

Fred Jones of Peoria, sitting in a sidewalk cafe in Tunis, and needing a light for his cigarette, asks the man at the next table for a match. They fall into conversation; the stranger is an Englishman who, it turns out, spent several months in Detroit studying the operation of an interchangeable-bottlecap-factory. "I know it's a foolish question," says Jones, "but did you ever by any chance run into a fellow named Ben Arkadian? He's an old friend of mine, manages a chain of supermarkets in Detroit . . ."

"Arkadian, Arkadian," the Englishman mutters. "Why, upon my soul, I believe I do! Small chap, very energetic, raised merry hell with the factory over a shipment of defective bottlecaps."

"No kidding!" Jones exclaims in amazement.

"Good lord, it's a small world, isn't it?"



## The Small-World Problem

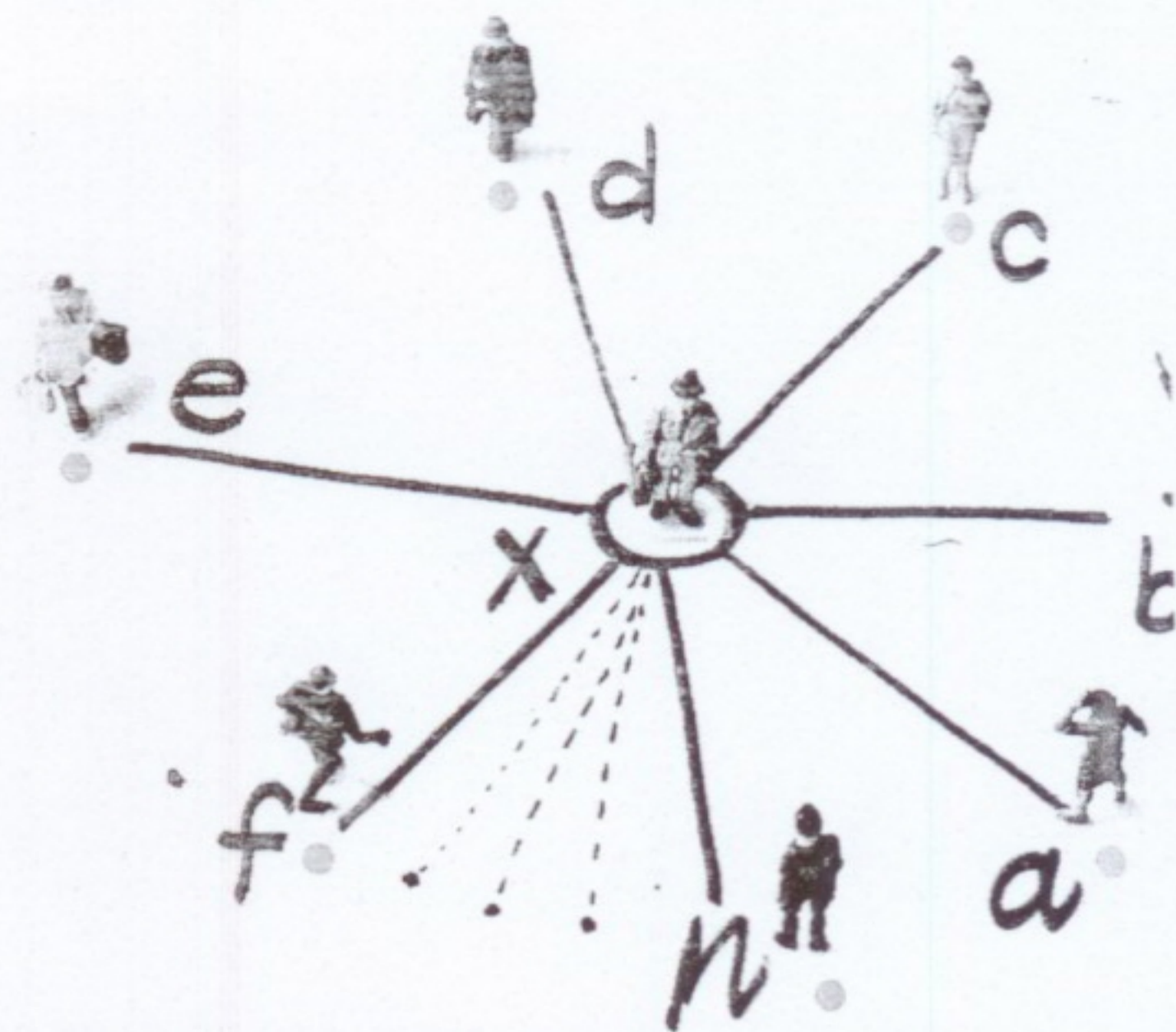
By Stanley Milgram

**A**lmost all of us have had the experience of encountering someone far from home, who, to our surprise, turns out to share a mutual acquaintance with us. This kind of experience occurs with sufficient frequency so that our language even provides a cliché to be uttered at the appropriate moment of recognizing mutual acquaintances.

We say, "My it's a small world."



Random dispersement of people in the small world.



Each person's first-hand acquaintances are shown, A through N.

The simplest way of formulating the small-world problem is: Starting with any two people in the world, what is the probability that they will know each other? A somewhat more sophisticated formulation, however, takes account of the fact that while persons X and Z may not know each other directly, they may share a mutual acquaintance—that is, a person who knows both of them. One can then think of an acquaintance chain with X knowing Y and Y knowing Z. Moreover, one can imagine circumstances in which X is linked to Z not by a single link, but by a series of links, X-a-b-c-d . . . y-Z. That is to say, person X knows person a who in turn knows person b, who knows c . . . who knows y, who knows Z.

Therefore, another question one may ask is: Given any two people in the world, person X and person Z, how many intermediate acquaintance links are needed before X and Z are connected?

Concern with the small-world problem is not new, nor is it limited to social psychologists like myself. Historians, political scientists, and communication

specialists share an interest in the problem. Jane Jacobs, who is concerned with city planning, describes an acquaintance chain in terms of a children's game:

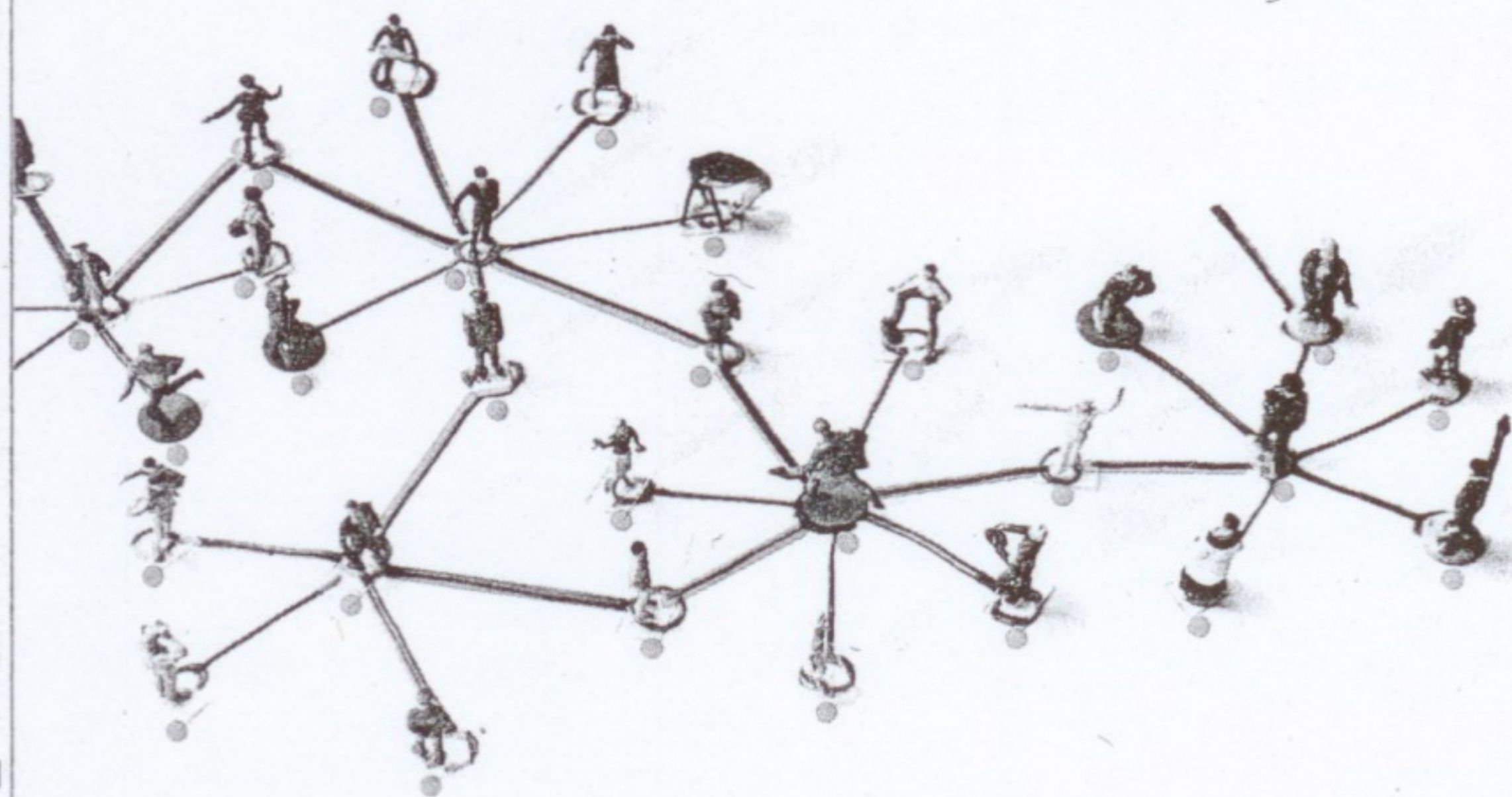
When my sister and I first came to New York from a small city, we used to amuse ourselves with a game we called Messages. I suppose we were trying, in a dim way, to get a grip on the great, bewildering world into which we had come from our cocoon. The idea was to pick two wildly dissimilar individuals—say a head hunter in the Solomon Islands and a cobbler in Rock Island, Illinois—and assume that one had to get a message to the other by word of mouth; then we would each silently figure out a plausible, or at least possible, chain of persons through which the message could go. The one who could make the shortest plausible chain of messengers won. The head hunter would speak to the head man of his village, who would speak to the trader who came to buy copra, who would speak to the Australian patrol officer when he came through, who would tell the man who was next slated to go to Melbourne on leave, etc. Down at the other end, the

cobbler would hear from his priest, who got it from the mayor, who got it from a state senator, who got it from the governor, etc. We soon had these close-to-home messengers down to a routine for almost everybody we could conjure up . . .

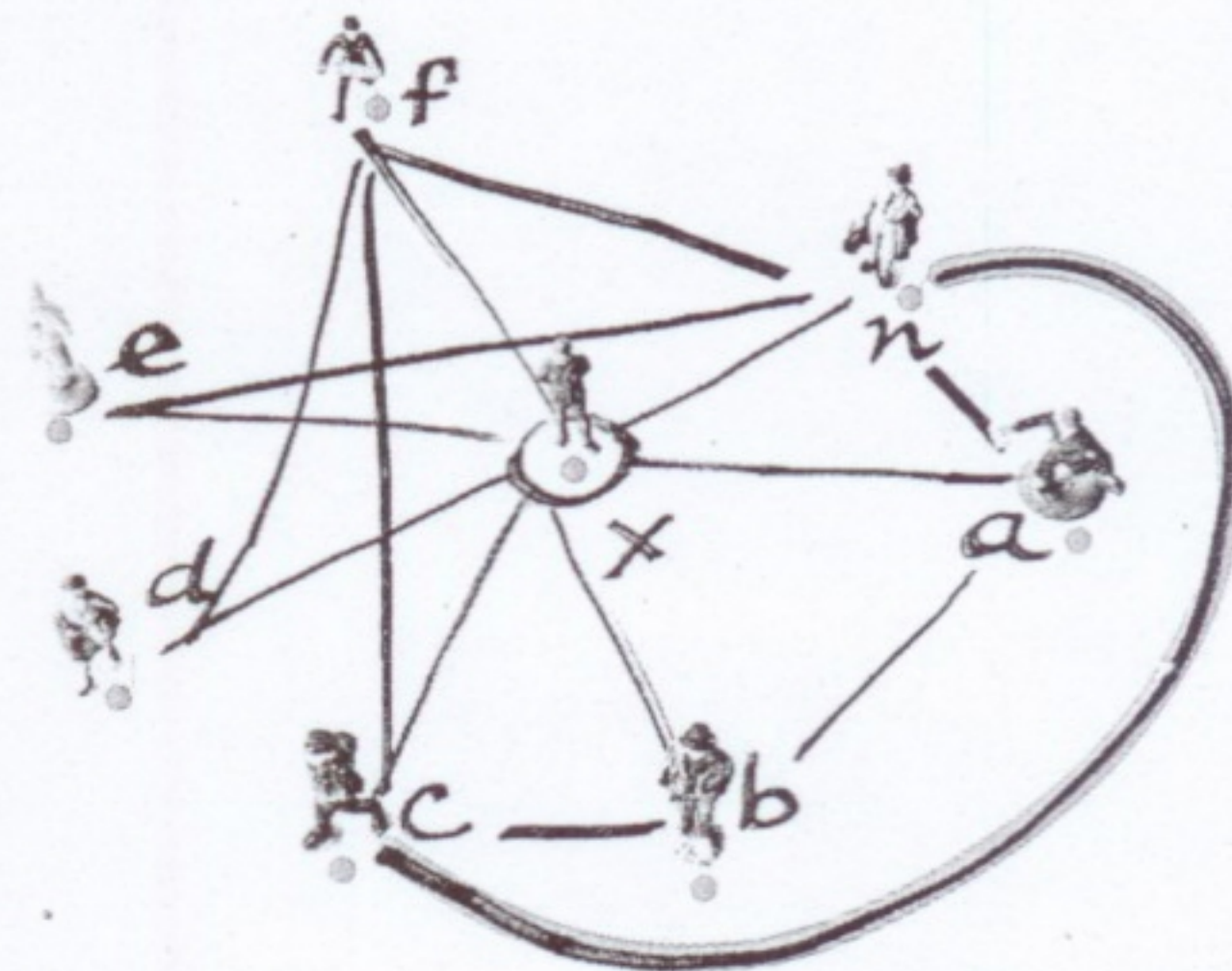
The importance of the problem does not lie in these entertaining aspects, but in the fact that it brings under discussion a certain mathematical structure in society, a structure that often plays a part, whether recognized or not, in many discussions of history, sociology, and other disciplines. For example, Henri Pirenne and George Duby, important historians, make the point that in the Dark Ages communication broke down between cities of western Europe. They became isolated and simply did not have contact with each other. The network of acquaintances of individuals became constricted. The disintegration of society was expressed in the growing isolation of communities, and the infrequent contact with those living outside a person's immediate place of residence.

There are two general philosophical views of the small-world problem. One

The network spreads, with complicated inter-connections.



With group inbreeding, X's acquaintances feed back into his own circle, normally eliminating new contacts.



view holds that any two people in the world, no matter how remote from each other, can be linked in terms of intermediate acquaintances, and that the number of such intermediate links is relatively small. This view sees acquaintances in terms of an infinitely intersecting arrangement that permits movement from any social group to another through a series of connecting links.

The second view holds that there are unbridgeable gaps between various groups and that therefore, given any two people in the world, they will never link up because people have circles of acquaintances which do not necessarily intersect. A message will circulate in a particular group of acquaintances, but may never be able to make the jump to another circle. This view sees the world in terms of concentric circles of acquaintances, each within its own orbit.

### The Underlying Structure

Sometimes it is useful to visualize the abstract properties of a scientific problem before studying it in detail; that is, we construct a model of the main features of the phenomenon as we understand them. Let us represent all the people in the United States by a number of blue points. Each point represents a person, while lines connecting two points show that the two persons are acquainted. [See top illustration, opposite page.] Each person has a certain number of first-hand acquaintances, which we shall represent by the letters *a, b, c, . . . n*. Each acquaintance in turn has his own acquaintances, connected to still other points. The exact number of lines radiating from any point depends on the size of a person's circle of acquaintances. The entire structure takes on the form of a complex network of 200 million points, with complicated connections between them [see bottom left illustration, opposite page]. One way of restating the small-world problem in these terms is this: Given any two of these points chosen at random from this universe of 200 million points, through how many intermediate points would we pass before the chosen points could be connected by the shortest possible path?

### Research at M.I.T.

There are many ways to go about the study of the small-world problem, and I shall soon present my own approach to it. But first, let us consider the important contributions of a group of workers at The Massachusetts Institute of Technology, under the leadership of Ithiel de

Sola Pool. Working closely with Manfred Kochen of IBM, Pool decided to build a theoretical model of the small-world, a model which closely parallels the idea of points and lines shown. However, unlike my own model, which is purely pictorial, Pool and Kochen translate their thinking into strict mathematical terms.

To build such a model they needed certain information. First, they had to know how many acquaintances the average man has. Surprisingly, though this is a very basic question, no reliable answers could be found in the social science literature. So the information had to be obtained, a task which

The beginning of a typical chain (#111) in the Nebraska Study.



### STARTING PERSON

Widowed clerk in Omaha, Nebraska

Michael Gurevitch, then a graduate student at M.I.T., undertook. Gurevitch asked a variety of men and women to keep a record of all the persons they came in contact with in the course of 100 days. It turned out that on the average, these people recorded names of roughly 500 persons, so that this figure could be used as the basis of the theoretical model. Now, if every person knows 500 other people, what are the chances that any two people will know each other? Making a set of rather simple assumptions, it turns out that there is only about one chance in 200,000 that any two Americans chosen at random will know each other. However, when you ask the chances of their having a mutual acquaintance, the odds drop sharply. And quite amazingly, there is better than a 50-50 chance that any two people can be linked up with two intermediate acquaintances. Or at least, that is what the Pool-Kochen theory indicates.

Of course, the investigators were aware that even if a man has 500 acquaintances, there may be a lot of in-

breeding. That is, many of the 500 friends of my friend may be actually among the people I know anyway, so that they do not really contribute to a widening net of acquaintances; the acquaintances of X simply feed back into his own circle and fail to bring any new contacts into it [see bottom right illustration, opposite page]. It is a fairly straightforward job to check up on the amount of inbreeding if one uses only one or two circles of acquaintances, but it becomes almost impossible when the acquaintance chain stretches far and wide. So many people are involved that a count just isn't practical.

So the big obstacle one runs up against is the problem of social structure. Though poor people always have acquaintances, it would probably turn out that they tend to be among other poor people, and that the rich speak mostly to the rich. It is exceedingly difficult to assess the impact of social structure on a model of this sort. If you could

think of the American population as simply 200 million points, each with 500 random connections, the model would work. But the contours of social structure make this a perilous assumption, for society is not built on random connections among persons but tends to be fragmented into social classes and cliques.

### A Harvard Approach

The Pool and Kochen mathematical model was interesting from a theoretical standpoint, but I wondered whether the problem might not be solved by a more direct experimental approach. The Laboratory of Social Relations at Harvard gave me \$680 to prove that it could. I set out to find an experimental method whereby it would be possible to trace a line of acquaintances linking any two persons chosen at random.

Let us assume for the moment that the actual process of establishing the linkages between two persons runs only one way: from person A to person Z. Let us call person A the *starting* person, since he will initiate the process, and person Z the *target* person, since he is the person to be reached. All that would be necessary, therefore, would be to choose a starting person at random from the 200 million people who live in the United States, and then randomly choose a target person.

This is how the study was carried out. The general idea was to obtain a sample of men and women from all walks of life. Each of these persons would be given

