

However, the most surprising defect seen in these embryonic fibroblasts was a pronounced delay in the kinetics of cytochrome c release and Bax translocation in response to ultraviolet radiation. This suggests that caspases 3 and 7 may participate in a feedback amplification loop to promote mitochondrial cytochrome c release in some circumstances. How might this operate?

It is already known that the BH3-only protein Bid can be activated through proteolysis by caspase-8 and caspase-3 (and possibly also by caspase-7). Thus, where only a subpopulation of mitochondria may have initially undergone mitochondrial outer membrane permeabilization, Bid proteolysis by downstream caspases may further enhance Bax activation to amplify cytochrome c release and seal the cell's fate (see the figure).

But is amplification of mitochondrial damage by caspases merely incidental, or can this dictate whether cells will live or die in some sit-

uations? In the case of postmitotic cells, such as neurons and cardiomyocytes, it seems that caspase activation may be essential for death. Exposure of the latter cell types to stimuli that induce mitochondrial outer membrane permeabilization under conditions where caspase activation is pharmacologically blocked resulted in survival of cells for days (9) and recovery upon restoration of normal culture conditions (10). This argues that certain cell types may be rescued from apoptosis by blocking this feedback amplification loop, and this may help to explain the failure of normal heart development in the caspase-3/caspase-7 double-knockout animals. Thus, postmitotic cells that have limited capacity to regenerate may not be discarded as readily as mitotic cells and may observe different death rituals as a result.

Although we now know much about how caspases are activated during apoptosis, it remains unclear why so many of them become

engaged in dying cells and what they all do. Hundreds of mammalian caspase substrates have been identified to date, yet the consequences of only a handful of caspase-mediated proteolytic events are understood. British author W. Somerset Maugham once admonished that "Death is a very dull, dreary affair, and my advice to you is to have nothing whatsoever to do with it." We disagree.

#### References

1. S. J. Martin, D. R. Green, *Cell* **82**, 349 (1995).
2. J. Goldstein *et al.*, *Nat. Cell Biol.* **2**, 156 (2000).
3. S. A. Lakhani *et al.*, *Science* **311**, XXX (2006).
4. A. Strasser, *Nat. Rev. Immunol.* **5**, 189 (2005).
5. T. Kuwana *et al.*, *Cell* **111**, 331 (2002).
6. H. Yoshida *et al.*, *Cell* **94**, 739 (1998).
7. K. Kuida *et al.*, *Cell* **94**, 325 (1998).
8. K. Kuida *et al.*, *Nature* **384**, 368 (1996).
9. M. Deshmukh, E. M. Johnson, *Neuron* **21**, 695 (1998).
10. M. B. Potts *et al.*, *J. Cell Biol.* **171**, 925 (2005).

10.1126/science.1124154

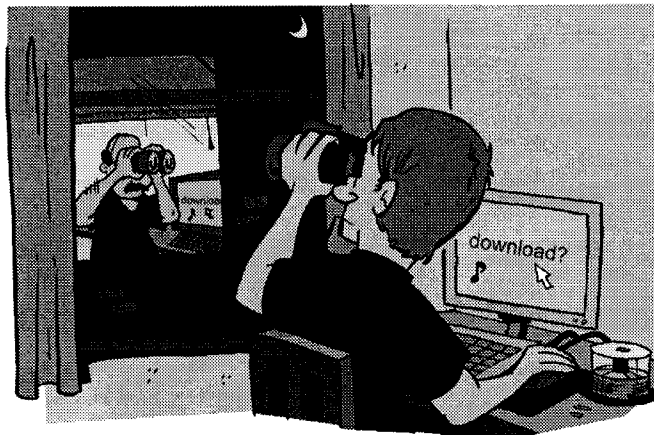
## SOCIOLOGY

# Experimental Macro Sociology: Predicting the Next Best Seller

Peter Hedström

Sociologists typically are not concerned with explaining the behavior of single individuals. Their focus is instead on collective or social outcomes such as the strength of social norms: those of reciprocity and fairness; the norm against living off the work of others; the extent to which cities are racially segregated or workplaces are gender segregated; or various forms of inequalities in earnings and school performance. That is, the focus is on collective or macrolevel properties that are not definable for a single member of the collectivity (1). But to make sense of such properties, it is essential to take into account the actions and interactions of the individuals that brought them about. The study by Salganik *et al.* on page xxx in this issue (2) shows how large-scale internet (World Wide Web)-based experiments can help us understand the complex processes that generate such outcomes.

About ten years ago, Coleman (3) pointed out that even if we are exclusively interested in explaining the relationship between two macro-



**With a little help from my friends.** When making choices, individuals are influenced by what others think is best, making the final outcome unpredictable.

level entities—for example, how patterns of social interaction influence the strength of certain norms—a proper explanation would require us to try to explicate the microlevel processes that brought it about. Thus, we must understand how macrolevel states at one point in time influence the individuals' orientations to their actions, their preferences, beliefs, etc., how these orientations to action influence how individuals act, and how these actions of individuals generate the macrolevel outcomes that we seek to explain.

As Coleman emphasized, the link from

A popular book, movie, or song can generate millions of dollars. But the social process that creates a blockbuster makes it difficult to predict which ones will succeed.

micro to macro has been the main intellectual hurdle for the development of sociological theory. The reason for this can be sought in the complexities involved. Whereas the other two links (macro to micro and micro to micro) can often be analyzed as if they concerned the actions of a single representative agent, once the micro-to-macro link is brought into the analysis, we are dealing with a dynamic process in which people react individually to an environment that consists mainly of other individuals who are reacting likewise.

Empirical sociological research usually is based on survey data—that is, on data derived from questionnaires addressed to random and representative samples of the population at large. Such data are excellent for many purposes, but they are not particularly useful for understanding or testing theories about interactive social processes. The data-collection design is generally such that one ends up with rich information about the attributes of individuals, but little information on the actions of those with whom these individuals interact. Although the statistical methods for analyzing contextual and social-interaction effects on the basis of observational data have

The author is at Nuffield College, University of Oxford, New Road, Oxford OX1 1NF, UK. E-mail: peter.hedstrom@nuffield.oxford.ac.uk

developed considerably in recent years (4, 5), so-called selection and omitted-variable bias make causal inference based on such data difficult indeed (6).

Salganik *et al.* (2) circumvent many of these problems by using experimental rather than observational data. They created a Web-based world where more than 14,000 individuals listened to previously unknown songs, rated them, and freely downloaded them if they so desired. Subjects were randomly assigned to different groups. Individuals in only some groups were informed about how many times others in their group had downloaded each song. The experiment assessed whether this social influence had any effects on the songs the individuals seemed to prefer.

As expected, the authors found that individuals' music preferences were altered when they were exposed to information about the preferences of others. Furthermore, and more importantly, they found that the extent of social influence had important consequences for the collective outcomes that emerged. The greater the social influence, the more unequal and unpredictable the collective outcomes became. Popular songs became more popular and unpopular songs became less popular when individuals influenced one another, and it became more difficult to predict which songs were to emerge as the most popular ones the more the individuals influenced one another.

It is important to note that these results refer to a situation in which individuals were randomly assigned to different groups and all individuals evaluated exactly the same set of alternatives. Nevertheless, when individuals influenced one another, identical populations that started from identical initial conditions each reached different final states. These findings are of considerable sociological importance. They offer persuasive evidence in support of one of the core ideas of sociology; namely, that the structure of social action—that is, the pattern and strength of social influence—in and of itself is of considerable importance for explaining the social phenomena we observe.

The Salganik *et al.* study also makes an important methodological contribution by showing how the Web can be used for conducting large-scale experiments. Experimental sociology typically is conducted in traditional lab settings and the focus is on small-group processes. Moving beyond the small group poses enormous logistic difficulties. To study multiple realizations of a collective social process requires thousands of participants. Experimental methods therefore have been thought to be of interest mainly to social psychologists. Salganik *et al.* show how the technology of the internet can be used for overcoming these restrictions. They show that experimental macrosociology that takes into account all the three micro-macro relationships that Coleman discussed are indeed pos-

sible. They also demonstrate the importance of explicitly taking social influences into account when modeling micro-macro linkages. These are major contributions to the discipline at large.

As Salganik *et al.* show, social processes are highly path-dependent because what others have done in the past influence what we do in the present. Their study surely will influence others to use similar methodologies, but only time can tell whether this type of approach will be a “best seller” within the discipline. Social processes like these always are unpredictable.

#### References and Notes

1. P. Hedström, *Dissecting the Social: On the Principles of Analytical Sociology* (Cambridge Univ. Press, Cambridge, UK, 2005).
2. M. J. Salganik, P.S. Dodds, D.J. Watts, *Science* **311**, XXX (2006).
3. J. S. Coleman, *Foundations of Social Theory* (Harvard Univ. Press, Cambridge, MA, 1994).
4. D. J. Harding, *Am. J. Sociol.* **109**, 667-719 (2003).
5. S. W. Raudenbush, R. J. Sampson, *Sociol. Method.* **29**, 1-41 (1999).
6. C. F. Manski, *J. Econ. Perspect.* **14**, 115-136 (2000).

10.1126/science.1124707

#### ASTRONOMY

## Is the Mystery of Cosmic Magnetic Fields Solved?

Ruth Durrer

The origin of the magnetic fields seen throughout the cosmos has been puzzling. New calculations show that the density fluctuations in the early universe can produce fields of the right amplitude.

Observing astrophysical magnetic fields is difficult. Nonetheless, fields of surprisingly consistent amplitudes on the order of microgauss have been discovered in many galaxies and clusters of galaxies (1). So far, the generation of these fields has remained a mystery. For a long time, scientists tried to conceive of a mechanism by which tiny primordial fields would be created in the early universe (2). Later, during gravitational collapse, such fields could be amplified—for example, by means of a dynamo mechanism—and thereby lead to the observed fields in galaxies and clusters. Even if the seed fields needed for dynamo amplification were as small as  $10^{-25}$  G or smaller, these primordial seed fields have been shown to be severely constrained by the gravity wave background that such fields induce (3, 4). As Ichiki *et al.* report on page XXX of this issue (5), there is another possibility. They show that second-order cosmological perturbations necessarily generate magnetic fields that are of the right order to be amplified by the dynamo mechanism into the currently observed fields in galaxies and clusters.

This is a very exciting proposal. It implies that tiny magnetic fields on the order of  $10^{-22}$  G are present even in intergalactic space (see the figure). Furthermore, the clustering properties of magnetic fields carry an imprint of the primordial fluctuation spectrum from inflation (6). If true, magnetic fields might come to play a very important role in cosmology, comparable to the cosmic microwave background (CMB)

anisotropies. In analyzing these fields, we might learn about the physics of inflation that occurs at very high energies, probably about 10 orders of magnitude higher than the energy that will be reached at the Large Hadron Collider, the world's largest particle accelerator now under construction at CERN in Geneva.

During ordinary inflation, a period where the temperature may reach  $T \approx 10^{14}$  GeV (7), no magnetic fields are generated, because electromagnetism cannot be induced by the expansion of the universe. Only when introducing additional quantum fields can one generate magnetic fields during inflation (2). On the other hand, at the electroweak phase transition, which takes place at a temperature of  $T_{\text{ew}} \sim 200$  GeV, where the electromagnetic and weak nuclear forces separate, magnetic fields can be generated and their amplitude might be correlated to the baryon number produced during the transition. Within the standard model, both mechanisms, the production of baryons and of magnetic fields, are too inefficient to explain the observations, but in slightly generalized (e.g., supersymmetric) versions, the production of sufficient seed fields might be possible (2).

The most problematic aspect of such primordial scenarios is, however, that the galactic scales we are interested in are far larger than the Hubble scale (8) at the time of magnetic field generation. This leads to very substantial generation of gravitational waves during horizon crossing (9). This is in conflict with the helium abundance in the universe, which requires that at the time of nucleosynthesis, when  $T \sim 0.1$  MeV, the gravity wave contribution to the energy density of the universe must have been less than about 10%.

The author is in the Department of Theoretical Physics, University of Geneva, Geneva CH-1211, Switzerland. E-mail: ruth.durrer@physics.unige.ch