with possible dangers as well) is that the framework recognizes the complexity of human behavior and attempts to build it into the explanation of network systems. The forces driving individual behavior are much more variegated and multiplicitous than is acknowledged in most network and group research. Simply put, people are complicated. People's motives tend to change over time, over context, and according to the people they are interacting with. An individual may well feel a desire for the comfort of familiarity and similarity (homophily), but in almost the same breath desire to differentiate him or herself from others who suddenly seem boringly the same. Furthermore, people are reflexive, and they can come to know larger dynamics that are shaping them and choose other grounds of action that can be locally insulated from the wider influence of the network.

The relative simplicity of most current group and network explanations is in part a product of the desire for parsimony. Although a case can be made for parsimony, it can also be argued that our theories can be too parsimonious and ignore human nature. A balance between parsimony and realism must be struck. Simple models are also in part a methodological artifact of fitting the prevalent explanation to a large sample of individuals and "averaging" across them and controlling out the "error" due to other explanations. In this case, other explanations represent perturbations in the prevalent model that could be detected using more sensitive methodologies. Simplicity may also be a real property of networks that only a few drivers can hold at any given point in time if the system is to be stable. It may well be the case that one or a few generative mechanisms must hold for a coherent system to exist and that too much diversity in generative mechanisms undermines the grounds of the system and breaks it into smaller systems.

The great diversity of generative mechanisms for human behavior has two implications for network ecosystems. First, generative mechanisms other than those driving a network system may "erupt" due to human agency. This introduces variation into the system. Second, the multiple levels of generative mechanisms offer one way of incorporating this diversity into the system. Although one level may operate in one mode, other levels offer the opportunity for diverse generative mechanisms to emerge. The group level is particularly diverse in terms of the generative mechanisms it offers, because group dynamics often feature multiple factors.

Research within this framework requires the development of new methods for studying networks and their linkage to local group processes. As noted, it requires methods for dynamically identifying groups, network configurations, and network generative mechanisms. It also requires methods to measure other variables related to group generative mechanisms coordinated with the network analysis.

The framework also suggests some interesting future directions. One is to explore developmental sequences for network generative mechanisms. For example, one might posit that the homophily generative mechanism at the global level would foster and be sustained by social identity dynamics at the local level. Social identity dynamics would promote the emergence of homogeneous groups, which in turn would give rise to a tendency toward differentiation within these groups at the local level. If this differentiation occurred via a process of special and eventually generalized exchange, then the exchange generative mechanism would be established at the local level and would compete with homophily as an organizing principle. If exchange led to more effective groups, then eventually it may supplant homophily as the organizing principle for the network. This can be described in terms of a developmental sequence in the network, from homophily (global) and social identity (local) as the first stage to exchange (global) and exchange (local) as the second stage. With sufficient data, developmental models for networks could be defined.

AU: Correct to identify the second stage as "exchange … and exchange"?

yes

A second important goal is to work out the various ways in which generative mechanisms at global and local levels might be related. In the previous paragraph, we gave an example of a competitive relationship in which one generative mechanism supplanted the other. However, other relationships are possible. It might also be the case that homophily may define large-scale groupings at the network level, and exchange may be the prevalent mechanism within these large-scale groupings. In this case, there is a hierarchical or heterarchical relationship between the two generative mechanisms. It is important to work out the types of possible relationships among generative mechanisms and the factors that promote them.

The theory also suggests some implications for the study of MTSs. First, it suggests that MTSs must be understood in the context of the larger organization and group network in which they are embedded. It also suggests that MTSs are embedded in an ongoing temporal process in which they may persist in multiple incarnations as teams add to and leave the MTS. For instance, the emergency response MTS described by Mathieu et al. (2001) may add a utility worker team, if an accident involves downed power lines. This "natural history" of the MTS suggests that we can also study it, not as a predefined structure with set goals, but in terms of ongoing behavior. This allows us to discern slippage in the goals of the MTS and how it interacts with other teams and MTSs in its environment.

The network ecosystem model also implies that there may be more generative mechanisms operating in the MTS than simply functional interdependence based on goal hierarchies, as assumed by Mathieu et al. (2001). Social identity dynamics may also intrude on all or parts of an MTS through homophily-generated networks, and other generative mechanisms may also come into play. To greater or lesser extent, these may interfere with the functioning of the MTS and reduce its effectiveness.

Though not every network ecosystem is an MTS, every MTS is part of a network ecosystem. Considering the dynamics in operation in the network ecosystem promises to provide a richer understanding of MTSs.

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REFERENCES

Abrams, D., Hogg, M., Hinkle, S., & Otten, S. (2005). The social identity perspective on small groups. In M. S. Poole & A. H. Hollingshead (Eds.), *Theories of small groups: Interdisciplinary perspectives* (pp. 99–138). Thousand Oaks, CA: Sage.

Contractor, N. S., & Monge, P. R. (2003). Using multi-theoretical multilevel models to study adversarial networks. In R. Breiger, K. Carley, & P. Pattison (Eds.), *Dynamic social network modeling and analysis: Workshop summary and papers* (pp. 324–344). Washington, DC: National Research Council.

Contractor, N., Wasserman, S., & Faust, K. (2006). Testing multi-theoretical multilevel hypotheses about organizational networks: An analytic framework and empirical example. *Academy of Management Review*, *31*, 681–703.

Cook, K. S. (1982). Network structures from an exchange perspective. In P. V. Marsden & N. Lin (Eds.), *Social structure and network analysis* (pp. 177–218). Beverly Hills, CA: Sage.

Corman, S. R., & Scott, C. R. (1994). Perceived communication relationships, activity foci and observable communication in collectives. *Communication Theory*, *4*, 171–190.

Desmond, M. (2007). *On the fireline: Living and dying with wildland firefighters*. Chicago: University of Chicago Press.

Feld, S. L. (1981). The focused organization of social ties. *American Journal of Sociology*, *86*, 1015–1035.

AU: I didn't see Gouran and Hirokawa cited, add to text or delete?

Gouran, D. S., & Hirokawa, R. Y. (1996). Functional theory and communication in decision-making and problem-solving groups: An expanded view. In R. Y. Hirokawa & M. S. Poole (Eds.), *Communication and group decision making* (2nd ed., pp. 55–80). Thousand Oaks, CA: Sage.

Heider, F. (1958). *The psychology of interpersonal relations*. New York: Wiley.

Holland, P. W., & Leinhardt, S. (1975). The statistical analysis of local structure in social networks. In D. R. Heise (Ed.), *Sociological methodology, 1976* (pp. 1–45). San Francisco: Jossey-Bass.

Hollingshead, A. H., Wittenbaum, G., Paulus, P. B., Hirokawa, R. Y., Ancona, D. G., Peterson, R., et al. (2005). A look at groups from the functional perspective. In M. S. Poole & A. H. Hollingshead (Eds.), *Theories of small groups: Interdisciplinary perspectives* (pp. 21–63). Thousand Oaks, CA: Sage.

Kontopoulos, K. (1993). *The logics of social structure*. Cambridge: Cambridge University Press.

Kozlowski, S. W. J., & Klein, K. J. (2000). A multilevel approach to theory and research in organizations: Contextual, temporal, and emergent processes. In K. J. Klein & S. W. Kozlowski (Eds.), *Multilevel theory, research, and methods in organizations* (pp. 3–90). San Francisco: Jossey-Bass.

Mathieu, J. E., Marks, M. A., & Zaccaro, S. J. (2001). Multiteam systems. In N. Anderson, D. Ones, H. K. Sinangil, & C. Viswesvaran (Eds.), *International handbook of work and organizational psychology* (pp. 289–313). London: Sage.

Mathur, S., Poole, M. S., Pena-Mora, F., Contractor, N., & Hasegawa-Johnson, M. (2009). Detecting interaction links in a collaborating group using manually annotated data (Working paper). Urbana: National Center for Supercomputing Applications, University of Illinois Urbana-Champaign.

McGrath, J. E. (1984). *Groups: Interaction and performance*. Englewood Cliffs, NJ: Prentice Hall.

McPherson, M., Smith-Lovin, L., & Cook, J. M. (2001). Birds of a feather: Homophily in social networks. *Annual Review of Sociology*, *27*, 415–444.

Monge, P. R., & Contractor, N. (2003). *Theories of communication networks.* New York: Oxford University Press.

Monge, P. R., Heiss, B., & Margolin, D. (2009). Communication network evolution in organizational communities. *Communication Theory, 18,* 449–477.

Poole, M. S., Bajcsy, P., Contractor, N., Espelage, D., Fleck, M., Forsyth, D., et al. (2009). GroupScope: Instrumenting research on interaction networks in complex social contexts (Working paper). Urbana: National Center for Supercomputing Applications, University of Illinois Urbana-Champaign.

AU: I didn't see Poole and Hollingshead cited; add to text, or delete?

Poole, M. S., & Hollingshead, A. B. (2005). *Theories of small groups: Interdisciplinary perspectives.* Thousand Oaks, CA: Sage.

Putnam, L. L., & Stohl, C. (1996). Bona fide groups: An alternative perspective for communication and small group decision making. In R. Y. Hirokawa & M. S. Poole (Eds.), *Communication and group decision making* (2nd ed., pp. 179–214). Thousand Oaks, CA: Sage.

Smith, K. K., & Berg, D. N. (1987). *Paradoxes of group life: Understanding conflict, paralysis and movement in group dynamics.* San Francisco: New Lexington Press.

Taylor, H. F. (1970). *Balance in small groups.* New York: Van Nostrand Reinhold.

Thibaut, J. W., & Kelley, H. H. (1959). *The social psychology of groups.* New York: Wiley.

Thompson, J. D. (1967). *Organizations in action.* New York: Harper.

Williams, D., Contractor, N., Poole, M. S., Srivastava, J., & Cai, D. (2009). The virtual worlds exploratorium (Working paper). Urbana: National Center for Supercompting Applications, University of Illinois Urbana-Champaign.

Zaltman, G., & Duncan, R. (1977). *Strategies for planned change.* New York: Wiley.