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Stephen C. Levinson

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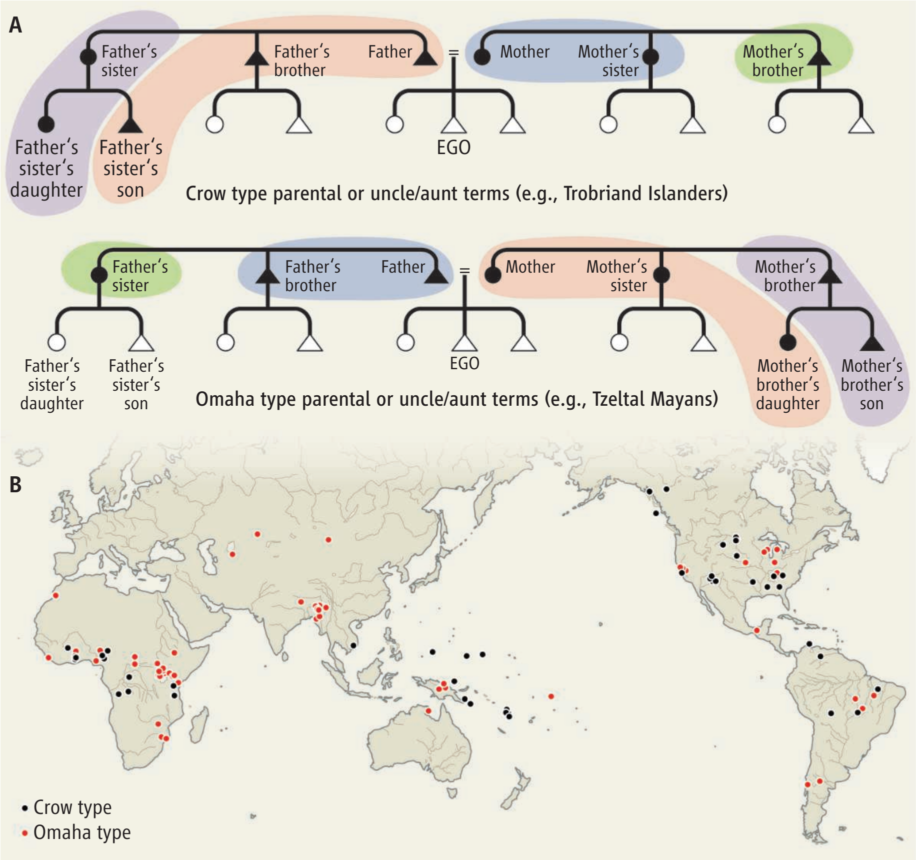
PSYCHOLOGY

Kinship and Human Thought

Language and communication are central to shaping concepts such as kinship categories.

Stephen C. Levinson



Two inverse types of kin category systems and their worldwide distribution. The world's kinship systems fall into half a dozen major types. For example, the Crow system correlates with matrilineal clans, and the inverse Omaha system with patrilineal ones; the two systems have mirror-image "parental" and "uncle"/"aunt" categories, as color-coded in (**A**). Both systems are found across the world (**B**) (data from 7, 8). Kemp and Regier argue that intrinsic constraints based on ease of conceptualization and communication determine the observed kinship category systems. However, they are also shaped by social functions and by common descent from earlier cultures.

In 1860, Lewis Henry Morgan heard an Iowa man on a Nebraska reservation describe a small boy as "uncle." Fascinated, he embarked on lifelong research into the kinship systems of the world's cultures, which culminated in a typology of kin categories (see the figure, panel A) (*1*, *2*). Work on kinship categories flourished for a hundred years, but then became unfashionable. Yet, kinship is crucial to the transmission of human genes, culture, mores, and assets. Recent studies have begun to reinvigorate the study of kinship categories (*3*, *4*). On page 1049 of this issue, Kemp and Regier (*5*) explore the relation between observed kinship systems and all possible such systems (the potential "design space"). They suggest that actual kinship systems optimize both ease of conception and communicative import. On page 998 in this issue, Frank and Goodman (*6*) provide an experimentally grounded characterization of communicative optimization.

Kinship is a fertile domain in which to ask a question at the heart of the cognitive sciences: Why do humans have the conceptual categories they do? On the one hand, kinship offers a forest of systems. There are more than 6000 languages, each with a different system of kin classification, at least in detail. On the other hand, kinship has a biological basis, namely the set of primary kin relations: father, mother, spouse or partner, brother, sister, son, and daughter. Each such person has the same set of links, resulting in an indefinitely large network of kin. Languages and cultures reduce these to a much smaller set of categories. In English, a father's brother, mother's brother, mother's sister's husband and father sister's husband are all called "uncles." In other languages, "uncle" may denote kinsmen on only the mother's or only the father's side and can spread over two or more generations, the source of Morgan's fascination (see the figure).

What constrains this exuberant diversity of systems? Murdock collated data from about 500 systems worldwide (*7*), identified half a dozen major types, and showed strong correlations with social organization (see the figure) (*8*). Recently, Jones (*4*) showed systematic principles of merger. For example, more distant relatives tend to get lumped together, as in our category "cousins."

Using Murdock's data (*7*), Kemp and Regier now show that actual existing kinship systems occur in only a tiny corner of the possible design space. Although 85% of their 487 sample systems have some distinct categories, they all conform to a tendency to balance maximal informativeness (discriminating kin types) while avoiding cognitive complexity. Calculating that there are 10^{55} theoretically possible systems over the 56 relatives they focus on, they show that attested kinship systems cluster in the corner of design space that minimizes both complexity and communicative cost. That is, cultures do not construct kin categories that are hard to define and hard to communicate.

Cognitive psychologists have suggested that categories, for example color concepts (*9*), are formed to maximize within-category similarity and between-category dissimilarity (*10*). However, these studies have downplayed the role of language and communication. Kemp and Regier elucidate the crucial role of communication in shaping our categories.

Frank and Goodman explore the nature of inference in communication. Because the reference of words will often be context-dependent, listeners must combine assumptions of speakers' informativeness with what is salient in the context in order to resolve a

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message. The authors show that listeners follow a precise model of Bayesian inference in making these inferences. Kemp and Regier's model uses corpus frequencies as an analog of saliency. The two approaches are closely connected, sharing an information-theoretic approach to informativeness.

Neither model tells us where our categories come from; they merely place constraints on what is good to think and good to communicate. Here, they could be usefully complemented by another recent line of work in the evolutionary modeling of culture. One approach is experimental and shows how categories get honed through iterated learning across simulated generations (cohorts of participants) (*11*). A second approach uses the computational techniques of biological phylogenetics to extract the historical development of patterning in cultural categories (*12*). This work puts into question the importance of Kemp and Regier's finding that attested kin term systems cluster in a small corner of the potential space. Existing systems may be largely descended from one another in deep historical time (*13*) and reflect patterns of irreversible evolution (*14*). But the study of kinship categories seems set for a revival, for they epitomize the nature of human concepts as biocultural in nature.

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PHYSICS

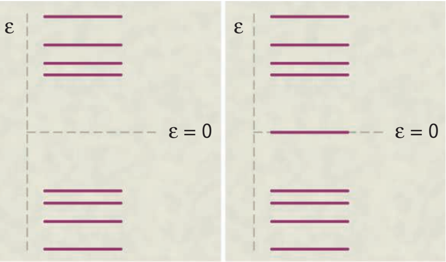
Enter the Majorana Fermion

Electrical measurements on a semiconductor–superconductor hybrid structure reveal the signature of this long-predicted exotic particle.

Piet W. Brouwer

All known fundamental particles are either bosons or fermions. Fermions are subject to the Pauli principle, which forbids two particles being in the same quantum state; bosons, by contrast, tend to bunch together in the same state. The same rule applies to the excitations of most solid-state systems, such as metals and semiconductors, which can be classified as fermionic or bosonic. However, sometimes excitations—quasiparticles—of a fundamentally different type emerge that resemble particles that hitherto have been considered only as a mathematical possibility. On page 1003 of this issue, Mourik *et al*. (*1*) report on a superconducting nanostructure that harbors such an exotic quasiparticle, a "Majorana bound state," an excitation that can best be described as half a fermion. The Majorana bound state is named after the Italian physicist Ettore Majorana, who proposed an equation describing a fermionic particle with a real-valued wave function (*2*). In contrast to the standard (Dirac) fermion, which has a complex wave function, a particle with a real-valued wave function is equal to its own antiparticle. No fundamental particles are known to be Majorana fermions, although there are speculations that the neutrino is one (*3*). The reported bound state is a localized version of Majorana's fermion.

Mathematically, two Majorana fermions combine into one Dirac fermion, just as two real numbers form a complex number. This is why a Majorana bound state can be considered as a half-fermion. Because the Majorana fermion is its own antiparticle, the Majorana bound state always has zero energy (a particle and its antiparticle have opposite energy ε, so ε = 0 is the only possibility if they are one and the same). Majorana fermions are also intriguing because they are examples of what are called non-Abelian anyons (*4*). These are a particular class of particles whose quantum state can change simply by exchanging particles, unlike standard bosons and fermions, whose exchange does not have measurable consequences. Once they can be controlled and manipulated, non-Abelian anyons are expected to find application in topological quantum computing (*5*, *6*), a radically different computer design that uses the exchange of non-Abelian anyons to perform certain computational tasks.



Now you see it. Schematic of the two possibilities of the excitation spectrum of a superconductor. The two spectra are said to be topologically different, because no continuous rearrangement of energy levels can transform one spectrum into the other, while preserving the symmetry of the spectrum. Mourik *et al*. report the creation of a topological superconductor with a spectrum like that of the right panel. The state at zero energy is the Majorana bound state.

Mourik *et al*. build on a series of theoretical proposals, which showed that Majorana bound states can be engineered in nanostructures that combine a superconductor and other materials (*7*–*10*). In this context, an antiparticle is in fact a hole, an excitation that consists of removing an electron from the device. In superconductors the electrons form bosonic Cooper pairs, which then condense into a single quantum state. Superconductors are a natural environment for particles that are their own antiparticle because the Cooper pair condensate blurs the difference between electron-like and hole-like excitations.

Indeed, the theory of superconductivity treats electron-like and hole-like excitations on an equal footing and has all excitations appear as a pair at opposite energies, ±ε. Particle-hole symmetric (i.e., Majorana) states can occur at ε = 0 only. Once there is a single excitation with energy ε = 0, its existence is said to be topologically protected, because no continuous perturbation can drive it away from its position at ε = 0 (see the figure).

In the experiment of Mourik *et al*., an InSb wire, a semiconductor with strong spin-orbit coupling, is coated with the superconductor

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