of vigorous and poorly controlled virus production after each treatment interruption (*11*). So far, there is no evidence for virus control in chronic HIV infection after structured treatment interruptions. Therefore, any attempts to apply the observations of Walker and co-workers to chronically infected HIV patients should be discouraged until there is conclusive evidence of efficacy.

The encouraging results obtained in patients with a primary HIV infection support the rationale for combining interrupted drug therapy with immunological interventions such as immunization. Indeed, the heavy cost and toxicity of the current drug regimens frequently lead to unsupervised cessation of treatment. To quickly obtain a low, steady-state viral load when treatment is withdrawn, we should ideally restore strong and diverse T_H1 and cytotoxic T cell responses against HIV before, and not after, the virus rebounds. In addition, we should not be content with a deleterious immunogen such as HIV itself; instead, nonpathogenic antigenic formulations (such as those in candidate vaccines) should be administered to patients even though their immunogenicity might still be limited. Several clinical trials, involving about 200 acutely infected and 500 chronically infected patients, are currently combining antiretroviral drug regimens with immunization using various HIV immunogens. The response of these patients to cessation of drug treatment after the completion of therapeutic immunization may provide us with the best large-scale evidence yet that, when given a fighting chance, the immune system can indeed control HIV.

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PERSPECTIVES: EVOLUTION AND SOCIAL SCIENCE

A Tale of Two Selves

Karl Sigmund and Martin A. Nowak

Our urban life-style, with its intensity and bustle, is often compared to life within a colony of social insects. But the similarities are superficial: Most humans working in large teams are not related, whereas insects in a colony are usually very closely related. The recent trend toward globalization, epitomized by a worldwide market and universal communications network, hints at the emergence of a superorganism composed of all members of the human race, but not based on genetic ties.

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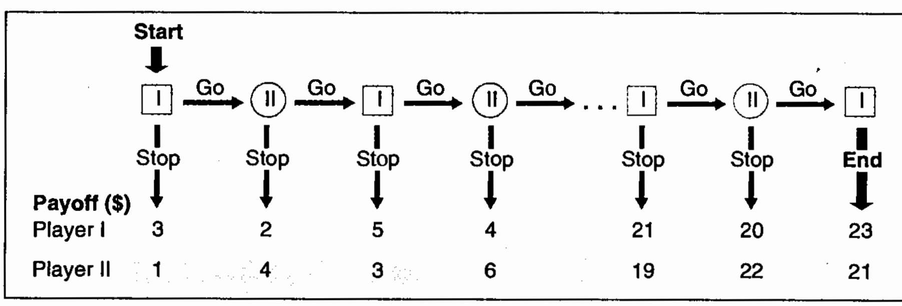
Modern human societies, with their economies revolving around stock markets and bond trading, are highly complex, yet theorists interested in the evolution of human cooperation and communication prefer to study the simplest aspects of human society, such as cooperation within a household. This became clear at a meeting held this summer in the picturesque Austrian town of Steyr (*1*). The meeting brought together scientists from two vastly different backgrounds: the evolutionary biologists, including those studying human as well as animal behavior, and the social scientists, including anthropologists and economists.

Interestingly, both of these groups—representative of our two selves—assume that the societies that they study are composed of selfish individuals, and each group has coined its own definition of selfishness. Economists think of the selfish individual as someone who uses rational behavior to achieve personal preferences or goals (*Homo economicus*), whereas biologists view selfishness in terms of selfish genes that when selected maximize their chance of being passed on to the next generation.

The symposium opened with an address by John Maynard Smith (University of Sussex, UK), a founding father of the field of evolutionary biology, who described some of the major transitions in evolution (*2*). He proposed that the emergence of cooperation and communication among our hominid ancestors was but the last (at least so far) evolutionary flourish following in the footsteps of earlier evolutionary leaps in which competing entities joined forces to form a stronger, larger unit upon which natural selection could work—the fates of genes are linked together in chromosomes; ancient bacteria become the building blocks of eukaryotic cells; there is coordination among different cell types in a complex multicellular organism; individuals, be they termites or humans, unite in colonies or societies.

In each of these cases, the individual building blocks have to work toward a common goal rather than for their own immediate benefit, and so the temptation to defect looms large. In fact, societies—whether they be cellular, insect, or human—are composed of would-be mutineers. As David Haig (Harvard University, USA) pointed out when describ-



The centipede game. You and a coplayer are sitting on opposite sides of a table. On your side of the table are two stacks of money, one smaller than the other. You can either STOP the game by taking the larger stack, leaving the smaller one for your coplayer, or GO to the next round by pushing both stacks to your coplayer's side of the table. In this case, the experimenter adds $1 to each stack. It is now the other player who can STOP the game and pocket the larger stack, leaving the smaller one for you, or alternatively GO to the next round by pushing both stacks to your side, in which case each stack increases by $1 again. But the rules require that the stacks cross the middle-line at the most 20 times. At the beginning of the game, one stack contains $3 and the other stack $1. If you and your coplayer opt for GO as long as you can, you will end up with $23 and your coplayer with $21. But, in the last round, your coplayer has two options: to push the stacks toward you or alternatively to pocket the larger stack (which contains $22), leaving you with the smaller stack (only $20). If you suspect that your coplayer will pocket the larger stack in the final round, then you should not push the stacks toward your coplayer in the penultimate round, but rather should take the larger stack for yourself ($21). Arguing backwards, you can quickly see that you should never choose GO, but should choose STOP right away. But this leaves you with only $3! In actual experiments, people rarely adopt this "rational" but counterproductive stance.

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ing his kinship theory of genomic imprinting (*3*), individuals in a colony or society are not single-purpose agents but may be torn by opposing interests. For example, genes that program either rapid dispersal of offspring or greater parental care of offspring can result in different outcomes depending on whether the gene is inherited from the father or the mother. Expression of a gene for rapid dispersal of offspring shortens the weaning period, a great advantage to the mother, and so it is more likely that a maternal rather than a paternal copy of this gene will be expressed.

The common language of the meeting was evolutionary game theory, which assumes that a particular type of behavior (strategy for interacting with other members of a group) is more likely to spread within the group if it leads to success (*4*). Mathematicians developed game theory about 50 years ago to explain the economics of human societies. Despite its popularity, game theory was slow to catch on among skeptical economists. It was not until evolutionary biologists applied game theory to explain behavioral traits in social animals—such as sentinels providing the alarm call for their threatened colony and putting themselves at risk of being spotted by the predator (an unselfish behavior)—that mainstream economists became more receptive to game theory.

Evolutionary game theory (*5*) can explain a diverse spectrum of social behaviors—such as, conflict, cooperation and coordination—confirming, as Robert May (Oxford University, UK) stressed in his address, that very simple rules can explain the complex behavior of societies (*6*). With a few party hats and cunningly simple games such as "the Centipede game" (*7*) (see the figure), Andrew Colman (University of Leicester, UK) clearly demonstrated that game theory enables irrational behavior in humans to be observed. There are few better examples for demonstrating how irrational behavior can actually benefit economic exchange than the "Public Goods" game. Four persons are given $10 each by the experimenter, and asked (independently) to invest any part of it into a common pool. The experimenter then doubles this common pool and distributes it evenly among the four players. If all players invest their whole sum, they can double it. But the temptation to freeload is strong because players get back only half of their own offerings. Nevertheless, a substantial number of the players contribute a lot. But if the game is repeated for a few more rounds, the players learn quickly to defect; soon, all contributions are negligible—and so are the earnings, of course. The whole game changes dramatically, however, if the players can, at the end of each round, punish their less generous coplayers by fining their accounts. This punishment is economically irrational, because the fines return to the experimenter, not to the punisher; in fact, the rules request that punishers have to pay half as much as the fine they impose. In his talk, Ernst Fehr (University of Zurich, Switzerland) showed that, nevertheless, the tendency to engage in this costly (and irrational) form of punishment is widespread, and its effect is beneficial: Players invest for fear of being punished (*8*). As Mark Twain put it, "the surest protection against temptation is cowardice."

Punishment is a newcomer to the long list of possible factors influencing cooperation among individuals, which includes kinship and reciprocal altruism (where an act of generosity is returned either by a recipient or a third party). Reciprocal altruism has been demonstrated in animals as diverse as stickleback and cichlid fish, chimpanzees, and undergraduates (*9*). The possibility that cooperation is based on reciprocal altruism (that is, whatever we do, we expect some sort of return) becomes less likely as the size of the group increases because, in larger groups, the interactions among individuals are more numerous and more complex. This is particularly intriguing as group size may well have been the decisive factor enabling *Homo sapiens* to displace its Neanderthal ancestor (*10*)—larger groups meant pressure for selection of genes that favored intricate neural pathways (*11*) and the greater communication capabilities of language (*12*).

The development of human language is a recent evolutionary transition. Language consists of words and the grammar rules that arrange them. Words are stored in a person's mental lexicon, whereas rules are generated by a computational grammar book that enables us to produce an infinite number of sentences. Understanding how language evolved is one of the great challenges still facing evolutionary biologists. By building models of language that interface with linguistics, computer science, and learning theory, we soon should be able to explain how natural selection enabled the emergence of our universal language capabilities.

Early philosophers—such as, Hobbes, Rousseau, and Hume—realized that economic exchange is dominated less by rational deliberation and more by a set of instincts (human nature). Now we are ready to design experiments, encompassing both natural and social science, to test models of human nature, thus allowing these two scientific worlds to merge.

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PERSPECTIVES: CHEMISTRY

Stretched Water Is More Reactive

George C. Schatz

Two reports in this issue on pages 958 and 961 (*1*, *2*) present important new results on a topic of long-standing interest to chemists, namely how reagent vibrational motions influence the dynamics of chemical reactions. This topic is particularly important for "activated" reactions, in which a potential energy barrier must be overcome for the reaction to occur. The barrier can sometimes be overcome more efficiently by exciting vibrational modes of the reagents than by supplying the same amount of energy in the form of heat. Branching between different products can also be controlled by vibrational excitation. Thus, the control of chemical reaction rates by vibrational excitation has been a long-sought goal in chemistry (*3*). There has also been much interest in determining the amount of excitation in the vibrational modes of the products, which provides a signature of the path by which the reaction occurs.

We often think of barriers to chemical reactions in terms of a simple diagram showing the energy along the reaction path from reagents to products (see the first figure). The barrier along this path limits the reaction rate. If the reagent energies are governed by a thermal (Boltzmann) distri-

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