A Theory of Group Stability *

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Abstract

Some groups endure longer, are more stable, and are better able than other groups to incorporate new members or ideas without losing their distinctiveness. I present a simple model of individual behavior based on the thesis that interaction leads to shared knowledge and that relative shared knowlege leads to interaction. Using this model I examine the structural and cultural bases of group stability. Groups that are stable in the short run do not necessarily retain their distinctiveness in the long run as new members enter or new ideas are discovered.

A Theory of Group Stability

Consider two hypothetical high-tech consulting companies -- Fairview and Taliesin -- that specialize in designing medical information systems. Over the years, both companies have gained considerable expertise. Despite these similarities, however, the companies are quite different. Fairview was founded by six men, all graduates of BL Tech with degrees in business. The current members of the company get along well -- they frequently hold Monday evening meetings and tend to have a unified perspective on how to develop systems. Taliesin resulted from a chance meeting in an airport between a computer science major and a business major interested in health care. Taliesin currently employs 12 men and women, who graduated from different universities and who represent a variety of disciplines. As at Fairview, the Taliesin employees get along well. Even so, they spend less time together than do Fairview employees, and often split into subgroups to handle multiple clients. Fairview and Taliesin thus represent very different sociocultural configurations: Fairview is small, socially undifferentiated, and culturally homogeneous; Taliesin is large, socially differentiated, and culturally heterogeneous.

Because of increasing requests by clients, both companies are considering moving into the area of limited medical expert systems. Such a move may require hiring at least one new person. Will the addition of a new member or new information destabilize these groups? What are the structural and cultural bases for group stability? For example, what types of groups are the most stable? What types of groups are least affected by the addition of new members? What types of groups are least affected by expansion of the group's knowledge base?

Various theories attempt to explain why some groups endure longer than others. These explanations usually suggest that favorable contexts are necessary for group stability, particularly when memberships change and new technologies and ideas emerge, and that highly differentiated contexts produce multiple groups. Such contexts frequently are characterized in terms of their environmental (Aldrich 1979; Hannan and Freeman 1977), institutional (Blau 1967; Collins 1975; Etzioni 1964; Sills 1957; Simmel [1908] 1955), ritual (Durkheim [1912] 1954; Goffman 1959; Mead [1934]1962), or functional (Aberle, Cohen, Davis, Leng, and Sutton 1950; Mack 1967; Parsons 1949, 1951) characteristics, but rarely in terms as simple as "who knows what." Although these explanations tend to assume that groups members learn, interact, and communicate, the precise mechanisms underlying such processes are underspecified and the power of these fundamental "cognitive" mechanisms in producing and maintaining groups are ignored.[1]

In contrast to these context-dependent themes, I present a "constructural" perspective that is spare and highly general (see also Carley 1986a, 1986b, 1990, forthcoming a, forthcoming c). According to this perspective, social change and stability result from changes in the distribution of knowledge as individuals interact and acquire and disseminate information. Constructuralism can be viewed as a modification of structural symbolic interactionism (Stryker 1980) in which knowledge mediates interaction and language, or it can be viewed as a modification of social differentiation theory (Blau 1977) in which knowledge mediates social dimensions (e.g., religion, sex, and age) and interaction. According to both theories, groups can be defined by shared social, demographic, or sociocultural features -- e.g., Catholic boys age 13. According to the constructural perspective, each position on a social dimension is associated with a particular body of knowledge that is acquired by individuals with that characteristic -- e.g., Catholics learn the tenets of Catholicism, the order of the mass, the holy days of obligation, and so forth. It is the wealth and uniqueness of the information associated with that dimension, not the dimension per se, that determines behavior.

Constructural theory derives group characteristics and behavior from the characteristics and behaviors of individual group members that, in turn, are generated by processes relating individual knowledge to individual behavior. Three axioms capture this relationship: (1) individuals are continuously engaged in acquiring and communicating information; (2) what individuals know influences their choices of interaction partners; and (3) an individual's behavior is a function of his or her current knowledge.

According to the constructural perspective, groups form and endure because of discrepancies in who knows what. Groups typically are in flux simply because members are continually acquiring new information and communicating it to each other. A group is perfectly stable only when no new information enters the group and everyone in the group knows everything that anyone else in the group knows. From this perspective, neither institutional nor motivational factors are necessary for group stability, nor is a differentiated environment or a differentiated set of institutional or motivational factors necessary for distinct groups. Rather, these factors may serve as secondary forces modifying the impact of the primary force -- interaction and the exchange of information. To the extent that institutions are forms of knowledge (Berger and

Luckman 1966), this perspective suggests that the distribution of knowledge across the population corresponds to the distribution of institutions and that perfect stability signals the effective demise of institutions because individuals, by knowing everything, are effectively members of all institutions. Institutions can maintain their identity, stability, and cultural distinctiveness by preventing the flow of information.

Differences in the information possessed by individuals may arise for many reasons, e.g., because they were born at different places or at different times. Demography, geography, and innovation permit information to be distributed unequally across the population. Regardless of the sources of these discrepancies, at any point societies can be characterized in terms of their social structure, culture (distribution of information), population, number of groups, size of groups, and total amount of information. According to the constructural perspective, this sociocultural configuration changes as individuals interact, communicate, and adapt to new information. The initial sociocultural configuration and the processes of information exchange will determine whether groups endure and whether these groups, when confronted with new members or new ideas, will be able to reconstruct, i.e., adopt new members or ideas without losing their uniqueness as a group.

I develop a simple dynamic simulation model of the interaction shared knowledge cycle in which individuals interact, communicate, and adapt to new information. (The Appendix presents an outline of the simulation program.) A more detailed technical description of the model is presented in Carley (1990).) Despite its simplicity, important and complex social behaviors emerge, many of which are consistent with existent empirical data. I use the model to explore group stability and endurance in one-group and two-group societies in which there is no change in group membership and no new ideas. I then examine the ability of these groups to assimilate a new member or idea without losing their uniqueness as a group. Finally, I discuss the model's scope, some important extensions to the model, and the role of simulation in this type of analysis.

BASIC MODEL

The members of our hypothetical consulting companies, Fairview and Taliesin, and others interested in medical information systems (MIS), can be though of as the MIS society. Fairview and Taliesin are regarded as groups. The definitions of society and group, however, are relative. Thus, we can also regard the members of a single company, such as the Taliesin employees, as a society, in which case Taliesin's computer scientists can be considered as one group and its health-care personnel as another. I define a society simply as a collection of individuals, and a group as a subset of these individuals. Logically, if not in practice, a group can contain one individual, the entire society, or any portion of that society. I refer to the number of individuals in the society, denoted by I, as the population.

Every society has a culture. Culture is often characterized in terms of the distribution of information (e.g., ideas, beliefs, concepts, symbols, technical knowledge, etc.) across the population (Archer 1988; Krackhardt and Kilduff 1990; Namenwirth and Weber 1987; Stryker 1980). Many research traditions, including cultural dynamics (Melischek, Rosengren, and Stappers 1984; Namenwirth and Weber 1987), attitude and belief formation (Ajzen and Fishbein 1980; Anderson 1971; Hunter, Danes, and Cohen 1984), diffusion (Coleman, Katz, and Menzel 1966; Rapoport 1953), and individual learning (Bush and Mosteller 1955) characterize information as discrete pieces that can be learned independent of each other. I employ both of these characterizations. Thus, society contains a certain number of pieces of information or facts,[2] denoted by K, that the individuals in that society can learn. The number of available facts determines the complexity of the culture. An individual either knows each fact or does not. This situation is denoted by $F_{ik}(t) = 1$ if fact k is known by individual i at time t, and 0 ik otherwise.

Group members, such as those in the consulting companies, engage in a cyclical process of interacting, exchanging information, learning, adapting their behavior, interacting, and so on. According to the constructural argument, this cyclical process simultaneously determines individual and group behavior. Formalization of this process is necessary if group behavior is to be predicted. I divide the interaction shared knowledge cycle into three stages similar to those used by Turner (1988) in his social interaction theory. The first, which corresponds to Turner's interactional process, is action -- what happens during an interaction. The second, which corresponds to Turner's structuring process, is adaptation -- what happens to the individual and society as a result of interactions. The third, which corresponds to Turner's motivational process, is motivation -- who interacts with whom. These three stages can also be viewed from a structural symbolic interaction perspective as a process of self construction in which "self" is the individual's social and cultural position and the actions taken as a result of this position. These stages form a continuous cycle -- action → adaptation → motivation → action → adaptation. Thus, any of the stages could have been presented first, e.g., like Turner, we could have begun with motivation. The order of presentation was chosen, to minimize the intrusion of mathematical formulae in the text.

Stages of the Cycle

Action. During an interaction, people exchange information (e.g., Festinger, Cartwright, Barber, Fleichl, Gottsdanker, Keysen, and Leavitt 1948; Festinger 1950; Garfinkel 1968; Granovetter 1974). Every day the six members of Fairview interact and exchange information about clients and projects. In exchanging information, people typically come to share more information. Numerous studies have shown that dyads with high levels of interaction, such as friends, generally possess more shared knowledge (Carley 1986a) and more shared attitudes and beliefs (Ajzen and Fishbein 1980; Berscheid 1985; Byrne 1971) than dyads with lower levels of interaction. In addition, high levels of interaction tend to increase the level of shared information over time (Carley 1986a, forthcoming b). The men who formed Fairview had more in common after four years of going to the same college and taking the same courses than when they were freshmen. After being in business together and interacting daily for several years, they had even more shared knowledge.

A central premise in constructural theory is that interaction leads to shared knowledge. However, I make three simplifying assumptions when detailing the process by which individuals come to share knowledge. (1) All facts are treated alike. Although an individual may "know" conflicting pieces of information, such as the *sky is blue* and *the sky is green*, the model does not address these conflicts -- it treats shared knowledge between two individuals simply as the number of pieces of information they both possess. For example, individual i may know that *the sky is blue*, whereas individual j knows that *the sky is green*. If j communicates to i that *the sky is green*, the overlap in the knowledge shared by j and by i increases. (2) All interactions are one-to-one. Each of two interacting individuals communicates one fact to the other, and both individuals always acquire the piece of information that is communicated to them. (3) All facts known by an individual are equally likely to be communicated.

A specific piece of information, k, is communicated from one individual to another if the two individuals interact and if k is the fact that the communicator chooses to transmit. Whether i interacts with j at time t is denoted by $INT_{ij}(t)$, where $INT_{ij}(t) = 1$ if they interact and 0 otherwise. Whether j chooses to communicate fact k at time t is denoted by $u_{jk}(t)$, where $u_{jk}(t) = 1$ if k is chosen and 0 otherwise. Thus, whether i communicates k to j at time t can be denoted by

$$C_{jik}(t) = INT_{ij}(t)\; u_{jk}(t) = \begin{cases} 0 \text{ if } j \text{ does not communicate } k \text{ to } i \\ 1 \text{ if } j \text{ communicates } k \text{ to } i \end{cases} \tag{1}$$

The function $u_{jk}(t)$ chooses a fact randomly from all facts known by j; all facts known by j are equally likely to be chosen (see Carley 1990, App. 2, for additional details) .

Adaptation. Within constructural theory, a second major premise is that individuals are continuously learning and that what they learn affects future behavior. For example, individuals generally acquire information that is communicated to them if they do not already have that information. In modeling this learning process, I assume that this occurs without error. Thus, an individual will know a fact during the next time period if he or she already knew the fact or if someone in the society communicated it to him or her.[3] This situation is represented as

$$F_{ik}(t+1) = F_{ik}(t) \quad C_{1ik}(t) \quad C_{2ik}(t) \quad \ldots \quad C_{Iik}(t), \tag{2}$$

which means that there is: no forgetting (once an individual knows a fact, he or she always knows it); no discovery (if the individual "interacts with him/herself," as when spending time alone, no change occurs in what he or she knows); and no miscommunication (if the individual hears a new fact, he or she always learns that fact and never learns an alternative fact). For example, if Adam from Fairview tells co-worker Martin that a new type of spreadsheet called FactFinder is available, Martin henceforth takes this piece of information into account when dealing with clients or other members of the company. Martin does not dream up new types of spreadsheets, and he does not think of FactFinder as a new word processor.

Motivation. A third major premise of constructural theory is that relative similarity between individuals leads to interaction. Thus, interaction at Fairview, which was formed by a group of similar individuals, should be more frequent than at Taliesin. Within Taliesin, the computer scientists should spend more time with each other than with the business majors. Similar individuals interact for a variety of reasons. For example, individuals may be more "comfortable" interacting with someone with whom they have much in common, individuals may avoid "costs" because information exchanges may be more efficient between similar individuals, or individuals may acquire "rewards" because common knowledge may produce more opportunities for interaction. The point of constructural theory is that an individual's perception of his or her motivation to interact is not the determinant of interaction; rather, it is the sheer volume of what each individual has in common with other individuals relative to how much he or she has in common with everyone else that determines interaction.[4]

Sociologists are familiar with the link between similarity and interaction. One of the best-established findings in sociology is the tendency of friends to be similar, particularly on such dimensions as age, sex (Lazarsfeld and Merton 1954; McPherson and Smith-Lovin 1987; Verbrugge 1979), education, prestige, social class, and occupation (Coleman 1957; Laumann 1966; Lipset, Trow, and Coleman 1956; McPherson and Smith-Lovin 1987; Verbrugge 1979) . A similar perspective is also at the heart of balance theory (Heider 1958).

Systematic formulations of the connection between similarity and interaction have been provided by Homans (1950), Davis (1966), Granovetter (1973), Blau (1977), and Fararo and Skvoretz (1987). In these formulations, particularly Blau's and its formalization by Fararo and Skvoretz, similarity is determined by the number of dimensions that people have in common. Fararo and Skvoretz (1987) go so far as to unify Granovetter and Blau by specifying a unification principle that links interaction and similarity directly on social dimensions: "The greater the number of dimensions along which associates differ, the greater is the chance that the tie is weak" (p. 1199). This specification weights all dimensions equally.

I extend this approach in several ways: (1) The weaker the tie, the lower the probability of interaction; (2) different points on each dimension have a body of knowledge associated with them that each individual at that point has a certain likelihood of knowing; (3) similarity is defined in terms of shared knowledge (this definition effectively weights the dimensions); and (4) interaction is predicted in terms of <u>relative</u> similarity. Relative similarity is represented in the model by allowing the base probability that individual i interacts with individual j at time t, denoted by $P_{ij}(t)$, to be a function of how much information i and j share relative to the sum, across the population, of how much information i shares with each member of the society, including himself[5] :

$$\boldsymbol{P_{ij}(t)} = \frac{\sum_{k=1}^{K} \boldsymbol{F_{ik}(t) \quad F_{jk}(t)}}{\sum_{h=1}^{I} \sum_{k=1}^{K} \boldsymbol{F_{ik}(t) \quad F_{hk}(t)}} \qquad \textbf{(3)}$$

Equation (3) suggests that i and j know how much information they share. Individuals constantly update their view of what everyone else knows through interactions in which i learns what each j knows, both directly from j and indirectly by "hearing" about j from others. Thus, i's decision to interact is guided by i's mental model of what *j* knows, rather than by what *j* actually knows. I assume that although this process is not perfect, it is sufficiently accurate that every individual's mental model of the relative amount of information they share with each other member of the society is not systematically biased.

Substantively, equation (3) says that an isolated pair of individuals may behave differently from the same pair of individuals in a group of three, and that three individuals in isolation may behave differently from the same three individuals in a group of four, and so on. The result of basing action (in this case, interaction) on <u>relative</u> similarity is that seemingly minor changes, such as the entry of a new group member, may have massive social consequences, such as group dissolution. Thus, hiring someone who knows how to build medical expert systems at Fairview or at Taliesin may change the group dynamics not only because the number of members has increased, but because new information has become available to other group members. Equation (3) also suggests that individuals maintain a sense of self. That is, basing action on similarity to everyone, including one's self, implies that individuals cannot interact with anyone more frequently than with themselves. Finally, Equation (3) says that different individuals may react differently to the same event. For example, if several individuals acquire the same piece of information, their reactions (i.e., changes in interaction probabilities) may be different. Or, if two individuals interact, one individual might become more likely to interact with the other in the future and the other become less likely. Consider the following example. Action: when they communicate, *j* tells *i* something new to *i* that also is known by *l*, and *i* tells *j* something that *j* already knows. Adaptation: from *i*'s perspective this exchange increases how much information *i* shares with both *j* and *l*, thereby decreasing *i*'s relative similarity with *j*. From *j*'s perspective, however, only the amount of information shared with *i* has increased, thereby increasing *j*'s relative similarity with *i*. Motivation: *i* is now less likely to choose *j* as an interaction partner in the future and *j* is more likely to choose *i* as an interaction partner.

Whether two individuals actually interact is determined by their probabilities of interacting with each other, and by whether either is already interacting with someone else or is spending the time alone. As in the real world, individuals who are "busy" are unavailable for interaction. As a further simplification, I assume that the choice of interaction partners, or of spending time alone, occurs serially. An individual *i* is chosen randomly to begin the selection of interaction partners. Initially, all individuals are equally likely to be selected as the first to choose an interaction partner.[6] Let $A_j(t)$ denote whether individual *j* is available for interaction, such that $A_j(t) = 0$ if *j* is interacting already during time *t* and 1 otherwise. Then, whether individuals *i* and *j* interact during time *t* is

$$\boldsymbol{INT_{ij}(t) = v_{ij}(P_{ij}(t, A_j(t))) = \begin{cases} 0 \text{ if } i \text{ does not interact with } j \\ 1 \text{ if } i \text{ interacts with } j \end{cases}} \quad \textbf{(4)}$$

The function v_{ij} (P_{ij} (t),A_j (t)) represents the random selection of an interaction partner by *i* from individuals in the society who are not interacting already, based on his or her probability of interacting with those individuals (see Carley 1990, App. 2, for additional details). Once interaction partners have been chosen, all individuals, in parallel: (1) action -- exchange information with their partners; (2) adaptation -- acquire the communicated information and update their probabilities of interaction; and then (3) motivation -- choose new interaction partners on the basis of their new probabilities of interaction.

Conceptual Definitions and Measures

Stability. I examine stability in terms of three concepts: perfect stability, time to stability, and endurance. Perfect stability is an ultimate condition; it occurs only when no new information is entering the group, there are no changes in the distribution of information, and there are no changes in the interaction probabilities. Perfect stability is an equilibrium condition that occurs only if the members of all dyads with nonzero probabilities of interaction know everything that the other member knows. We can think of Fairview, before the hiring of a new person, as an approximation of perfect stability because each employee basically knows everything that all other employees know.

Time to stability is the number of time periods until the society reaches perfect stability. The longer it takes, the less stable the society. For example, if Fairview hired a male college buddy of the current employees, the resultant group would be more stable than if Fairview hired a woman who went to a different college. The new man, who already shares much information with the current employees, would be expected to learn everything that everyone else knows in a shorter time, and the other employees should quickly learn what he knows. If the woman is hired, a longer period of time will elapse before perfect stability occurs.

Endurance makes sense only in a multigroup society. A group is said to endure as a distinct group for as long as its members are more likely to interact with each other than with individuals outside their group. More precisely, endurance time for a group is the number of time periods until the probability of intragroup interaction is greater than the probability of intergroup interaction. I define the probability of intragroup interaction as the average probability of interaction across all dyads in the group, excluding self interaction. Similarly, I define the probability of intergroup interaction as the average probability of interaction across all dyads in which one individual is in one group and the other individual is in another. As I demonstrate, groups often dissolve long before the society becomes perfectly stable.

Cultural Homogeneity. No single measure can capture all that is meant by cultural homogeneity. I consider two important properties -- connectedness and diversity. I refer to any two individuals or groups that share at least one fact as being connected[7]; groups or individuals who have a zero probability of interaction are disconnected. Two groups can be disconnected only if knowledge in one is entirely unmatched in the other; i.e., if no pair of individuals, one in each group, shares any knowledge. A society in which there are no disconnected groups (regardless of size); is termed fully-connected.[8]

Cultural homogeneity is measured by the percentage of possible dyadically shared facts that actually are shared. A fact k is shared by a dyad if $F_{ij}(t) = F_{ji}(t) = 1$. The number of possible dyadically shared facts is $\binom{I}{2} \times K$. Thus cultural homogeneity is measured as

$$\textbf{Cultural homogeneity (t)} = \frac{\sum_{i=1}^{I} \sum_{j=i+1}^{I} \sum_{k=1}^{K} F_{ik}(t) \times F_{jk}(t)}{\binom{I}{2} \times K} \times 100 . \qquad (5)$$

The distinctiveness of these two ideas is illustrated by considering two hypothetical societies, each composed of four people (P1, P2, P3, and P4) with access to eight facts (A,B,C,D,E,F,G, and H). In the first society, P1 and P2 know facts A,B,C, and D; P3 and P4 know facts E,F,G, and H. In the second society everyone knows fact A; P1 knows facts B,C, and D; P2 knows facts D,E, and F; and P3 knows facts F,G, and H. In both societies, cultural homogeneity is 16.7 percent. In the first society, however, the two groups have nothing in common and so are disconnected, whereas in the second society all individuals know one fact in common and thus form a fully-connected society. These seemingly minor structural differences in the two societies have important implications for group behavior and stability: In the first society, groups will continue as distinct entities indefinitely, whereas in the second society, groups will eventually cease to endure and will merge.

Properties of the Model

There are several important properties of the model. Some of these properties do not deal directly with group stability and endurance, but help us understand the model and to find empirical evidence that confirms or contradicts the model.

Parallel cultural and structural evolution. As I have defined them, social structure and culture tend to evolve in parallel: Social structure is the distribution of interaction probabilities, and culture is the distribution of facts. Because the strength of the tie between individuals -- i.e., their interaction probability -- depends on their relative similarity, changes in culture (who knows what facts) result in changes in relative similarity. These changes, in turn, result in changes in the interaction probabilities, which finally change the social structure (the distribution of these probabilities). Thus, for an individual, high levels of interaction eventually correspond to high levels of shared knowledge. For example, if Aaron interacts more with Zebadiah than with Deety, he will share more information with Zebadiah than with Deety. This change in shared knowledge will then alter their levels of interaction. Over time, changes in social structure change culture and changes in culture will change social structure.

For all dyads, the level of shared knowledge and the level of interaction will be highly correlated. Figure 1, shows the relationship between shared knowledge and the probability of interaction at a particular time. In this illustrative society, there are four people -- Aaron, Zebadiah, Deety, and Hilda -- and five facts -- A, B, C, D, and E. The distribution of who knows what is shown at the top, e.g., Aaron knows only facts A and B. On the basis of this distribution, the level of shared knowledge between all dyads (i.e., the number of facts that each pair of individuals shares) can be computed (middle panel), e.g., Aaron and Zebadiah share two facts (A and B). Finally, the probability of interaction (bottom panel) can be calculated using equation (3) as the relative amount of shared knowledge, e.g., Aaron shares two facts with Zebadiah and has a row sum of five, so his probability of interacting with Zebadiah is 2/5, or .40. In this society, because Aaron knows less than Deety, he has a higher probability of interaction with Zebadiah than Deety does with Hilda (.4 vs. .3), even though Aaron shares fewer facts with Zebadiah than Deety does with Hilda (two vs. three).

Asymmetric behavior. Because action (interaction) is based on relative similarity, and because individuals may share different amounts of information with different others, actual and perceived asymmetries result. For a pair of individuals, the probability of interacting with each other may be unequal. This situation can occur if one of the individuals knows more than the other or shares more information with

Who Knows What

People	Facts A	B	C	D	E
Aaron	1	1	0	0	0
Zebadiah	1	1	1	0	0
Deety	0	1	1	1	1
Hilda	0	0	1	1	1

Shared Knowledge

People	People: Aaron	Zebadiah	Deety	Hilda
Aaron	2	2	1	0
Zebadiah	2	3	2	1
Deety	1	2	4	3
Hilda	0	1	3	3

Probability of Interaction

People	People: Aaron	Zebadiah	Deety	Hilda
Aaron	.40	.40	.20	.00
Zebadiah	.25	.38	.25	.12
Deety	.10	.20	.40	.30
Hilda	.00	.14	.43	.43

Figure 1. A Small Society

others. In Figure 1, for example, even though Aaron and Zebadiah share two facts, Aaron has a .4 probability of interacting with Zebadiah, and Zebadiah has a .25 probability of interacting with Aaron. Such asymmetry has a variety of consequences:

(1) based on the model for a dyad, the individual with a higher probability of interacting with the other will be more likely to initiate the interaction; (2) if the strength of a relationship, such as friendship, is a direct function of the interaction probabilities, then dyads with asymmetric interaction probabilities will be more likely to disagree about their level of friendship compared with those with symmetric interaction probabilities; and (3) if an individual is more likely to recall an interaction with a partner with whom he or she interacts frequently, then it follows that, because asymmetric interaction probabilities tend to produce asymmetric relative frequencies of interaction, some dyads will disagree about their level of interaction.

What are the substantive results of these asymmetries? Consider the implications of status indices, like prestige and education whereby people with higher status simply know more than those with lower status. Figure 2 illustrates the relationship between status and interaction, in a sample society composed of 10 individuals and 10 facts in which all individuals of the same status possess the same information. Here the probability that a high-status individual will interact with a low-status individual is .025, while the probability that a low-status individual will interact with a high-status individual is .10. If knowing someone is a function of one's likelihood of interacting with that person, then low-status people are more likely to report knowing high-status people than the reverse, as shown in Figure 2.

Consider the stratification of scientists. Assume that high-status scientists know more than low-status scientists -- they have had access to more grants, tend to be older, and have served on more and a greater variety of committees. Consequently, one would expect to find asymmetries in reports of interaction between high- and low-status scientists. Considering citations as a type of interaction, the model predicts that even when the quality of the work is controlled, eminent scientists are more likely to cite other high-status scientists than to cite low-status scientists, and that low-status scientists are more likely to cite high-status scientists than the reverse. Cole and Cole (1973) found this to be the case.

Cultural modulation of structure. The level of interaction between groups is a function of the ratio of group sizes and the degree to which the groups share the same culture, i.e., their overlap in shared knowledge. This follows from the fact that interaction is a function of the interaction probability, which in turn is a function of the number of people and the amount of information shared with each of those people.

Table 1 is based on the following assumptions: Individuals are divided into two groups, with n people in the minority and m in the majority and $m + n = I$. All members of a group know identical facts: a facts are known by all members of the minority and b

facts by all members of the majority and $a + b = K$. The fraction of the majority's facts shared by the minority is y; the fraction of the minority's facts shared by the majority is x. On the basis of these assumptions, the functional form for the group interaction probabilities, regardless of the size of the population, can be computed using equation (3). The probability of interaction of the minority with the minority is

Who Knows What

		Facts									
People	**Status**	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**
Deety	High	1	1	1	1	1	1	1	1	1	1
Jake	High	1	1	1	1	1	1	1	1	1	1
Aaron	Med	0	0	0	0	0	1	1	1	1	1
Zebadiah	Med	0	0	0	0	0	1	1	1	1	1
Hilda	Med	0	0	0	0	0	1	1	1	1	1
Lazarus	Low	0	0	0	0	0	0	0	0	0	1
Maureen	Low	0	0	0	0	0	0	0	0	0	1
Eunice	Low	0	0	0	0	0	0	0	0	0	1
Ian	Low	0	0	0	0	0	0	0	0	0	1
Slayton	Low	0	0	0	0	0	0	0	0	0	1

Probability of Interaction

	People									
People	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**	**(10)**
(1) Deety	.25	.25	.13	.13	.13	.02	.02	.02	.02	.02
(2) Jake	.25	.25	.13	.13	.13	.02	.02	.02	.02	.02
(3) Aaron	.17	.17	.17	.17	.17	.03	.03	.03	.03	.03
(4) Zebadiah	.17	.17	.17	.17	.17	.03	.03	.03	.03	.03
(5) Hilda	.17	.17	.17	.17	.17	.03	.03	.03	.03	.03
(6) Lazarus	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10
(7) Maureen	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10
(8) Eunice	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10
(9) Ian	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10
(10) Slayton	.10	.10	.10	.10	.10	.10	.10	.10	.10	.10

Figure 2. Status and Interaction Probabilities

$\frac{a + yb}{n(a + by) + m(ax + yb)}$ and with the majority it is $\frac{ax + yb}{n(a + by) + m(ax + yb)}$. In contrast, the probability of interaction of the majority with the minority is $\frac{ax + yb}{n(ax + by) + m(ax + b)}$ and with the majority it is $\frac{ax + b}{n(ax + by) + m(ax + b)}$.

Assuming for illustrative purposes that there are 12 people in the society and that the number of facts known by members of each group is identical (setting $a = b$ and $x = y$), one can generate the matrices in Table 1. Looking down any column, for minority to majority interactions, for a particular level of cultural overlap (such as 10 percent) the smaller the size of the minority relative to the majority, the greater the probability of intergroup interaction. In contrast, moving along any diagonal, for minority to majority interactions, the more culturally similar the minority and the majority (i.e., the greater the shared knowledge) and the closer the two groups in size, the higher the probability of intergroup interaction (e.g., .048, row 3 column 1, vs. .067, row 1 column 3.

Table 1. Intragroup and Intergroup Interaction Probabilities by Relative Size of Group and Overlap in Shared Knowledge: Two-Group Society of 12 Members

Ratio of Group Sizes		Percent Overlap in Shared Knowledge: 10	25	50	75	100
Minority to Minority						
	6:6	.141	.119	.100	.090	.083
	4:8	.183	.139	.107	.092	.083
	2:10	.262	.167	.115	.095	.083
Minority to Majority						
	6:6	.026	.048	.067	.077	.083
	4:8	.033	.056	.071	.079	.083
	2:10	.048	.067	.077	.081	.083
Majority to Minority						
	6:6	.026	.048	.067	.077	.083
	4:8	.021	.042	.063	.075	.083
	2:10	.018	.037	.059	.073	.083
Majority to Majority						
	6:6	.141	.119	.100	.090	.083
	4:8	.115	.104	.094	.088	.083
	2:10	.097	.093	.088	.085	.083

The model also suggests that in a two-group society, the smaller the minority relative to the majority, the greater the probability of intergroup interaction for the minority, holding constant the level of cultural overlap between the groups and the level of cultural homogeneity in each group. More generally, the model suggests that in multigroup societies, intergroup interactions are both structurally and culturally determined. To illustrate, compare a "culturally equivalent" society with one that is "culturally distinct." In both societies there are three groups -- two minorities and a majority -- that may be distinguished by some parameter like religion, and the two minorities are of different sizes. In the culturally equivalent case, the distribution of information across the two minorities is identical. Consequently, according to this model, the smaller minority will have a higher proportion of intergroup interactions than will the larger minority. In the culturally distinct case, the distribution of information across the two minorities is different. If the minorities therefore share different amounts of information with the majority, then the minority that shares less information may have a lower probability of intergroup interaction even if that minority is the smaller minority. In Table 1, for example, when the group ratio is 2:10 and the level of shared knowledge is 10 percent, the probability of minority interaction with the majority for the society is .048, whereas when the group ratio is 4:8 and the level of shared knowledge is 50 percent, the probability of intergroup interaction is .071.

The impact of the proposed model is seen by comparing it with a well-known model developed by Blau (1977). Blau's model treated only the culturally equivalent case in which the minority's probability of interacting with the majority changes with the ratio of group sizes: "The probability of extensive intergroup relations increases as the size of the groups distinguished by a given nominal parameter decreases "(p. 42). It follows from this theorem that in two-group societies the smaller the minority relative to the majority, the greater the probability of intergroup interaction for the minority but the smaller for the majority. The probability of intergroup interaction for the minority should be proportional to the ratio $(m/n)/I$ and for the majority it should be proportional to $(n/m)/I$. Furthermore, in multigroup societies with two minorities, the smaller minority will have a higher proportion of intergroup interactions.

However, a problem arises for Blau's straightforward demographics. As he noted, (1977, p. 26), numerous studies have shown that although Jews are a smaller minority than Catholics in the United States, the intermarriage rate for Jews is lower than for Catholics (e.g., Glick 1960; Kennedy 1944; Yinger 1968). Blau explained this negative case post hoc by invoking such notions as differentials in parameter salience to groups and commitment of group members to an ideology. For the constructural model, however, this finding supports the culturally distinct case, which adds differing amounts of information-sharing to demographics. In the area of religion, Catholics and Protestants, being Christians, share more information than do Jews and Protestants. Therefore, Catholics should exhibit a higher probability of intergroup interaction with Protestants despite their larger population.

The above discussion applies only to groups distinguished by a single social dimension. The members of naturally formed groups, such as bridge clubs and work groups, can be characterized by many such dimensions. With respect to these groups, Blau (1977) provided a key theorem: "The lower the positive correlation between parameters, the more extensive are intergroup relations" (p.98). In Blau's characterization, there is no a priori differentiation between parameters. Thus, if we consider two different minority groups of the same size that have the same correlation between parameters, then they should have the same level of intergroup interaction regardless of what the parameters are or whether the parameters are the same in the two groups. Furthermore, two different minority groups of the same size that have different correlations between the same number of parameters should have different levels of intergroup interaction regardless of whether the parameters are identical in the two groups. Again, Blau explained negative cases post hoc by invoking parameter salience. In contrast, the proposed model differentiates parameters a priori by the knowledge associated with them and argues that intergroup relations are a function of the correlation between the knowledge associated with the dimension and the degree to which that knowledge dominates all other facts known by the individuals. In general, the greater the positive correlation between parameters, the greater the shared knowledge between group members. Whether this greater shared knowledge translates to greater interaction depends on the distribution of all other knowledge. Thus, two different groups of the same size that have different correlations between the same number of parameters may have the same level of intergroup interaction even when the parameters are identical in the two groups. Indeed, the group with the higher correlation may have more extensive intergroup relations.

Knowledge-generated overlaps in networks. The individual's social network (often called the ego network) is composed of those individuals with whom the individual interacts. For any dyad, the level of shared knowledge corresponds to the overlap in their social networks. As two individuals share more information, each partner also comes to share more information with those individuals with whom the partner shares information. Because sharing information[9] is a prerequisite to interaction, dyads who share more information will, on average, have a greater overlap in their networks. Thus, dyads that have experienced more of the same things will share more friends. Research by Shulman (1975) and Lowenthal, Turner, and Chiriboga (1975) suggested that network overlap is greater for more "experienced" relationships, i.e., for married couples compared to unmarried couples, for couples with children compared to couples without children, and for older couples compared to younger couples.

Nonpositive feedback. The interaction shared knowledge cycle does not guarantee positive feedback, i.e., it is possible for two individuals to interact and increase their shared knowledge, and yet be less likely to interact in the future. For example, if Aaron and Zebadiah interact, and if Deety and Hilda interact at the same time, then Deety and Hilda may exchange information that is already known by Aaron, thereby increasing the information they share with each other and also the information they share with Aaron. Thus, both the amount of information that Aaron shares with Zebadiah and the amount of information that Aaron shares with everyone else increases. If the amount of information that Aaron shares with everyone else increases more in proportion to the increase in the amount of information shared by Aaron and Zebadiah, then the probability that Aaron and Zebadiah will interact in the future decreases. This is more likely to happen if Aaron and Zebadiah exchange information that they both already possess. These contingencies -- according to this very spare model -- are quite random: knowledge is unstructured, after all, and the interactors' choice of information to exchange is random.

Increasing cultural and structural homogeneity. Regardless of its population, knowledge, initial social structure, or initial culture, a one-group, fully-connected society will become increasingly homogeneous, both culturally and structurally. Thus, for any dyad in a fully-connected society, the probability of interaction may oscillate throughout its history, but for the society as a whole, the average probability of interaction will increase monotonically to the reciprocal of the number of people in the society ($1/I$). Moreover, a turning point in the history of the society or group will occur after which there will be a decrease in the variance of who knows what and the interaction probabilities. At the dyadic level, this increasing social and cultural homogeneity will produce an increasing overlap in all dyads' social networks. Differentiation in the intensity of relationships therefore decreases. In other words, as the society becomes stable, all individuals come to share the same friends and all individuals become equally friendly. Milardo (1982) and Parks, Stan and Eggert (1983) showed that, over time, couples come to share more of the same friends.

<u>Perfect stability.</u> Societies eventually become perfectly stable. Consider two basic cases, a fully-connected society and a disconnected society (i.e., a society composed of disconnected groups). A fully-connected society ultimately will be composed of a single group that is perfectly stable. Over time, all group members will come to know all of the facts that are known by any group member because, by definition, individuals do not forget and any dyad that shares at least one fact has a nonzero probability of interaction. Thus any fully-connected group or society will eventually reach perfect stability regardless of the size of the population, the number of facts (cultural complexity), or the initial level of shared knowledge (cultural homogeneity). In contrast, a disconnected society ultimately will be composed of multiple groups, each of which is perfectly stable and all of which will endure indefinitely with completely distinct cultures. Because no facts are shared between two disconnected groups, no intergroup interaction ever occurs. Over time, the distinct groups will become increasingly different in that the average probability of intragroup interaction will continue to increase to the reciprocal of the number of people in the group while the probability of intergroup interaction remains at zero. In the stable sociocultural configuration, there is perfect intergroup heterogeneity (groups have distinct cultures and no intergroup interaction) and perfect intragroup homogeneity (all group members are equally likely to interact with all other group members, and the culture is uniform).

In summary, for a society with an initial distribution of knowledge: (1) stability is always achieved (stable solution); (2) the stable society is one in which a specific sociocultural configuration exists and does not oscillate among a set of configurations (single limiting state); and (3) once the stable configuration is reached, nothing will change (the limiting state is a "sink").

Under the assumptions of this model, every society eventually becomes perfectly stable, and may contain multiple groups that will coexist indefinitely as distinct groups with distinct cultures because each group has a monopoly on its facts. Thus, distinct groups can endure even if there are no differences between groups in their environments or in institutional and functional factors. Furthermore, when groups are disconnected, forces other than those discussed here will be necessary to initiate the interaction shared knowledge cycle, which will start the process that ultimately leads to assimilation. Any force that results in just one group member sharing one fact with one other member of the other group will eventually lead to the merger of the two groups and complete cultural and structural homogeneity. Sharing even one fact is sufficient to produce a nonzero probability of interaction, which opens the door to future exchanges of information.

Sharing information has certain organizational, cultural, and social consequences. If the "value" of an individual to a group is positively related to that individual's ability to contribute new information, then in a perfectly stable group all individuals are dispensable and no one is special to anyone else. In a perfectly stable group, interactions will be unproductive, i.e., they do not lead to the exchange of new information. Consequently, interactions will be ritual or perfunctory rather than functional. If behavior is a function of knowledge, then in a perfectly stable group all individuals will behave in the same way in the same situation. In this sense, behavior will appear to be ritualized. Furthermore, individuals will be able to predict each other's behavior. Because everyone knows everything, consensus is complete and the group does not need to interact in order to reach a group decision. Indeed, one individual could make the decision for the group and there would be no dissension. If group productivity is a function of both new information and shared knowledge, then a perfectly stable group will tend to be unproductive. Because dyads are equally likely to interact in a perfectly stable group, complete overlap is present in any dyad's social network. Consequently, there can be no such thing as a best friend.

Approach to perfect stability. Although two groups will always merge eventually, in a fully-connected society, their trajectory as they approach the final state need not be monotonic.[10] Figure 3 portrays the convergence of a two-group society by charting the probability of intragroup interaction (solid line) and the probability of intergroup interaction (dashed line) for one group. This group loses its distinctiveness, i.e., ceases to endure, (time period 22) long before the society becomes perfectly stable (period 176). Group behavior is not monotonic. In the process of becoming less distinct, the group becomes relatively more cohesive (peak in intra- and valley in inter-) and less cohesive (valley in intra- and peak in inter-).

Groups, families, couples, and other collections of individuals frequently exhibit oscillatory behavior because interaction is based on relative shared knowledge and groups do not exist in isolation. Recall that even though two individuals interact and come to share more knowledge, their probability of interaction may decline because of the interactions of others. At the group level, even though individuals within the group obtain more information in common, they also acquire more information in common with those outside their group. Thus, for the group, relative shared knowledge will sometimes increase and sometimes decrease. Both intragroup and intergroup interaction probabilities may increase and decrease. This oscillatory behavior means that at times group members will seem more similar than they appear later, even though the amount of shared knowledge within the group is growing. If the probability of intragroup interaction indicates cohesion, then even though cohesion in the society is increasing, intragroup cohesion may appear to increase, then to decrease, then to increase, and so on. For example, the members of a family may appear to be quite similar and interact more among themselves than with nonfamily members; at another time the reverse may be true. If attitudes and beliefs are a function of what one knows, then intergenerational transmission of attitudes and beliefs will be sometimes high, sometimes low, even if in the long run the family is relatively enduring. A study by Glass, Bengston, and Dunham (1986) found that the impact of parental attitudes on children's attitudes, and vice versa, changed over the course of both the children's and the parents' lives. In addition, the intergenerational transmission literature sometimes suggests a strong relationship between children's and parents' attitudes and at other times a weak relationship (contrast studies by Bengston 1975; Bengston and Troll 1978; Hoge, Petrillo, and Smith 1982; Jennings and Niemi 1982; McBroom, Reed, Burns, Hargraves, and Trankel 1985; Thomas and Stankiewicz 1974).

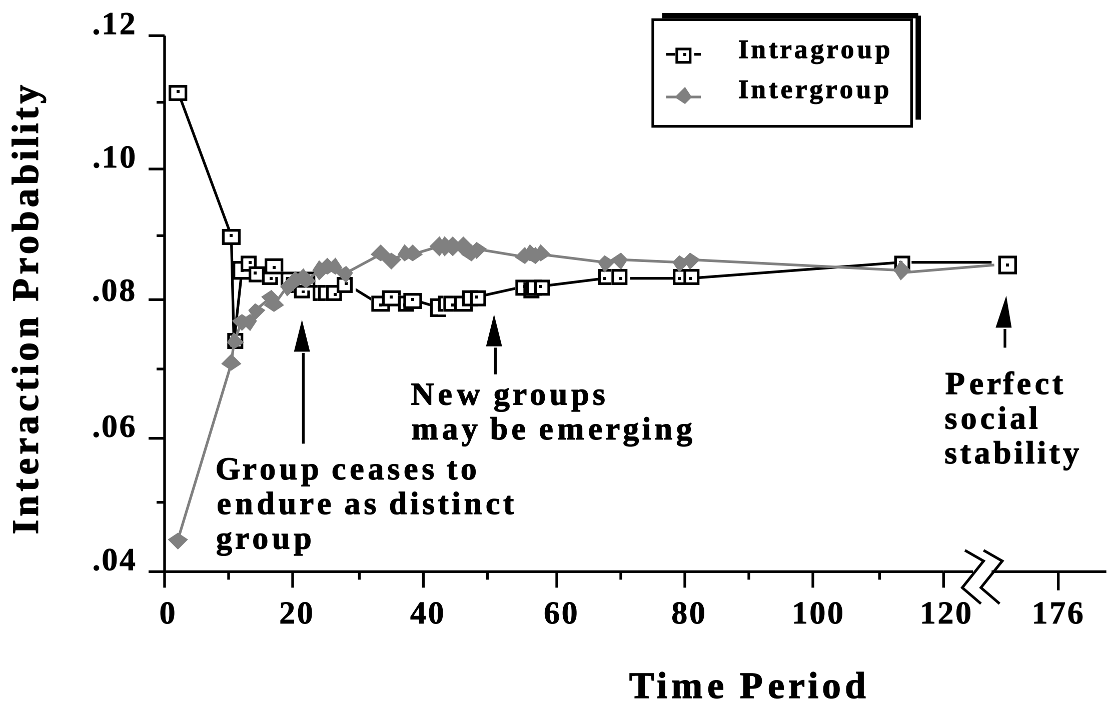

Figure 3. Intergroup and Intragroup Interaction Probabilities Over Time: One Group in a Two-Group Society

A snapshot of a society at a particular time portraying its social structure, culture, subcultures, and so on is not sufficient to determine the history of that society. Not only is its history not monotonic, but because of the chance interactions of individuals and the random communication of particular facts, the "same" initial society can pass through many possible alternative "histories" as it approaches perfect stability. For example, different simulations of the society portrayed in Figure 3 shows peaks and valleys at different times, and even different numbers of peaks and valleys.

In summary, using the model it is possible to derive a number of theoretical propositions. In many cases, there is corroborating data from prior studies. The model synthesizes a number of distinct studies and extends others, e.g., linking culture (shared information) and demographics (size of groups). Because of the complexity of linking a number of parameters longitudinally over multiple time points, I turn to simulations to illustrate some of the more dynamic predictions of the model.

CONSTRUCTION: DETERMINANTS OF STABILITY

To simplify the analysis, I discuss the dynamic implications of the model for one-group and two-group fully-connected societies. Eventually these societies will be perfectly stable: Everyone will know everything that anyone knows. In the process, most groups in multi-group societies come and go. *Why do some groups endure longer than others?* Totally disconnected groups will endure indefinitely, longer, obviously, than groups in a fully-connected society since there can be no communication between disconnected groups. But in human societies, disconnected groups are not the norm. Individuals in one group often interact with individuals in other groups: couples meet to play bridge, Catholics and Protestants work together, and so on. The question of group stability, therefore, becomes a question of the relative endurance of groups with different populations and different distributions of information across people.

Just as we may ask why some groups last longer than others, we also may ask what population size, what level of cultural complexity, and what distribution of knowledge across people promote a rapid convergence to perfect stability at the societal level. Consequently, the ensuing discussion examines how social composition over a society's "history" affects the society's convergence to perfect stability and influences the relative endurance of groups within that society. I use Monte Carlo-type analysis to estimate the number of time periods required for each one-group society to reach perfect stability and the number of periods required for each two-group society to reach the point where the first group (which is generally the smaller group) is no longer a distinct group. The results are based on 600 simulations for each initial society.[11]

One-Group Societies

One-group societies should converge quickly to perfect stability when: (1) the population is small; (2) the culture is less complex (i.e., has fewer things to know); and (3) initial cultural homogeneity is high.

To examine these expectations, I simulated a set of societies with different initial structural configurations. Each of the simulated societies had either two, three, four, five, six, 12 or 18 people. Each contained a total of 10, 20, or 30 facts, and each fact was known by at least one person. Facts were distributed so that each person initially knew either 25 percent, 50 percent, or 75 percent of them. Thus the level of cultural homogeneity was either 6.25 percent, 25 percent, or 56.25 percent.[12] Only fully-connected societies were simulated, which eliminated societies in which the total number of facts divided by the number of people was greater than the percentage of facts known by each person, and guaranteed that in a society of I people and K facts, all I people ultimately would know all K facts. I determined randomly who initially knew what facts. Table 2 shows the average time to stability for 600 simulations for each type of society. Recall that the lower the number, the more essentially stable the society.

In order to determine the relative impact of the number of facts (cultural complexity), size of population, and the percentage of facts known (cultural homogeneity) on social stability, I performed a regression analysis of the means (Table 3).[13] Because of the large sample size, all coefficients are significantly different from zero. Cultural complexity increases the time to stability whereas cultural homogeneity decreases time to stability. Size of the population has virtually no effect -- a simple stepwise regression shows that the size of population adds little additional explanatory power.

Table 2. Average Time to Perfect Stability by Size of Population, Number of Facts, and Percent of Facts Known: Simulations for One-Group Societies

Number of Facts and Percent of Facts Known	Size of Population: 2	3	4	5	6	12
10 Facts						
25% Known	*a*	*a*	*a*	70.17	74.75	74.51
50% Known	60.69	61.66	70.30	68.04	64.78	59.15
75% Known	48.99	52.61	42.55	41.92	46.87	50.35
20 Facts						
25% Known	*a*	*a*	*a*	170.35	165.48	163.81
50% Known	153.82	161.25	149.58	149.91	146.01	132.85
75% Known	113.66	119.98	113.87	118.39	103.22	108.43
30 Facts						
25% Known	*a*	*a*	*a*	268.90	264.72	256.03
50% Known	249.98	265.29	252.30	229.06	212.80	227.68
75% Known	189.09	229.21	212.70	185.27	196.69	189.56

Note: N = 600 for each cell. [a] Societies of fewer than five people cannot be fully-connected if each individual knows on average only 25 percent of the facts. Therefore, such societies are excluded from this analysis.

Table 3. Regression Coefficients for Average Time to Perfect Stability on Selected Independent Variables

Independent Variable	Standardized Regression Coefficient	Stepwise R^2
Number of facts	.953 ***	.908
	(45.534)	
Percentage of facts known	-.263 ***	.970
	(-11.532)	
Size of Population	-.074 **	.975
	(-3.235)	
Number of cases	54	

** p < .01 *** p < .001 (two-tailed)

Note: This is a regression of the 54 means in Table 1. Numbers in parentheses are t-statistics.

At least in one-group societies, then, the model suggests that population size does not determine time to stability. Although dyads converge more quickly than triads, they are not always the quickest to converge. Population size has minimal impact because the larger the group, the more people there are to tell people both what they do not yet know and what they already know . In contrast, the simpler the culture, the more quickly the society reaches stability because there is less for people to learn. Furthermore, the more homogeneous the culture, the more quickly the society reaches stability because there is proportionately less to learn. In addition, people in less culturally homogeneous societies can form subcultures or splinter cultures (pockets of shared knowledge and shared ignorance) that reinforce themselves and destabilize the society.

Finally, the model suggests that the absolute amount of information possessed by people in the society does not determine its time to stability. For example, (Case 1) a society of three people and 10 facts in which each person begins by knowing five facts (50%) reaches stability faster (average time to perfect stability is 61.66) than (Case 2) a society of three people and 20 facts in which each person begins by knowing 10 facts (50%) (average time to perfect stability is 161.25). In (Case 3) a society of three people and 20 facts in which each person begins by knowing 15 facts (75%) reaches stability faster (average time to perfect stability is 119.98) than Case 2 and slower than Case 1. These findings suggest that things that decrease cultural complexity, such as norms, bureaucratization, and rituals, shorten the time to societal stability, whereas those things that increase how much people know, such as education, newspapers, and books, shorten the time to societal stability only if they increase cultural homogeneity.

Consider what these predictions might mean in an organization. In the context of a project group, for instance, a possible interpretation of the parameters might be that the number of facts is the complexity of the project facing the group and the percentage of facts known is each participant's prior knowledge about that project. Such a group might be a set of Taliesin employees assigned to develop a system for a particular customer. Developing a drug inventory system for a single doctor's office would be a small task involving less information than developing such a system for a large metropolitan hospital. In both cases, because Taliesin employees have worked on similar projects in the past, the amount of known information would be high. In contrast, if the same people were assigned to develop an expert system for prescribing drugs, the Taliesin employees would have little previous experience to apply to the problem regardless of the complexity of the project. Consensus is guaranteed, by definition, once everyone knows everything, i.e., once perfect stability is reached. If the goal is to achieve consensus quickly, groups should be assigned simple tasks and should be set up to ensure a high initial level of homogeneity in each group. In addition, for a particular task, individuals who know most about that task should be chosen. Since task complexity matters, a large, less homogeneous group composed of people who know less, faced with a simple task may reach consensus more quickly than a small, more homogeneous group composed of people who know more, faced with a complex task. Regardless of the complexity of the task, changing the level of homogeneity in the group has a greater effect on timely stability than does group size. At Taliesin, project agreement will be achieved more quickly when two computer scientists are assigned to the project than when one computer scientist and one business major are assigned.

Two-Group Societies

A more complex but more realistic analysis considers patterns over time in societies in which initially only two groups are connected. When we deal only with connected groups, the societies modeled are consistent with those envisioned by Blau (1977, p. 42) in his basic axiom: "The members of a society associate with others not only in their own but also in different groups", and in theorems derived from that axiom. From the perspective of a society, the mark of stability is time to stability, i.e., the speed with which all groups are extinguished and the society becomes homogeneous. In contrast, from the perspective of a group, the mark of stability is endurance, i.e., the amount of time until the probability of intragroup interaction is no longer greater than the probability of intergroup interaction. In the following analysis, the focus shifts from the time until the entire society reaches perfect stability to the endurance of a group within a larger society, keeping in mind that the greater the group endurance the longer the time to stability for the society.

This shift if focus involves subgroup assimilation, which in many respects is an information problem. Even rival high school gangs, who appear to have much in common, have their own unique set of facts (club name, secret code words, knowledge of special meeting places, dress codes, hair styles, and so forth). Thus, despite a large base of facts in common, behavior is controlled by small differences in who knows what. Thus in a two-group society, the question of subgroup assimilation becomes: Do the size of the group and its cultural distinctiveness affect its rate of assimilation?[14]

<u>Impact of number of people and number of facts.</u> Groups in two-group societies should endure longer if (1) their population is large and (2) their

culture is highly distinctive. To examine this contention, I simulated several societies with different structural configurations. Each society had either six, 12, or 18 people and a total of 10, 20, or 40 facts. Each society initially consisted of two equal-sized groups. Each group had a monopoly on half the facts, except that one person in each group knew one fact that was known by one member of the other group. These two individuals are tied weakly and act as a bridge between the two groups by which group knowledge initially can be exchanged. This type of bridge is analogous to situations in which CEOs sit on the Boards of Directors of unrelated companies or in which exchange students stay with host families. Table 4 shows the average endurance time of the first group for each simulated society.

Table 4. Average Endurance Time by Size of Group and Number of Facts: First Group in Two-Group Societies

	Size of Population		
Number of Facts	6	12	18
10	40.82	41.73	42.08
20	90.64	85.13	86.19
40	203.04	181.84	189.21

Note: N = 600 simulations for each cell.

To determine the relative impact of the number of facts (cultural complexity) and the size of population on group endurance, I performed a regression analysis on the means (Table 5). Size of population has virtually no effect on group endurance, but the greater the distinctiveness of the group's culture (the more facts), the greater the group's endurance. As the complexity of the cultures (number of facts) and the difference in the cultures (number of facts peculiar to that group) increase, groups endure longer despite an inherent tendency to societal stability. This finding suggests that things that provide group members with "group only" knowledge, such as entry rituals, secret handshakes, and specialized corporate cultures, help groups to endure longer; they maintain the group's stability at the cost of societal stability.

Table 5. Regression Coefficients for Average Endurance Time on Number of Facts and Size of Population

Independent Variable	Standardized Regression Coefficient	Stepwise R^2
Number of facts	.996 ***	.992
	(30.050)	
Size of Population	-.037	.993
	(-1.111)	
Number of cases	9	

*** p < .001 (two-tailed)

Note: This is a regression of the 9 means in Table 3. Numbers in parentheses are t-statistics.

Impact of ratio of group size and cultural overlap. In two-group societies in which the groups are of unequal sizes, i.e., a minority and a majority, the smaller the minority, the more quickly it will be assimilated because the smaller the minority, the higher the proportion of intergroup interactions, which leads to shared knowledge and hence to assimilation. Furthermore, the greater the cultural overlap between the two groups, the more quickly their members will assimilate and the less enduring the groups.

To examine these hypotheses, I simulated societies with different sociocultural configurations. Each society contained 12 people and 40 facts[15] and was composed initially of two possibly unequal-sized groups (a minority and a majority). Each group had a quasi-monopoly on half of the facts: All of the people in the first group (minority) knew the first 20 facts; all the people in the second group (majority) knew the second 20 facts. These societies differed in the relative sizes of the groups and the initial level of cultural overlap (percentage of the other group's facts that each group knew initially). Group ratios were 1:1 (two groups of six each), 1:2 (a minority of four and a majority of eight), and 1:5 (a minority of two and a majority of 10). The percentage of other group's facts known was set equal for both groups. I examined four different percentages: 10 percent, 25 percent, 50 percent, and 75 percent. Because of the cultural overlap, there were many weak ties between the groups. Table 6 shows the average endurance time for each simulated society.

Table 6. Average Endurance Time by Percentage Overlap in Shared Knowledge and Ratio of Group Sizes: First Group in Two-Group Societies

	Percentage Overlap in Shared Knowledge			
Ratio of Group Sizes	10	25	50	75
1:1	167.22	156.33	148.36	144.32
1:2	213.06	193.84	176.33	134.78
1:5	350.47	333.02	321.61	278.50

Note: N = 600 simulations for each cell.

To test the hypotheses regarding the size of the minority group and its cultural overlap with the majority, I performed a regression analysis of the means using the ratio of group sizes and the percentage overlap in shared knowledge (cultural overlap) as the independent variables and group endurance time as the dependent variable (Table 7). The results show that, contrary to the first hypothesis, the smaller the minority relative to the majority, the longer the time required before the group assimilates if all else is held constant. In keeping with the second hypothesis, the greater the cultural overlap, the less enduring the groups. Thus, relatively small minorities who share more knowledge with the majority actually may endure longer than larger minorities who share less information with the majority. One reason for this is that as the ratio of minority to majority decreases, the minority's probability of intergroup interaction increases but the majority's probability of intergroup interaction decreases. For a society of 12 people with a 50 percent overlap in shared knowledge and a ratio of group sizes of 1:2, the average interaction probabilities are:

	Minority	Majority
Minority	.107	.071
Majority	.063	.094 .

When the ratio of group sizes is 1:5, they are

	Minority	Majority
Minority	.115	.077
Majority	.059	.088 .

As the ratio of group sizes decreases, two effects become more pronounced: (1) because the majority contains more members, they are more likely to be the ones to choose interaction partners first; and (2) because members of the majority are less likely to interact with members of the minority, they are more likely to choose other members of the majority. Over time, the level of knowledge shared between the groups increases. Hence, even if the size of the minority increases relative to the size of the majority, the probability of intergroup interaction may increase. These results suggest that factors that keep groups small in relation to the majority, such as limited memberships, immigration controls, and birth control, actually increase the endurance of those groups. Furthermore, factors that keep groups culturally distinct and reduce the amount they have in common with other members of society, such as private schooling, living in the same part of the city, and being members of the same religious community, also increase the endurance of those groups.

Table 7. Regression Coefficients for Average Endurance Time on Ratio of Group Sizes and Percenta
Overlap in Shared Knowledge

Independent Variable	Standardized Regression Coefficient	Stepwise R^2
Percentage of Overlap in shared knowledge	-.271 (-2.065)	.772
Ratio of group sizes	-.879 *** (-6.697)	.845
Number of cases	9	

*** p < .001 (two-tailed)

Note: This is a regression of the 9 means in Table 5. Numbers in parentheses are t-statistics.

Weak ties. Contrasting two societies with the same number of facts (40) and the same number of people (12) in Tables 4 and 6, shows that for the society in which there is one weak tie (Table 4) groups endure longer (181.84 time periods) than in the society in which there are many weak ties (Table 6, 10 percent level, endurance is 167.22 time periods.) These results show that group endurance decreases as the number of weak ties between groups increases. Thus, the model's behavior is consistent with the common observation that weak ties are socially integrating but destabilizing to the local group. Correspondingly, the model also predicts that the stronger the "weak" ties, i.e., the more culturally similar the two individuals, the lower the group's endurance. The endurance of a group thus may be increased by cutting ties to the outside, by decreasing relative shared knowledge with individuals outside the group, and by decreasing the size of the group relative to the majority.

RECONSTRUCTION: THE IMPACT OF CHANGE

So far I have discussed societies in which the number of people and the number of facts do not change over time. In reality, of course, people immigrate and emigrate, are born or die, are hired and fired; new facts emerge as discoveries are made and new people enter the society. Because such changes occur, the stability of a group is often regarded as depending on the group's ability to "reconstruct" itself. One line of sociological reasoning, which generally follows the Durkheimian or the Marxian tradition, suggests that societies are reconstructive and that they teach or coerce their members to behave in ways that reinforce and reproduce the extant social structure (Collins 1975; Durkheim [1912] 1954; Garfinkel, Lynch, and Livingston 1981; Giddens 1984; Goode 1960). Sanctions and rituals are often seen as necessary precursors to reconstruction. It is possible, however, that at least some form of reconstruction occurs without sanctions or rituals.

Using perturbation analysis, I examine the impact of a single change on the stability of groups in a two-group society. I use the change in a group's endurance time as a measure of that group's ability to reconstruct itself. The less the group's endurance is decreased by the change, the more reconstructive the group.

When a New Person Enters the Society

Groups and societies have dynamic populations: Babies are born, new people are hired, and so on. The hypothetical consulting companies Taliesin and Fairview, for instance, might consider hiring a new person competent in medical expert systems. New people often join a group with little or no contact with competing groups and with little in common with their new group. The question now is whether such changes affect the relative endurance of the group. Do new people have a destabilizing influence, or can groups reconstruct themselves in the face of such population changes? To address such questions, I altered the societies analyzed for Tables 4 and 6 by adding a new person at the beginning of the run and then repeating the 600 simulations. The new person was always added to the same group (the minority, if the groups were of unequal size) and knew only one fact. That fact was already known by all members of the group. I then subtracted the original endurance time of the group from the endurance time after perturbation.

The results show that adding a new person to a two-group society decreases the group's endurance considerably. A regression analysis using the change in average endurance time as the dependent variable (Table 8) shows that the new person has less impact the larger the population, the less complex the culture (the fewer the facts), the more distinctive the group's subculture, and the closer the two groups are in size. Thus, the model suggests that groups with one or more of these characteristics can reconstruct themselves more quickly. Large groups are more reconstructive because there are more people interacting with the new person, enabling the new person to acquire group knowledge more quickly. Groups with simpler cultures are more reconstructive because there is less for the new person to learn. Groups that are more culturally distinct are more reconstructive because it is more likely that the information that members give the new person will be special to the group, and hence increase the probability that the new person will interact within the group. Because, the new person is always added to the minority, the closer the groups are in size, the more reconstructive the minority will be because there are proportionately fewer people outside the group with whom the new person can interact. Thus, the new person acquires the other group's knowledge more slowly. These results suggest that hiring a new person will be more destabilizing for Fairview than for Taliesin because Fairview is smaller and more culturally homogeneous (members of Fairview are of the same sex, went to the same college, got the same degree, and so on).

Table 8. Regression Coefficients for Change in Average Endurance Time Due to a New Person on Selected Independent Variables

Independent Variable	Standardized Regression Coefficient	Stepwise R^2
Absolute Variables		
Number of facts	-.761 **	.580
	(-4.098)	
Size of population	-.462 *	.793
	(-2.487)	
Number of cases	9	
Relative Variables		
Ratio of group sizes	.829 ***	.687
	(-5.719)	
Percentage of Overlap in shared knowledge	-.352 *	.811
	(-2.427)	
Number of cases	9	

* $p < .05$ ** $p < .01$ *** $p < .001$ (two-tailed)

Note: Each regression is a regression of 9 means. Numbers in parentheses are t-statistics.

When a New Fact is Discovered

Much social and cultural change is often attributed to new technologies and new ideas. Such discoveries typically are made by a single person, who of course is a member of some group. Do such discoveries affect the relative endurance of the group? Do new ideas have a destabilizing influence, or are groups able to reconstruct themselves in the face of such cultural changes? To address such questions, I altered the societies analyzed in Tables 4 and 6 by adding a new fact at the beginning of the run and then repeating the 600 simulations. The new fact was known initially by only one person, who was always in the same group (the minority, if the groups were of unequal size). Then I subtracted the original endurance time of the group from the endurance time after perturbation.

The results reveal that a new fact tends to increase the group's endurance slightly. A regression analysis using the change in average endurance time as the dependent variable (Table 9) shows that the new fact has more impact the more complex the culture initially (the greater the number of facts). Other factors, such as absolute or relative group size and degree of cultural overlap, have no effect on the group's reconstructiveness in the face of new information. Discovery increases the difference in shared knowledge between the two groups, thus increasing the time to convergence. This point suggests that as groups develop "things" that increase their cultural distinctiveness (and hence increase sociocultural diversity), such as inventions, discoveries, new words, or new rituals, they increase their endurance (and hence their stability as a group). Discoveries, however, also increase the variance within the group in terms of who knows what, and thereby decrease the probability of intragroup interaction. Generally these two factors (endurance and variance) compete with each other, making the social and cultural results of discoveries a complex process. The factors work together, however, to result in the conclusion that the less complex the culture and the less distinctive the subgroups, the less reconstructive the group in the face of new information. To illustrate, if a computer scientist at Taliesin were assigned to learn about medical expert systems , it might be difficult to predict its impact on the company. If, however, that computer scientist had already shared a great deal of information with the other computer scientists employed by Taliesin and had shared little with other company employees, this assignment would increase the distinctiveness and the cliquishness of the computer science subgroup. In a large company, it might even result in the formation of a special division.

Table 9. Regression Coefficients for Change in Average Endurance Time Due to a New Discovery on Selected Independent Variables

Independent Variable	Standardized Regression Coefficient
Absolute Variables	
Number of facts	.695
	(2.365)
Size of population	-.001
	(-.002)
R^2	.482
Number of cases	9
Relative Variables	
Ratio of group sizes	.150
	(.475)
Percentage of Overlap in	.283
shared knowledge	(.895)
R^2	.102
Number of cases	9

* $p < .05$ ** $p < .01$ *** $p < .001$ (two-tailed)

Note: Each regression is based on 9 means. Numbers in parentheses are t-statistics. When the absolute variables are used, size of population contributes less than .150 to the R^2. When relative variables are used, both variables combined contribute less than .150 to the R^2.

In summary, a group's endurance (and hence its stability) is compromised less by new information than by new people, even when the ratio of new facts to old is as great as the ratio of new people to old. Both the structural and the cultural composition of the society affect its reconstructive ability. With new people, the relationship among structure, culture, and reconstruction is strongly determinative. With new facts, the relationship is less clear because the diffusion of a specific piece of information is affected by the network of ties among individuals and by the strength of those ties.

DISCUSSION

The proposed model simplifies many aspects of "real social life." Consequently, valuable insights may result from incorporating into the base model any of several secondary models and associated subprocesses: (1) a structured model of information, (2) a model of information forgetting, (3) institutional or environmental limits on interaction or forced interaction, (4) a model of population dynamics, or (5) a model of information discovery.

The model is most applicable to small groups over a limited time span. Extensions to large communities or nations over centuries would be highly speculative. Within small groups in a limited time span, the model is most applicable to freely chosen associations rather than associations forced by the strictures of the organization, such as board meetings and required seminars. Furthermore, though the model does not distinguish types of interactions, it is more applicable to interactions concerned primarily with the exchange of information than with the exchange of money, goods, and services. Even within the scope of the model, care is warranted in extrapolating from these results. Because of computational limits, I did not map out the complete space of group behavior as changes occurred in the number of people, facts, ratios of group sizes, and initial distribution of shared knowledge.

Despite its simplified nature, however, the proposed model has considerable explanatory power. Many of its implications are consistent with known findings such as the asymmetry of interaction and the oscillatory nature of group behavior. New theoretical insights can also be derived from the model. For example, groups that are the most stable in the short run (i.e., when no new people enter or when no new discoveries are made) may not have the greatest reconstructive capability in the long run. For example, small groups are the most stable in the short run, but large groups are more reconstructive in the long run when new people enter. Large groups are less enduring because with more members there are more links to the outside and thus more ways group culture can diffuse. Large groups are more reconstructive because there are more people to interact with and to "socialize" the new member to the group's culture. Groups with less complex cultures are more reconstructive in the long run when new people enter, and less stable in the short run. A simpler culture contains fewer facts; hence there is less for both the new person and for the other group to learn.

Even in this simple model in which interactions are characterized only by the giving and/or receiving of information and in which there is no differentiation of information, individuals still assume multiple roles. Individuals act as windows through which external culture enters, i.e., they act as carriers of the internal culture, "students" acquiring new information, "teachers" providing information, harbingers of change, and so on. Similarly, information serves multiple purposes such as tying groups together, segregating groups, inhibiting group membership, and defining group membership. At the group level, these diverse roles for people and facts, although the result of a single underlying and very simple process, produce group stability or change depending on the structure of the society.

However, a certain basic asymmetry exists between people and facts. (1) Groups are more reconstructive in the face of new people if there are more people but fewer facts. (2) Group endurance is decreased by new people but increased by new discoveries. (3) Societal stability is increased by new people but decreased by new discoveries. (4) Structure determines strongly the reconstructive nature of the group when new people enter, but not when new facts are discovered. Asymmetry is fundamental to the social act of interaction: Two people are needed to exchange one fact, but only one fact is needed to link two individuals. This simple, fundamental difference means that when a new person is added to the society, the number of ways in which a piece of information can be exchanged increases combinatorially and the average probability of interaction decreases. In contrast, when a new fact is added to a society, the number of pieces of information that can be exchanged increases in linear fashion and the probability that any one piece of information will be exchanged during a particular interaction decreases. Even with extensions to the model, such as information forgetting and population dynamics, this asymmetry will continue to be an important feature.

The proposed model is a dynamic model: Individuals interact, exchange information, adjust their sociocultural position, and implicitly enter and exit groups as they change their interaction probabilities. Such dynamics make it possible to address questions of stability directly. Furthermore, as an analytic model of the process of change, the model suggests under what conditions heterogeneity and inequality are maintained and what can be done to counter them. Yet the full dynamic range of the model has not been explored. When two-group societies were examined, the subject of concern was the endurance of the predefined groups. It could be argued that the mechanism described also generates groups; yet it has not been demonstrated that new groups emerge. Thus, a next step would be to use procedures such as clustering, blocking, and network techniques for locating groups forming, and perhaps even to develop new techniques to do so. In addition, the emergence of groups may be of particular interest when information is differentiated, because differentiated information may produce differentiated groups.

The basic constructural theory suggests that there is a natural tendency to stability that, in the absence of communication barriers, will ultimately dissolve all group boundaries. Groups, however, can endure indefinitely if no cultural overlap exists. Thus, environmental, institutional, and motivational factors are not *necessary* for group survival; such factors may be sufficient, but they are not necessary. From a more practical standpoint, group endurance is usually concerned with groups that endure longer than others, not with perpetual endurance. In this more limited view of endurance, the proposed perspective provides a variety of insights. It suggests that things that serve to disrupt this natural tendency, such as discoveries, population dynamics, institutions, and motivations, are critical to the perpetual endurance of groups simply *because* they disrupt this tendency to stability.

Constructural theory is a processual theory. According to this perspective, self construction and social reconstruction are not contradictory processes. Even a simple process of self construction, when carried out in parallel by all the members of a society, is a process of reconstruction and change at the social level.

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APPENDIX: TECHNICAL DETAILS ON THE IMPLEMENTATION OF THE MODEL

Simulation Algorithm

Read input data
Set up end conditions
For each desired Monte Carlo run:
    Set up society
        If not using fixed initial fact distribution
                Randomly distribute facts using group-level constraints
                Check for fully-connected
                Repeat process until a fully-connected society with these constraints has been built
        If using fixed initial fact distribution reinstate original societal description
    Interaction shared knowledge cycle
                Compute interaction probabilities
                Choose interaction partners
                All partners interact and exchange information
                All individuals update the facts they know
                Group- and societal-level cumulative statistics updated
                Repeat cycle until end condition is met
    Across-run statistics calculated
Compute final statistics
Print final statistics

Input

Input is a file describing the nature of the simulation and the society. The simulation is described in terms of maximum time periods, number of Monte Carlo iterations, and a condition for ending the interaction shared knowledge cycle (e.g., "go until probability of intragroup interaction for Group 1 is greater than probability of intergroup interaction" or "go until everyone knows everything"). The society is described in terms of number of people, number of facts, number of groups, who belongs to which group, and who knows which facts. Who knows which facts can be specified either in terms of group-level percentages or by specifying the facts known by each individual. Real or artificial data can be provided. Carley (1990) presents an illustration of this program using real data as input.

Output

Output is a series of summary statistics and information on the society and its subgroups. These statistics include, but are not limited to, time to stability, intergroup interaction probabilities, intragroup interaction probabilities, and time until first group is assimilated (endurance time).

Availability

The simulation program is written in C and runs on a UNIX work station. The program is available upon request from the author.

[1] Organizational ecologists (Carroll 1984; Hannan and Freeman 1977; Wholey and Brittain 1986) deliberately underspecify these mechanisms because they contend that individual-level mechanisms do not determine group behavior, that particular environments and a group-level evolutionary process determine the behavior of groups.

[2] The term "fact" is used interchangeably with the term "piece of information" without implying the legitimacy or truthfulness of the piece of information. A fact is either "known" or "not known." Anything that can be represented in symbols -- attitudes, beliefs, concepts, ideals, task-related information -- can be regarded as fact.

[3] The symbol stands for the logical "or."

[4] Individuals are not mindless creatures reacting to circumstances, which are, after all, external to the individual. Rather, this is what has come to be known as a knowledge-level argument within cognitive science -- individuals are acting exactly on the basis of what they know.

[5] For ease of exposition, I use the term "probability of interaction" whenever $P_{ij}(t)$ is the underlying construct. $P_{ij}(t)$ is not the full probability of interaction but rather the probability of interaction given that all individuals are available for interaction and that individual *i* has the opportunity to choose an interaction partner. The symbol represents the logical "and."

[6] Although the selection of an interaction partner depends on the interaction probabilities, the order in which individuals are chosen to select their partners is not. Furthermore, this order is different at each time period.

[7] Two individuals need never communicate to share a fact. Thus, for example, *i* and *j* can share a fact if *j* tells *i* that fact, or *i* tells *j* that fact, or third party tells both *i* and *j* the same fact.

[8] A fully-connected society exists for any two people if: (1) they share at least one fact or (2) they are connected by a chain of individuals such that each dyad along the chain shares at least one fact.

[9] Interaction is based on the individual's mental model of what they think they share. For individuals who have shared experiences (such as a husband and wife) their models vis-a-vis each other should be particularly accurate.

[10] The behavior of this single, illustrative society is not unique. When I simulated 500 other societies, all exhibited an oscillatory approach to stability. They differed from the society illustrated here in the number of peaks and valleys and in the location of these features over time. The particular society portrayed is composed of 20 people with 10 people in each group.

For this society there was a total of 20 facts. Members of the first group initially knew 50 percent of the first 10 facts and 15 percent of the second 10 facts. Members of the second group initially knew 50 percent of the second 10 facts and 15 percent of the first 10 facts (cultural homogeneity is 9.9 percent). Group 1 has an initial probability of intragroup interaction of .1095 and an initial probability of Group 1 to Group 2 interaction of .425. Over the next 10 time periods, the probability of intragroup interaction dropped to .083 and the probability of intergroup interaction rose to .075. Then the probability of intragroup interaction increases and the probability of intergroup interaction decreases. By time 22 the groups are no longer distinct; by time 111 the groups have re-emerged as distinct groups and remain so until everyone knows everything at time 176.

[11] Even with a particular set of sociocultural conditions (group size, population, cultural homogeneity, cultural complexity), there still exists considerable variation exists among the possible fully-connected societies that match these characteristics. I used a Monte Carlo approach to average out differences arising not only from different chance encounters between people but also from cultures that have the same level of cultural homogeneity but vary in the degree to which any particular member is isolated. I chose 600 simulations because it generally reduced the variance of the estimator of the mean time to stability to within the range .4 to 4. I considered this a reasonable compromise between computational time and the ability to distinguish significant differences among societies. To facilitate comparisons, I conducted the same number of runs on each simulated society.

[12] Computational limits were such that societies consisting of more than 40 facts and 18 people could not be analyzed. Given this limit, I chose values for each variable such that the resultant societies covered a wide range of sociocultural configurations (e.g., fewer facts than people, more facts than people, people knowing little, people knowing a lot). I chose at least three points for each variable to see whether the change in stability due to the variable was monotonic. In addition, in Table 1, I modeled all extremely small groups to demonstrate the impact of small changes in group size.

[13] Regressing the means rather than the underlying populations has four effects: The coefficients are correct, the standardized coefficients are slightly high, and the significance of the coefficients is underestimated. In addition, the fit of the equation (R^2) is slightly overestimated. These results follow because the dependent variable is a set of means such that the independent values are identical for all of the values averaged to create a specific mean. In addition, means were computed over 600 values. Hence, the central limit theorem applies and the standard deviations of the means are small; each mean becomes a highly reliable point estimate of the location of the true underlying distribution.

[14] This question holds even in the absence of membership rituals and complex processes to enforce group distinctiveness.

[15]`I chose societies of size 12 because these were the smallest societies that could be analyzed such that group ratios could range from 1:1 to 1:5 and no group had fewer than two people. I chose the largest computationally feasible number of facts so that it would be possible to distribute maximally the amount of information shared by groups.