Shared Norms and the Evolution of Ethnic Markers
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Reports

Preserving the Anthropological Record: A Decade of CoPAR Initiatives[1]

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Ruth Bunzel threw out all her fieldnotes from Zuni Pueblo after she had published her books, thinking that they no longer had any use. The Zuni could have used these fieldnotes, if they had been available, in a water claims case in the 1970s. James Mooney kept all his fieldnotes, and they have been saved in the National Anthropological Archives, where Kiowa scholars have used them to help reconstruct their history. The archives of the Wenner-Gren Foundation contain audiotapes of its supper conferences and international symposia that provide the opportunity to listen to hundreds of anthropologists developing their theoretical ideas. Unpublished anthropological records like these contain a vast array of information about historical and contemporary human diversity and about the history of anthropology. Both professional anthropologists and little-known but exceptional amateurs have produced these records. Their fieldnotes and other papers document how they engaged in their work and how knowledge is constructed in our discipline. The records cover virtually every culture in the world, past as well as present societies, and nonhuman primate as well as human populations, and they contain evidence of evolutionary processes, biobehavioral variation within our species, and cultural continuity and change. These data are invaluable because they form the basis for longitudinal and comparative studies. They can be used to solve new scientific problems through reanalyses of extant data, and they can be referred to repeatedly as research questions change.

The anthropological record is vast, complex, and scattered in repositories, museums, government agencies, universities, and private homes around the world. It is also in danger. Many irreplaceable records have been lost because of ignorance or neglect. Others that have been saved are effectively inaccessible because potential users do not know where they are housed or because anthropologically appropriate finding aids are lacking. As a result, the profession has little control over much of its own legacy. The situation ill serves the long-term interests of anthropology and threatens its future health and effectiveness.

ISSUES AND STRATEGIES

Cognizant of this situation, Sydel Silverman and Nancy Parezo organized a Wenner-Gren conference, "Preserving the Anthropological Record: Issues and Strategies," in 1992 to discuss the problem. The conference soon became more than an intellectual exercise for concerned scholars, developing into a multiyear initiative that has included nine conferences and workshops, several collective research and outreach projects, and numerous individual efforts designed to ensure that the information needed to make anthropology a strong discipline in the 21st century is preserved, made accessible, and used responsibly by future practitioners. It resulted in the volume *Preserving the Anthropological Record* (Silverman and Parezo 1992), which was distributed free of charge to anthropologists around the world and made available to librarians and archivists by the Wenner-Gren Foundation. While this conference has been the subject of a report in CURRENT ANTHROPOLOGY (Silverman 1993), subsequent conferences and projects have not been so documented. The present report summarizes the efforts of participants in these initiatives, which have not only promoted the preservation of our data but also thrown light on the nature of anthropological "work," professionalism, and changing research ethics.

TOWARD A DISCIPLINE HISTORY CENTER

A second conference was held in 1993 to consider possible courses of action that the discipline could undertake to implement the goals outlined at the first conference, specifically the possibility of establishing a manuscript repository and history center for anthropology. The participants soon recognized that anthropology, as a poor and numerically small discipline, would not be able to command the level of resources that such a center would require. In addition, the American Anthropological Association (AAA) had recently reorganized, and its leaders felt that it could not sustain permanent funding of a center through membership dues. The smaller associations were even less able than the AAA to contribute membership dues. The conferees decided that programmatic aspects of the discipline-center model could still be realized by using an alternative organizational structure: that of an information center and clearinghouse that could facilitate and coordinate preservation activities and ultimately help create a series of regional archival consortia. A nonprofit organization, the Council for the Preservation of Anthro-

1. [Supplementary material appears in the electronic edition of this issue on the journal's web site (http://www.journals.uchicago.edu/CA/home.html).]

pological Records (CoPAR), was created to provide a visible structure for the preservation initiative.

Educating practitioners about the scope of the problem and locating extant documents were to be the first priorities. An immediate result was a revised and expanded edition of *Preserving the Anthropological Record* (Silverman and Parezo 1995), which like the first edition was distributed free of charge. The book, designed as an educational tool, has been used in a number of anthropology classes and has been reviewed in several journals in North America and Europe. Another outcome of the conference was to have records preservation included in the long- and short-term strategic plans of the AAA and the Society of American Archaeology (SAA). Subsequently, participants in the conference assisted other organizations, among them the constituent units of the AAA, to develop record retention schedules and to arrange for the orderly transfer of inactive records to the National Anthropological Archives (NAA) and other appropriate repositories.

The problems of preservation are worldwide, as are the solutions that will be required. The wide distribution of *Preserving the Anthropological Record* was a first step toward bringing the problems to the consciousness of anthropologists in other countries. For practical reasons and because of the scope and complexity of the challenge, participants felt that it was necessary to concentrate on North America initially. At about the same time the CoPAR program began, there were initiatives in other countries as well.

SURVEY OF EXISTING COLLECTIONS

CoPAR's immediate task was to discover where barriers to preserving the anthropological record occur. Thus, the first CoPAR project was an inventory and needs assessment of institutions holding anthropological documents in order to gain background information on where anthropological records are currently located. The survey was designed to (1) gain a preliminary understanding of the types of extant archives and manuscript repositories, the general nature of their holdings, and the problems relating to their preservation and access, (2) document the electronic database capabilities of those archives, and (3) establish contact persons for later outreach efforts. A special effort was made to identify smaller repositories and anthropological departments that hold valuable records, institutions often overlooked by researchers.

In 1994, Don Fowler and his graduate students distributed a two-page mail survey to 644 anthropology departments, museums, and institutions that were known to hold anthropological records. Over 120 questionnaires were returned, 62 from anthropology departments, 34 from museums, and the remainder from archaeological repositories, research centers, and specialized libraries. The results generally confirmed CoPar's fears about the condition of anthropology's primary documents and the need to take action. Only a small minority of the responding institutions had adequate archival facilities and computer-based cataloguing systems, and virtually all reported minimal (or nonexistent) budgets and a need for information on how to organize and manage records or establish networks. It was evident, moreover, that while libraries and museums had faced the problem of access through the development of systematized standard lexicons and information networks, departments and other institutions were developing idiosyncratic systems that would hinder any effort to build a general database on the location and content of disciplinary records.

CoPAR members also informally contacted numerous practitioners, archivists, museologists, information specialists, and native peoples, both records generators and users, to gain an understanding of their perspectives on ethical issues in preservation and the value of anthropological records to future research and of the degree to which access to documents is hindered at present.

With this information Fowler and Parezo, with the help of several CoPAR members, submitted a proposal to the National Endowment for the Humanities in 1994 to begin to implement CoPAR's agenda. The core of the proposal was for a series of workshops (1) to institute an educational program to provide guidance to anthropologists and anthropological organizations for properly preserving current documents and (2) to develop standards for describing anthropological records for use in thesauri and finding guides for collections. The proposal was rejected, being viewed as a request for operating funds for an unusual and amorphous organization. In lieu of NEH support, the Wenner-Gren Foundation funded the workshops. CoPAR members organized themselves into working groups around these tasks and were joined by other scholars who were interested in the project.

EDUCATION AND OUTREACH WORKSHOPS

Two Wenner-Gren Foundation funded workshops on education and outreach were held, one in April 1995 and one in November 1998. In the first workshop, participants addressed a series of challenges: (1) to identify the preservation issues for specific categories of record producers and users, who would be CoPAR's target audiences, (2) to outline ways of educating anthropologists on the management of their records, (3) to enlarge our understanding of legal and ethical issues, and (4) to develop strategies for helping the archival community better comprehend the special problems relating to anthropological records.

As a result of these discussions, the participants drew up a prioritized set of awareness and education goals. Special attention was given to ways in which anthropologists could more effectively work with native communities to address their ethical concerns. After extensive consideration of a number of sensitivity issues, the conferees adopted a statement of principles focusing on the concept of stewardship and its ethical responsibilities.

The workshop participants also reviewed existing educational materials, particularly those produced by the Society for American Archivists, and discussed their limitations in light of anthropology's needs. To meet those needs, they devised the idea of a series of short bulletins or modules targeted to different audiences: anthropologists, both active records generators managing masses of data and those ready to retire and deposit their papers, literary advisers and executors, heirs, and information specialists who care for anthropological documents.

The second workshop was devoted to writing these bulletins: 1, *Why Preserve Anthropological Records?*, by Sydel Silverman; 2, *Easy Steps for Preserving Your Anthropological Records*, by Mary Elizabeth Ruwell; 3, *Creating Records that Will Last*, by Myra Appel; 4, *Locating Archival-Quality Supplies*, by Mary Elizabeth Ruwell; 5, *Electronic Records: The Upcoming Dark Age*, by Willow Powers; 6, *Photographs and Audiovisual Materials*, by John Homiak; 7, *Ethical Issues to Consider When Depositing Your Records*, by Catherine Fowler; 8, *Taking Stock of Your Records*, by Michael Little; 9, *Organizing and Transferring Research Records*, by Ruth Person; 10, *Appointing a Literary Executor, Trustee, or Advisor*, by Thomas H. Wilson; 11, *Finding a Home for Your Records*, by Lynne M. Schmelz; 12, *Saving Association Records*, by Nancy Parezo; 13, *The Special Nature of Linguistic Records*, by Victor Golla; 14, *Ethical Use of Anthropological Records*, by Catherine Fowler and Steven Crum; 15, *The Guide to Anthropological Records*, by Peter McCartney; and 16, *Understanding Anthropological Records: Archivists'Alert*, by Willow Powers.

In addition, a curricular module for use in anthropology courses is in preparation. It includes sections on archival research as fieldwork, ethical use of records, preventive measures, computers and preservation issues, and caring for data. The bulletins are available in both electronic and hard-copy format by mail (NAA, Smithsonian Institution, Museum Support Center, 4210 Silver Hill Rd., Suitland, Md. 20746, U.S.A.) or through the CoPAR web site or the NAA web site (www.nmnh.si.edu/naa/copar/bulletins/htm).

Several other educational and outreach initiatives were developed as a result of these workshops. First, graduate students Alanah Woody and Bonnie Salter of the University of Nevada, Reno, created a traveling display that was taken to several meetings of the AAA and the SAA. Second, a brochure was published and copies sent to departments and distributed at academic meetings. Third, a concerted effort was made to encourage the AAA's constituent units to develop records retention schedules in order to ensure that their records were properly preserved. A special bulletin was presented to the president and secretary of each unit, and CoPAR members subsequently helped several units gather their dispersed records from past officers and deposit them in the National Anthropological Archives.

Training Programs

Discussions at the Reno workshop highlighted the need for formal training mechanisms, such as mid-career workshops, directed at various groups. It was proposed that two- to three-day workshops be held in different parts of the country, perhaps in conjunction with professional meetings, which eventually could be redesigned for use in other communities around the world. Seven target groups and their workshop objectives were identified: (1) cultural resource managers, to focus on records currently generated; (2) professional anthropologists, to provide an overview of archival issues for both active and retired scholars; (3) native communities, to familiarize individuals with how to conduct research in existing repositories and how to establish tribal archives and manuscript repositories; (4) Native American linguists, to address the special demands of work with linguistic materials housed in scattered repositories; (5) native people, anthropologists, and archivists, to discuss culturally specific sensitivity issues surrounding archival documents; (6) archivists and information specialists, to acquaint them with the anthropological record and the needs of anthropological researchers; and (7) academic departmental chairs, to ensure that institutional records are cared for.

A training program to educate archaeological records managers about archival preservation techniques was developed by Diane Vogt-O'Connor under a grant from the National Park Service. The first course, "Field Records at the Millennium: Managing Anthropological Papers," was offered as part of a museum management and cultural heritage preservation program at the Heard Museum, Phoenix, in May 1999. The course demonstrated how anthropological documents deteriorate and provided information on how to create, manage, and preserve data. Vogt-O'Connor is currently planning a second course, "Sharing Our Treasures: Legal, Ethical, and Management Issues of Providing Public Access to Archival, Library, and Museum Collections," which will be cosponsored by CoPAR.

"Lines of Communication" Conferences

Although several Native American scholars have requested assistance with records preservation, it has been CoPAR's position that the first need was to develop collaborative relationships between anthropologists and archivists and native communities. As a result, two conferences were held to consider how to ensure that crucial documents relating to native peoples are preserved, made accessible ethically, and used for the benefit of native communities. Willow R. Powers and Joe Watkins organized the first of these conferences at the Newberry Library, Chicago, Illinois, in August 1999, which was cosponsored by the D'Arcy McNickle Center for American Indian History and the Wenner-Gren Foundation. A second conference, organized by Willow Powers and Diane Bird, was held under the auspices of the Museum of the American Indian and the American Association for State and Local History in Washington, D.C., in the fall of 2000.

The aim of the first conference was to ensure that archivists and museum professionals were aware of CoPAR's efforts and that CoPAR was aware of tribal preservation needs and desires. Tribal archivists gave presentations on their institutions, and archivists from government, university, museum, and private repositories discussed the anthropological records in their care and summarized the issues that had arisen in recent years concerning their use. Information was also shared about initiatives of the American Association for State and Local History and the Society of American Archivists that could assist native professionals, while native archivists discussed ways to form their own organization within the Society for American Archivists.

A central topic at each conference was the special nature of tribal archives and the information they hold in trust for their communities. Topics ranged from practical problems and strategies to abstract issues such as the privacy rights of community members and the responsibility of tribal archivists to ensure that information contained in records is used in the best interests of the community. Participants also discussed the philosophies on which tribal archives are based and the ways in which tribal archives differ from other types of repositories while sharing the goal of preserving historical legacies. Also discussed were questions of public access, intellectual property rights, sensitivities in both public and private institutions, and recent changes in federal law that will impact records.

The participants agreed that these conferences were a first step toward building shared understandings. Several individuals planned to disseminate information on the conferences through presentations at other workshops, news releases, articles in scholarly journals, and association newsletters. For example, Hartman Lomawaima and Karen Underhill made a presentation at a meeting of Arizona archivists held on the San Carlos Apache Indian Reservation shortly after the first conference. Also as a result of that conference, the Museum of the American Indian developed a training program for native archivists under the direction of Diane Bird.

WORKSHOP ON THE NATIONAL ANTHROPOLOGICAL ARCHIVES

The National Anthropological Archives (NAA), a unit of the Department of Anthropology at the Smithsonian Institution, has been a particular concern of CoPAR since the first conference. Since anthropology does not have a dedicated repository for practitioners' papers, the profession has historically relied on the NAA to house important research data and the records of anthropological organizations. During the 1980s and 1990s, federal budget cuts and personnel shortages due to attrition placed the NAA in a precarious position at the same time that there was an increase in its use by both disciplinary practitioners and native communities. In light of this concern, CoPAR held a workshop in May 1997 at the Airlie Center in Warrenton, Virginia, to discuss ways to increase the visibility of the NAA within the Smithsonian Institution and promote its fiscal viability. The workshop served, in effect, as an advisory group to the NAA, offering CoPAR's strategic planning experience as well as the support of the repository's main constituency. In addition to members of CoPAR, representatives of the Smithsonian's anthropology department, provost's office, and other archives and museums attended the workshop.

The purpose of the workshop was to assess the NAA's status within the Smithsonian structure and identify its current and potential institutional strengths and challenges. Participants presented background information on the history and mission of the NAA, the constituencies it serves, and its relationship to other parts of the Smithsonian. Special attention was given to budgeting processes and potentials. The conferees suggested ways to promote awareness of NAA's needs among the Smithsonian hierarchy, disciplinary practitioners, and the archival and information science communities. They also laid the groundwork for working partnerships with other Smithsonian archives.

After the workshop Fowler and Parezo, on behalf of the participants, submitted a report summarizing the strategic planning discussions and suggesting a suite of both short- and long-term solutions for NAA's problems. This report was presented to Smithsonian Provost J. Dennis O'Connor and Robert Fri, director of the National Museum of Natural History. The report assessed the NAA's severe space limitations, reduced operating budget and staff, and consequent reductions in preservation, cataloguing, and service activities. It proposed the creation of a National Center for Anthropological Documentation, which would be an umbrella organization for the NAA and the Human Studies Film Archives, and outlined the potential mission, policies, and functions of the proposed center.

The Smithsonian administration received the workshop's report favorably and began to act upon its recommendations. All the short-term solutions for FY 1997–98 and FY 1998–99 recommended in the report were put in place, and progress was made toward the longer-term building of staff and resources essential for the future of NAA. The steps taken included the hiring of a permanent supervisory archivist, temporary funds to process the papers of the National Congress of American Indians, and the detailing of anthropologist Ruth Selig from the provost's office to work with the NAA on strategic planning. In addition, funds were found for a permanent archivist for the National Museum of the American Indian, who is working closely with NAA archivists. Further progress was made in 1999 with the development of the NAA's web site, its active collecting of papers from senior anthropologists, the digitization of several collections, receipt of a $228,000 grant from the White House's "Save America's Treasures" initiative, and conservation of Native American artwork through the Smithsonian's Conservation Analytical Laboratory. While much remains to be done to bring the NAA up to an adequate level of operation, Smithsonian officials continue to express their support. In the future, CoPAR hopes to serve a similar function for other centers that specialize in the preservation of anthropological materials and that need assistance from their constituencies.

GUIDE TO ANTHROPOLOGICAL RECORDS WORKSHOPS

The most ambitious CoPAR initiative to date has been its project to develop a computerized database for locating anthropological records in existing collections. A series of workshops has been held to develop standards for accessing such records, to design and pretest a pilot project, and to create and evaluate appropriate thesauri. The initial Internet home base for the Guide to Anthropological Records was established at Arizona State University through the good offices of Peter McCartney and Michael Barton. In the summer of 2002 the Internet home base was moved to the University of California, Davis, Library, where a new web site is being developed.

KEEPING THE MESSAGE ALIVE

In order to keep records preservation and related issues before the profession, members of the CoPAR network have continued to present papers in scholarly arenas. They have also published in a number of venues that reach wider audiences, such as *American Indian Culture and Research Journal, American Archivist, Federal Archaeologist, Practicing Anthropology*, and *CRM*. In addition, members have participated in meetings of archival and museological professionals. For example, at the 1997 Society of American Archivists annual meeting in Chicago, Mary Elizabeth Ruwell organized a session on "Digging the Treasures: Access to Anthropological Records," in which she was joined by Nancy Parezo, who presented a paper on CoPAR's activities.

Nathalie Woodbury and other CoPAR members have successfully lobbied for the return of obituaries to the *American Anthropologist*, a major resource for the future location and contextualization of anthropological data. Other participants in the CoPAR initiative have been active in presenting preservation concerns to the ethics committees of professional associations. Sue Estroff represented CoPAR before the ethics committee of the American Anthropological Association, and preservation issues are now included in its recently revised code of ethics, while the Society for American Archaeology's Code of Ethics now contains a principle on the stewardship of archaeological records. Other anthropological associations are following suit, including preservation as part of their concerns about the ethical use of anthropological data. The efforts undertaken by CoPAR are a modest but important starting point toward addressing a critical need of the anthropological discipline both in the United States and around the world.

RELATED ANTHROPOLOGICAL ARCHIVES PROJECTS

At about the time that CoPAR was founded, anthropologists, archivists, and information specialists elsewhere in the United States and in numerous other countries were beginning similar projects as the possibilities of the Internet for archival and bibliographic research were being realized. By 2002 there are literally dozens of guides to anthropological archives available on the Internet. The National Anthropological Archives web site (www.nmnh.si.edu/naa/links.htm) provides a starting point for investigating these resources. Examples of different types of archives useful to anthropologists include the following: The anthropology archives of the British Library of Political and Economic Science at the London School of Economics are very extensive and include the papers of prominent anthropologists such as Bronislaw Malinowski, Audrey Richards, and C. G. Seligman and Brenda Seligman (www.library.lse.ac.uk/). The library and archives of the Canadian Museum of Civilization have extensive archival holdings on Canadian First Nations as well as worldwide ethnographic coverage (www.civilization.ca/cmc/biblio/index-e.html). The South Australia Museum Anthropological Archives in Adelaide have extensive holdings on the anthropology of Australia and the Pacific (www.samuseum.sa.gov.au/asa.htm). The archives of the Library of the Laboratories of Comparative Ethnology and Sociology at the University of Paris focus on unpublished ethnographic materials as well as historical documentation relating to various subfields of anthropology (www.u-paris10.fr/bibethno/index.html). Most of the several hundred anthropology or ethnology museums or natural history museums with anthropological collections worldwide have archives. These may be located most expeditiously through the Virtual Library Museum pages of the International Council of Museums (ICOM) web site (www.icom.org/vlmp).

Other archives are topically focused and exhibit the wide range of materials of anthropological interest. For example, the Archive for Visual Anthropology at the University of Zurich, Switzerland (www.musethno.unizh.ch/archiv/visanthr.htm) holds still photographs and motion pictures related to ethnography, religion, and ritual, especially of South Asia. The African Music Archive at Johannes Gutenberg University, Mainz, Germany, concentrates on contemporary and historical sub-Saharan African music (http://ntama.uni-mainz.de/~ama/archive.html). The Folklore and Ethnology Archive of the University College of Cork, Ireland, is centered on archival materials relating to Gaelic and Celtic folklore and anthropology. The Balch Institute for Ethnic Studies in Philadelphia houses major historical, ethnographic, and visual archives relating to over 60 ethnic minorities in the United States, including materials about their places of origin (www.balchinstitute.org).

Other examples are primarily on-line guides to archives similar to the CoPAR Guide. One is the Archives of European Archaeology, a consortium of some 20 institutions. The focus of the archives is on the history of archaeology, including the relationships between archaeology and national politics (www.inha.fr/area-archives/). Another example is HADDON (named for A. C. Haddon), an on-line catalogue of archival ethnographic photographs and film footage dated between 1895 and 1945. The scope is worldwide (www.rsl.ox.ac.uk/isca/haddon/). Two archival web sites and guides of special interest to anthropologists concerned with contemporary issues relating to indigenous and former colonial peoples are the University of Minnesota Human Rights Library (www.umn.edu/humanrts) and the Fourth World Documentation Project of the Center for World Indigenous Studies (www.cwis.org/fwdp).

Further information on all these activities may be found in Fowler, Parezo, and Ruwell (1996), Parezo (1996, 1999), Parezo and Fowler (1995), Powers (1996), and Vogt-O'Conner (1995, 1999).

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Ulu Knife Use in Western Alaska: A Comparative Ethnoarchaeological Study[1]

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Modern fish harvest camps provide archaeologists the opportunity to study processes and relationships in an ongoing traditional subsistence system (Chang 1988, 1991). This study deals with salmon butchering using a traditional semilunar knife known as the ulu. Ulu blades were made of slate during prehistoric times, but metal began to be used as it became increasingly available and the ulus currently in use all have metal blades. We asked native Western Alaskan women, the primary users of the ulu, to butcher fish with replica knives made of slate and metal in an effort to determine the differences in performance between the two and thus to model technological change associated with the replacement of ground-slate ulus with metal ones.

Ethnoarchaeological studies are a valuable tool for interpreting past human behavior (Owen and Porr 1999), but much of this research has focused on males and their material-culture correlates. Women's productive activities have been neglected (Kent 1998, Gero 1991). One reason for this is a tendency to focus on the primary kill rather than on the whole meat-acquisition process, which includes procurement, processing, production, and storage as well as skilled management and an appreciation of technological requirements and constraints (Gifford-Gonzalez 1993: 181–82; Brumbach and Jarvenpa 1997*a*:418; Ellanna and Sherrod 1995; Frink 2002). Women are intimately aware of the techniques of tool production and use, and overlooking their activities and contributions in this area compromises the deciphering of archaeological patterns. The adoption of new technology can considerably alter the division of labor. For example, the adoption of the fish wheel by native Alaskans increased the potential harvest and significantly added to women's productive load (Oswalt 1963:44). If technological change is to be understood, the social landscape (of which gender is an organizing principle) must be addressed. Consequently, this study of technology and change is located in the context of a native subsistence fish camp in which women's activities in fish processing are significant.

BACKGROUND

As in other regions in Alaska and the Northwest Coast culture area, salmon harvests on the Yukon-Kuskokwim delta were and remain a critical subsistence activity for indigenous groups. Archaeological evidence suggests that 1,200 years ago people began to spread inland throughout the delta and utilize the river systems for fish (Shaw 1998). Even more than today, prehistoric people lived off the land—hunting seal, gathering greens, and harvesting the abundance of fish (Fienup-Riordan 1986, Oswalt 1990). Prior to the early historic shift to steel

1. This research could not have been conducted without the support of the Chevak Elder Advisory Council, the Elders of Chevak, and the Chevak Traditional Council and the financial support of the United States Fish and Wildlife Service, Anchorage and Bethel Offices. Many thanks go to Mary Berthold, Debbie Corbett, Ken Pratt, James Savelle, and three anonymous CA referees for their thoughtful and very helpful comments. Also to be thanked are Samantha Bartling for assistance in the field, Mary C. Nanuwak, Lisa Unin, and Earl Atchak, and, for her *keggiinalek* drawing, Nancy Hoffman. Finally, this project could not have been accomplished without the patience and participation of the Ulroan and Matchian families. *Quyana cakneq*.

knives, inhabitants of the Yukon-Kuskokwim delta used a ground-slate *keggiinalek* (from *keggs*, "to bite" [Wolfe 1989*b*:22]) or ulu to cut up fish. In the archaeological record these ubiquitous semilunar knives are often associated with use by women (Dumond 1977:66), and slate ulus are recognized among native people as having been used by female ancestors. Today ulus are a personal and curated item used for the mass processing of fish[2] and the butchering of sea mammals and terrestrial animals among other domestic tasks (Chang 1988:155; Issenman 1997). With the intensification of Euro-American contact in the mid-19th century, stone knives were replaced by steel versions.[3] It may be true that native peoples will accept new materials and technology that lead to more efficient tools, but little is known about how the change in material and technology affects tool use, including the associated realignment of gender-based labor allocation.

The village of Chevak, located 48 km east of the Bering Sea coast, is home to some 800 Cup'ik (a subdialect of Yup'ik) Eskimos (Woodbury 1992:12). Although part of the modern global economy, many Chevak residents continue to live primarily off the land as subsistence hunter-fisher-gatherers (Fienup-Riordan 1986, Oswalt 1990). After the eight-month winter, many villagers spend the short summer at their fish camps. The most critical fish, salmon, typically begin to run by July and continue into September. All five species of this anadromous fish—king (*Oncorhynchus tshawytscha*), red (*O. nerka*), silver (*O. kisutch*), pink (*O. gorbuscha*), and chum (*O. keta*)—are available in the rivers and sloughs. Though there is yearly variation in the abundance of fish, summer is a season of plenty and winter must be anticipated and prepared for as a season of scarcity (Testart 1982:524). There is some winter hunting, trapping, and fishing, but most people rely on properly stored and managed provisions to make it through the winter months of cold temperatures and limited daylight.

The seasonal salmon harvest involves a gender-based division of labor. Men spend many hours using nets to catch the salmon. Fishing can require an enormous investment of energy during a short time period, but it is a critical element of winter prosperity. Today, Chevak families, depending on the size of the household, attempt to catch from 150 to 300 salmon per season. A man brings his catch to his grandmother, mother, sister, or wife, who owns it and is responsible for its processing, storage, and distribution. Processing can be intensive, often requiring 12 hours of continuous labor to cut from 60 to 100 fish per day (O'Leary 1992; Romanoff 1992:235). These numbers likely represent processing at near-maximum capacity.[4] To achieve this level of productivity, the processing operation must be run by technologically skilled and efficient managers (Frink 2002).[5] Processing is an intergenerational activity in which production knowledge is taught and learned through years of experience: mothers, daughters, and granddaughters cut fish together. Often the camps are managed by older women whose role extends beyond fish cutting to include management oversight of other camp operations such as drying and smoking fish. Furthermore, women are in charge of the distribution of foodstuffs throughout the year (Ellanna and Sherrod 1995, Fienup-Riordan 1986, Frink 2002).

Explaining Technological Change

Historians and archaeologists often explain technological change as a "problem-solving process" (Nelson 1991: 58). We generally assume that new technologies were adopted in the past because they were more practical, efficient, economical, reliable, sustainable, or adaptable than the technologies they replaced (Bamforth 1986, Bleed 1986, Casey 1998, Torrence 1989). Scholars likewise acknowledge that the adoption or rejection of a new technology is responsive to social and political conditions (Gero 1989, Hayden 1998, Nassaney and Pyle 1999). Technology operates at multiple levels and is charged with cultural meaning. A metal axe may be a practical solution to the problem of cutting wood, but it may also be a symbol of the owner's social position; therefore, ownership of an axe may have more to do with the politics of resource control than with the problem-solving ability of the owner.

It may seem logical that indigenous people would have adopted metal knives as soon as they became available, but this assumption could be erroneous. Because of the superior functioning of native technology, a wide range of tools, clothing, and other material-culture items continued in use long after "Western" manufactured goods became available. Traditional caribou-fur clothing, for example, provided better insulation and ventilation than any of the clothing brought to the Arctic by 19th-century Euro-American explorers (Buijs 1997, Stenton 1991), and native women preferred their sealskin thimbles to the steel ones offered by traders (Nelson (1983 [1899]:109).

2. Ben Fitzhugh (2001) has suggested a connection between the increased use of the ulu and high-volume fish processing.

3. Archaeologists generally attribute the use of ground-slate ulus in this region of the world to the expansion of Western Thule 1,000 years ago (Dumond 1977, Shaw 1998). Iron tools were also available in small numbers at this time, probably entering the region through contacts across the Bering Strait or from high-Arctic sources (McCartney 1991). The precise date of the transition from aboriginal knives to European metal knives is not known for this region, but Edward Nelson, who made a pioneering sledge journey through southwestern Alaska in the 1880s, collected many forms of "women's knives" and "men's knives" with blades of chipped stone, ground slate, and metal (Nelson 1983 [1899]: pl. 98).

4. Chevak families do not in fact catch and process this many fish (Frink 2002). According to our consultants, families determine how many fish they need each year and work toward that goal. Wolfe (1989*a*:18) reports that an ethic of no waste prevails, making it customary to harvest only what one needs. Consultants have suggested that families tend to catch from 150 to over 300 salmon per season; on a "busy" day a Chevak woman would clean 30 fish.

5. The women prioritize their production activities in terms of knowledge of the properties of different fish species, the condition of the fish at capture, the effect of weather and insects on processing, and the productive capacity of the available labor, as well as understanding of their families' (dietary and social) needs throughout the year (Frink 2002).

These cases illustrate the need to demonstrate, rather than assume, the functional properties of comparable technologies.

Even if we can confirm the superior efficiency of metal knives over slate knives in fish processing, a host of other social and political factors play roles in technological change. For instance, Zagoskin, a Russian who made early ethnographic observations around the Yukon-Kuskokwim delta in 1842–44, noted that native people could not "bring themselves to cut the beluga with iron," metal being considered "unclean" because it came from the Europeans (Michael 1967:113, 224; Nelson 1983 [1899]:145; Fienup-Riordan 1986:157). The consequences of breaking taboos in a native cultural system that closely linked people and animals could be disastrous. Nelson (1983 [1899]:440) mentioned one instance: a man "began to chop [with an iron axe] a log near a woman who was splitting salmon, and both of them died soon afterward."

Further, Peter Whitridge (2002) has found archaeological evidence for gender differences in access to metal in his study of Qariaraqyuk (PaJs-2), a large Eastern Thule village in the Central Canadian Arctic. Iron and copper artifacts are particularly abundant at Qariaraqyuk, as they are at many of the Classic Thule sites (A.D. 1000–1400). Most of the iron was obtained from Greenland meteorites and Norse sources (McCartney 1991). The Qariaraqyuk metal tools were predominantly those used by men (adzes, projectile points, men's knives); ulus with metal blades were significantly less common. Metal artifacts attributable to Qariaraqyuk's women were frequently objects of adornment. Whitridge considers metal's display value crucial to an understanding of Qariaraqyuk's metal distribution. Men spent much of their indoor time working in the *qargi*, a large communal "men's house" (cf. Larson 1991), and here the use and production of metal tools was highly visible to all occupants. Tool production using metal probably constituted a display of wealth during manufacture. According to Whitridge, the women at Qariaraqyuk spent much of their indoor time working away from the group in individual houses. Their time spent communally was usually during ceremonies in the *qargi*, when adornment items were a more convenient way to display metal wealth. This study dramatically illustrates how sociopolitical factors contributed to the nature of technological change.

The archaeological and historical record for western Alaska, although little known, suggests that the nonnative goods were adopted in a complex fashion, with metal knives not completely replacing aboriginal knives until late in the historic period (Oswalt and VanStone 1967:115, 120). Whether these patterns resulted from metal's limited availability, differential access, functional disadvantages, or sociopolitical processes is a significant research question. We begin the investigation by addressing the question of functional efficiency in its social context.

APRUN RIVER FISH CAMP: FIELD METHODOLOGY

Our field research consisted of observing and recording salmon butchering using replicas of the ulu form in both slate and steel. We defined a more efficient tool as one that would enable the processor to cut the fish faster and sharpen less often and be easier to use. Four knives were made by Shaw for the butchering trials, two of ground slate (G1 and G2) and two of steel (S1 and S2) (see fig. 1). They were patterned after ulus used on the delta during early historic times.[6] The hafting, plan-view form, edge curvature, and edge cross-section shape were close to the same for all four knives. Each fish-cutting episode

6. The design of the knives was selected from among those of knives collected along the lower Yukon by Nelson (1983 [1899]: pl. 48, figs. 4 and 5); the selection was somewhat arbitrary, since Nelson's collection included a wide variety of blade shapes and handle types. The blades are approximately 10 cm wide and have convex cutting edges, rounded corners, and antler hafts (fig. 1). The two steel replicas were made from inexpensive (Great Neck brand) handsaws (reuse of handsaws for making ulus is common in western Alaska). The edge was ground to a convex shape and sharpened on both sides to a form known as the sabre grind. The edge was created by allowing the blade to conform to a slack belt on a 2″ × 72″ cloth sanding belt. The final belt was a well-worn 400-grit belt (equivalent to about a 600-grit). A burr was ground along the entire sharpened edge; the burr indicates that the grind has intersected the grind made on the opposite face of the blade. The blade was then stropped to remove the burr and create a razor-sharp edge. The handsaw was factory-hardened. During knife manufacture, the blade was kept cool so as not to remove the temper. The two ground-stone replicas were made of slate from Prince William Sound at Tatiklek. (Local slate was not readily available, although Chevak residents are aware of a large area of slate in the region. Future research will include working with a local craftsman to identify this source and to create knives from this local material). Like the steel replicas, the stone ones had a sabre grind, a common edge shape on stone tools that is very strong for a given material because the edge cross section thickens rapidly with distance from the edge.

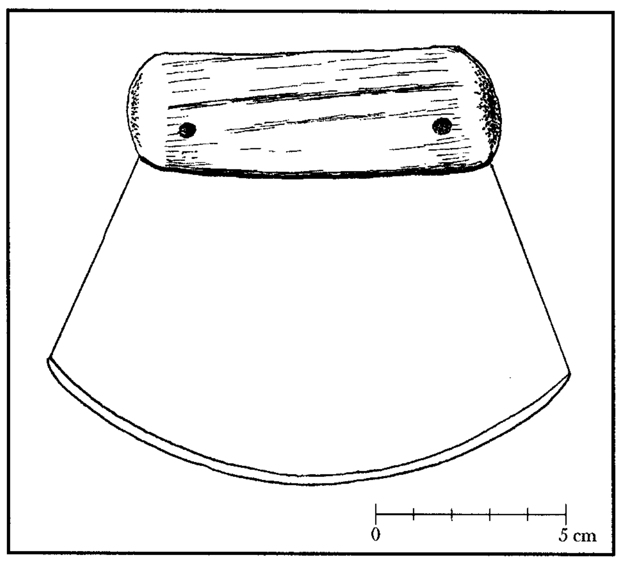

FIG. 1. *The replica ulu.*

TABLE 1
Salmon Processing with Slate and Steel Knives

Experiment	Knife	Fish Species	Fish Weight (pounds)	Processing Method	Time (minutes)	Minutes per Pound
1	G1	Chum salmon	7.0	Strip	36.3	5.2
2	S1	Red salmon	7.5	Strip	12.08	1.6
4	Own	Pink salmon	5.5	Strip	4.45	0.8
5	S2	Red salmon	8.5	Fillet	3.43	0.4
6	S2	Red salmon	6.0	Fillet	2.44	0.4
7	S2	Pink salmon	6.1	Fillet	3.13	0.5
8	Own	Chum salmon	6.6	Strip	6.12	0.9
9	G2	Chum salmon	5.6	Fillet	8.57	1.5
10	G2	Whitefish	1.3	Fillet	3.49	2.7
11	Own	Whitefish	1.4	Fillet	1.36	1.0
12	Own	Chum salmon	6.1	Fillet	3.03	0.5

NOTE: Experiment 3 was terminated before the fish was completely processed because the knife was deemed too dull to continue.

was considered an individual experiment; the species, sex, weight, and length of the fish were recorded for each event, along with the point at which the blade became too dull to use, the time spent cutting, and comments from the women.

The experiments were conducted at the Aprun River Fish Camp, the summer camp of a Chevak extended family that includes the households of 85-year-old Angelina Ulroan, her daughter Mary Matchian and her husband, Larry, and Mary C. Nanuwak (a Chevak field assistant). Nanuwak and Matchian (using stone and steel knives respectively) processed salmon using the "strip" and the "fillet" method. They began by cutting off the head directly below the gills and then splitting the belly and removing the fish's internal organs. Then they split the fish along both sides of the backbone, which they removed and either later dried or immediately discarded. In the fillet method two flanks of meat were left attached at the tail; in the strip method they were separated from the tail and then cut into strips. The strip style of cutting is decidedly harder on the blade, since it requires pressing the knife hard against a board. The women agreed that the knives dulled much faster with this approach; each episode of fish cutting required resharpening of the blade (their own knives needed to be resharpened only after cutting four to five fish). Ulroan commented that the strip method had not been used when she was younger and suggested that it may have come into use in the 1950s.

RESULTS

Nanuwak had a difficult time processing the salmon with the ground-slate knife (table 1).[7] Not long into the fish cutting, the blade showed several chips at the cutting surface. At the start she found that the stone knife cut the flesh much more easily than the salmon's skin. Eventually she was sawing at the fish and using "lots of muscle" to cut it. The salmon flesh clung heavily to the blade, requiring her to clean it off repeatedly. She remarked that the ancestral users of these knives may have dipped the knife blade into something like water [oil?] in order to keep the flesh from sticking.

Matchian had a different experience with the steel knives. In experiment 2 she cut the fish using the strip method in nearly the same time that it took for her to cut a salmon with her own knife. She liked the steel knife for its edge but was not impressed with its shape. Indeed, both of the women were more familiar with a flared knife with pointed ends. Their modern knives have more acutely pointed corners or tips and are much more effective in cutting the strips. Matchian then used the fillet method with the second steel knife for comparison (experiments 5, 6, and 7). She observed that the cutting was easy and this was a "good knife", but, again, she did not like its shape. The knife remained sharp through the end of the third fish in this series, and no more fish were cut with it.

Ulroan used the second ground-slate knife to cut a fish using the fillet method. At first she had a hard time slicing through the skin of the salmon. Initially she thought it hopeless, saying that the knife was "really dull" and commented on the state of the "poor fish." Almost immediately she wanted to sharpen the knife.[8] Once the skin was cut, the blade performed much better on the flesh. Ulroan was more comfortable with the shape of the knife, although using it made her more "tired" than using her own. She suggested that this style and size of knife could have been used on smaller fish like the whitefish rather than the larger salmon.

DISCUSSION

The processors identified edge durability, blade sharpness, blade shape, and blade strength as factors in their assessment of each knife's efficiency. The metal knives

7. The Aprun Camp residents may have had a cutting advantage over Nanuwak (who was visiting), since cutting style seems to be vary with the camp.

8. James Savelle, in his review of our paper, wondered whether our decision not to allow resharpening was an unrealistic condition that may have limited the effectiveness of the slate knives to a greater degree than it did the metal knives. Future experiments will test this possibility.

were clearly more effective at cutting fish in all situations. The slate knives, even though carefully presharpened, were comparatively dull and quickly lost their edge. Butchering fish using slate knives was consistently two or three times slower than butchering with steel knives (figs. 2 and 3). Skilled processors could fillet a salmon in three minutes using their own knives and in about the same amount of time using the steel replicas. A fish cutter working at this pace without interruption would be able to fillet 20 salmon an hour and 200 salmon in a ten-hour day. Since it took nine minutes to fillet a salmon using a slate knife, the same processor could fillet only 6.7 salmon per hour and 67 salmon in a ten-hour day, not counting the extra time required to keep the slate knife sharp. In the real world, however, processors can rarely cut fish without interruption. There are meals to cook, children to tend to, and a host of other daily domestic tasks to accomplish. Additionally, ancestral producers likely used their fish differently from modern families, for instance, to provide material for boots. Furthermore, our calculations do not include the time spent getting each fish ready to process or storing the fish. Fifteen chum salmon (approximately 7 lb. each) were filleted in a half hour by two women working together, and the camp children (particularly the girls) rinsed the fish and hung them up to dry. This observed rate more accurately reflects the amount of fish that can be processed than our experimental data.

The consultants were clearly at a disadvantage when using the slate knives compared with their ancestors, who would have been familiar with the characteristics of slate implements. As they worked with the slate tools, the women hypothesized about ways to use them more efficiently (such as using a lubricant or cutting toward oneself). These comments suggest that a processor experienced in using slate knives would have had strategies that maximized their effectiveness. How much faster the ancestral processors were with the slate knives is difficult to assess, but it is doubtful that they could have

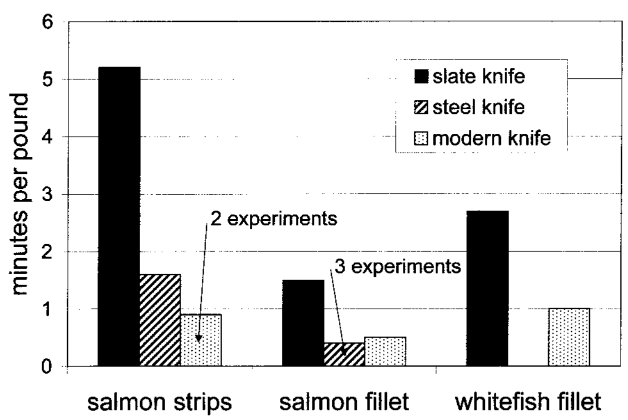

FIG. 2. *Time spent butchering (minutes per pound) with various knives.*

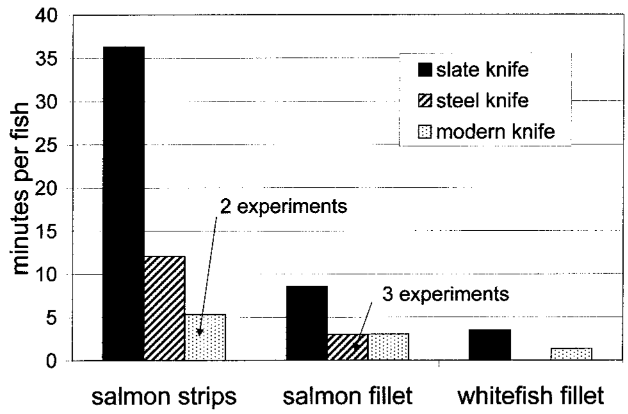

FIG. 3. *Time spent butchering (minutes per fish) with various knives.*

matched the relatively short time our consultants required to butcher fish using steel knives.

Despite these caveats, the time/labor data generated by the slate knife experiments represent our best estimate of the costs associated with salmon processing in prehistory. These estimates gain added importance when we consider that labor available for processing was probably a primary factor limiting the number of fish that could be acquired during the peak of the salmon run. Given that contemporary processors can butcher a maximum of 50 to 100 salmon per person per day using steel knives, our data suggests that processors using slate knives may have been limited to a maximum of 25 to 50 fish per day.

Blade sharpness was an obvious difference accounting for the lower efficiency of slate knives in processing salmon. Our consultants also identified blade shape and overall strength as additional factors important to them, and these were of greatest concern when cutting the salmon into strips. The women found the slate knives inadequate for this task; the relatively brittle stone edge disintegrated when they pressed the knives hard against their wooden cutting boards. Their only attempt to cut salmon strips with a slate knife took over 36 minutes, some six to eight times longer than when they used their own knives, and this cutting episode effectively ruined the blade by removing numerous flakes along the cutting edge. The women also found the rounded corners of the replica blades less effective than their own knives' flared corners. Their only attempt to cut strips with a steel replica took 12 minutes, substantially less time than when using the slate knife but still two to three times longer than when using their own knives. They believed that the additional time required was largely due to differences in blade shape.

These experimental results illustrate the interplay between technology and behavior. They suggest that the strip method of processing salmon is dependent on the availability of metal blades and, as suggested by our consultants, may well be a modern adaptation. They also imply that blade style and probably raw-material availability have behavioral implications. Raw-material availability may have strongly influenced butchering patterns through time, and butchering patterns may also have changed through time as users developed techniques to take advantage of the greater strength and flexibility of steel. Although the general semilunar shape is ideal for a wide variety of tasks, differences in blade style and size may indicate the intentional design of tools for different cutting tasks. There are probably numerous functionally related ulu shapes which are not systematically recorded in the literature. Archaeologists should pay close attention to details of shape and wear analysis when analyzing collections of ulu blades.

CONCLUSION

The strength of this study rests largely on the combination of ethnoarchaeological and experimental approaches. Performing the experiments in a real-world context in collaboration with native Alaskan women has inherent advantages. By tapping into the consultants' knowledge and skills and more fully understanding the social environment in which they are working, we gain a more accurate assessment of time/labor costs and the insight of their qualitative reflections. Salmon processing is a labor-intensive activity. These experiments demonstrate the practical advantages of metal knives over slate knives for those involved in this activity. Archaeological evidence strongly indicates that salmon were a critical resource of Yupiit people in the past, and the significance of salmon undoubtedly increased with participation in the cash economy after Russian contact in the 19th century as salmon became a valuable trade item (Wolfe 1984). It is incumbent upon archaeologists to explore the complexities of the modern uses of the ulu not only to apply this knowledge to the interpretation of the archaeological record but to allow these data to stimulate new questions concerning women's productive capabilities and contributions in the past and the possible social and economic effects of differing technologies on prehistoric and early historic communities.

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Shared Norms and the Evolution of Ethnic Markers[1]

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Unlike other primates, human populations are often divided into ethnic groups that have self-ascribed membership and are marked by seemingly arbitrary traits such as distinctive styles of dress or speech (Barth 1969, 1981). The modern understanding that ethnic identities are flexible and ethnic boundaries porous makes the origin and existence of such groups problematic because the movement of people and ideas between groups will tend to attenuate group differences. Thus, the persistence of existing boundaries and the birth of new ones suggests that there must be social processes that resist the homogenizing effects of migration and the strategic adoption of ethnic identities.

One recurring intuition in the social sciences is that, since ethnic markers signal ethnic group membership and ethnic groups are often loci of cooperation, markers persist because they allow people to direct altruistic behavior selectively toward coethnics (Van den Berghe 1981, Nettle and Dunbar 1997). On closer analysis, however, this argument turns out not to be cogent. Altruism can evolve only if some cue allows altruists to interact with each other preferentially so that they receive a disproportionate share of the benefits of altruism. One such cue is kinship (Hamilton 1964), and another is previous behavior (Trivers 1972, Axelrod 1984). Another idea is that selection might favor altruists who carried an external, visible marker that would allow them to limit their cooperation to others who exhibited the marker. However, evolutionary theorists argue that this mechanism is unlikely to be important (Hamilton 1964, Grafen 1990). Nonaltruists with the marker do best because they get the benefit without paying the cost. Thus, if any process breaks up the association between the co-

1. [Supplementary material appears in the electronic edition of this issue on the journal's web page (http://www.journals.uchicago.edu/CA/home.html).]

operator strategies and the markers, such individuals will rapidly proliferate and altruists will disappear.

Here we argue that markers function to allow individuals to interact with others who share their social norms. We present a simple mathematical model showing that marked groups can arise and persist if three empirically plausible conditions are satisfied: (1) Social behavior in groups is regulated by norms in such a way that interactions between individuals who share beliefs about how people should behave yield higher payoffs than interactions among people with discordant beliefs. (2) People preferentially interact with people with whom they share easily observable traits like dress style or dialect. (3) People imitate successful people, with the result that behaviors that lead to higher payoffs tend to spread. We also show that the preference to interact with people with markers like one's own may be favored by natural selection under plausible conditions. We conclude by outlining several qualitative, empirically testable predictions of our model.

A Simple Model of the Evolution of Ethnic Markers

Consider a population divided into a number of large groups. In each time period, each individual interacts with another individual from the same group. People's behavior in these interactions depends on culturally acquired beliefs. We will refer to this culturally transmitted belief as the *behavioral trait*. There are two alternative beliefs, labeled 1 and 0. Individuals' payoffs from the social interaction depend on their own behavior and the behavior of their partners in the way given in table 1. This simple coordination game is meant to capture the intuition that many real social interactions go well if people have the same beliefs about proper behavior. It is likely that human societies face many problems of this kind. An example familiar to many of us is the problems in cross-cultural communication that result from different expectations about interactions and codes for communicating (Gumperz 1982). The parameter δ measures the strength of this effect.

We also assume that it is difficult to determine another individual's beliefs about proper behavior before an interaction occurs. Given the large number of norms and the fact that some of them will be used only a few times in one's lifetime (Nave 2000), people cannot always reliably predict the behavior of everyone they must interact with or even predict their own behavior, since many such norms are unconsciously held. Much the same argument can be made for rules enforced by third-party punishment. A stranger who moves to a new village cannot guess ahead of time all of the social rules that regulate behavior in his new home. People may be able to tell him some of the things that he needs to know, but it is still likely that he will make many costly social blunders, perhaps even run afoul of basic moral principles (field anthropologists should be familiar with this sort of problem). As long as people are sometimes ignorant in these ways, people with uncommon behaviors will be at a disadvantage, and the model targets these situations, not the entire scope of interaction.

TABLE 1
Payoffs in the Coordination Game

	Player 2's Behavior	
Player 1's Behavior	1	0
1	1 + δ	1
0	1	1 + δ

NOTE: Payoffs shown for player 1; δ is assumed to be positive.

Of course, people have many traits, such as dialect, clothing style, and cuisine, that *can* be observed, and often these traits are the basis of assortative social interaction. To formalize this idea, we assume that there is also a readily observable *marker trait*. This trait also has variants, labeled 0 and 1, and we assume that individuals tend to interact with others who have the same variant of marker trait. The strength of this propensity is given by the parameter e. When $e = 1$, individuals interact at random; when $e = 0$, they always interact with someone with the same marker trait.

There is much evidence that people who do well in life are more likely to be imitated (Henrich and Gil-White 2000). To incorporate this process, we assume that the probability that an individual with behavior i and marker j will be imitated is proportional to $W_{ij}/\overline{W}$, where $\overline{W}$ is the average payoff in the group. This means that combinations of behavior and marker that lead to higher than average payoffs will be more likely to be imitated (see Gintis 2000 for derivation).

With these assumptions it is possible to derive expressions that describe how imitation and social interaction change the frequency of the behavior and marker traits in each group. The change in the fraction of the people with marker 1 within a group, p_1, is

$$\Delta p_1 = \delta U\{(p_1 - p_0)(1 - [1 - e])R^2\}, \qquad (1)$$

where $R\{= D/(UV)^{1/2}\}$ is the correlation of behavior and marker, U and V are the variances of behavior and marker, and D is the covariance between marker and behavior. If $R = 1$, everyone who has marker 1 also has behavior 1; if $R = -1$, then everyone who has marker 1 has behavior 0, and if $R = 0$ the traits are randomly associated. Equation 1 says that if more individuals use behavior 1 than behavior 0, it increases; if fewer individuals use it, it decreases. The rate at which this occurs depends on whether the marker allows individuals to interact preferentially with people who have the same behavior. When R^2 is near one, most individuals with a given behavior have the same marker, and if e is small they almost always interact with individuals with the same behavior as themselves and thus there is little advantage in having the common behavior. When R^2 is near zero, most interactions occur at random and individuals with the most common behavior have an advantage.

The change in frequency of the marker 1, q_1, is approximately given by

$$\Delta q_1 \approx 2\delta D(p_1 - p_0)\left(1 - \frac{e}{2}\right). \quad (2)$$

This expression is valid when the covariance between marker and behavior is small—when individuals' markers predict little about their behavior. When D is positive, marker 1 is associated with behavior 1, and if behavior 1 increases, so does marker 1. The complete expression for the change in q_1 shows that this effect decreases as D becomes larger.

Because the effects of social interaction and learning depend critically on the covariance between behavior and marker (D), we also need to know how they affect the covariance. Social interaction and imitation increase covariance between marker and behavior when the covariance is small. The reason is simple: individuals with the most common combinations of behavior and marker are more likely to interact with others with the same behavior and thus achieve a higher payoff.

We then represent population mixing due to intermarriage, relocation, and other factors with a migration phase which removes a proportion m of each group and replaces it with migrants drawn from neighboring groups. Clearly, such mixing will reduce the differences in the frequencies of both behavior and marker between neighboring groups. However, migration also has a less obvious and very important effect: as long there is any difference in the frequencies of marker and behavior between neighboring groups, migration increases the covariance between marker and behavior within groups:

$$\Delta D = m\{\overline{D} - D + (p_1 - \bar{p}_1)(q_1 - \bar{q}_1)\}, \quad (3)$$

where $\bar{p}_1$, $\bar{q}_1$, and $\overline{D}$ are the average frequencies of behavior and marker and the covariance between behavior and marker in neighboring groups that provide immigrants. To understand why mixing increases the covariance within groups, consider the case in which the frequency of marker and behavior is 0.9 in one group and 0.1 in a second group. Further suppose that the covariance between marker and behavior within both groups is zero, and therefore the marker is useless as a predictor of behavior. Now suppose that we mix the two groups completely. Most of the individuals coming into the first group will carry both marker and behavior 0, while those coming into the second will carry both marker and behavior 1. The frequency of both markers and both behaviors will be 0.5, but most (82%) of the individuals in the population will be either 1,1 or 0,0, with the result that markers are now good predictors of behavior within groups.

Finally, suppose that individuals sometimes acquire marker and behavior traits from different individuals, which leads to the randomization of behavior and marker—a process we term *recombination*. Recombination has no effect on the frequencies of behavior and marker, but it reduces the covariance between marker and behavior at a rate proportional to r.

SIMULATION RESULTS

We have derived recursions that give the net effect of imitation, migration, and recombination on the frequencies of behavior and marker and the covariance between them. However, these recursions are too complex to solve analytically, and we have, therefore, relied on numerical simulation. We begin by describing simulations of the model when there are only two interacting populations. This system provides an intuition for the processes that sometimes give rise to marked groups. We then explore the parameter space of the model, varying e (the chance of interacting at random), m (migration), δ (the effects of social behavior on individual welfare), and r (the rate of recombination) to map the range of conditions under which marked groups arise. Finally, we generalize the model, allowing larger numbers of populations and a general coordination game structure. These analyses suggest that the simple model is relatively robust.

1. *Stable behavioral differences between groups usually become ethnically marked.* Social interaction alone can lead to the evolution of stable differences in behavior between two groups. People with more common behaviors achieve higher payoffs in the coordination game and are more likely to be imitated. Thus if one behavior is initially common in one group and the alternative behavior is initially common in the other group, payoffs from social behavior coupled with imitation of the successful will cause the groups to become more different. If the diversifying effect of payoff-biased imitation is sufficiently strong compared with the homogenizing effect of migration, the two populations will reach an equilibrium at which behavior 1 is common in group 1 and behavior 2 in group 2. In contrast, if the rate of mixing is too high or if initially the same behavior is common in both populations, only one behavior will be present in both populations at equilibrium.

If stable behavioral differences between groups exist, each behavior can become associated with a different marker variant—behavior 1 will, for example, be associated with marker 0 and behavior 0 with marker 1. Figure 1 illustrates this dynamic. Initially behavior 1 is more common in population 1 and less common in population 2. Marker 0 is initially more common than marker 1 in *both* populations but relatively more common in population 2 than in population 1. There is no initial covariance within populations. At first, rare-type disadvantage causes behavior 1 to become more common in population 1 and behavior 0 in population 2. At the same time, migration generates a negative covariance between marker and behavior so that behavior 1 tends to co-occur with marker 0 and marker 0 with behavior 1. This in turn strengthens the forces increasing the dif-

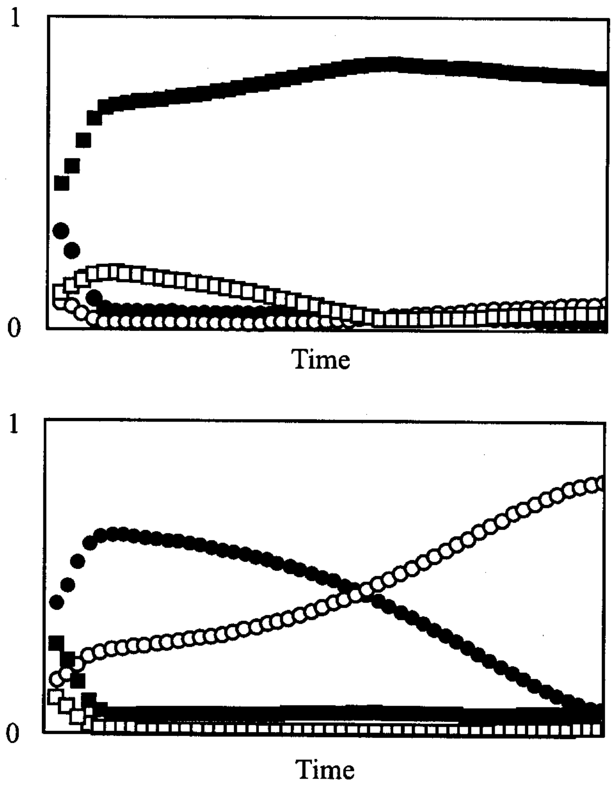

FIG. 1. *The frequencies of each the four combinations of behavior and marker over time in each of two populations for* m = *0.025,* e = *0.25, and* r = *0.1. The behaviors are denoted by the shape of the symbol,* circle (= *0*) *or* square (= *1*)*, and the markers are denoted by color,* black (= *0*) *or* white (= *1*)*. Initially behavior 1* (squares) *has frequency 0.55 in population 1 and 0.45 in population 2. Marker 0* (black) *is initially more common than marker 1 in both populations but relatively more common in population 1* (q_{11} = *0.8*) *than in population 2* (q_{12} = *0.7*).

ferences between the populations in frequencies of marker and behavior, which then generates greater covariance. This positive feedback process (fig. 2) continues until a symmetrical equilibrium is reached at which a different behavior is common in each population and each behavior is associated with a different marker. The adaptive behaviors have become symbolically marked, even though the same marker was initially common in both groups.

However, migration and recombination oppose the positive feedback process described above. Migration tends to make the two populations the same, equalizing the frequency of the markers in each population, and recombination destroys the covariance between marker and behavior. If recombination is strong, it dissipates the covariance between marker and behavior more rapidly than migration and imitation can create it. Even though the payoff advantage of being in the majority is sufficient to maintain behavioral differences between the two populations, these differences do not become ethnically marked. When individuals are unable to assort accurately on the basis of markers (e is large), the pattern is similar: stable group differences in behavior may emerge and persist, but selection on markers is too weak to generate covariance between marker and behavior.

The qualitative arguments are supported by systematic sensitivity analysis. We determined the range of parameters under which groups become marked by performing a large number of simulations. For each simulation we calculated the value of $\overline{D}$, the population average covariance between behavior and marker, averaged over the 100 simulations. We held parameter values constant at $m = 0.01$, $e = 0.3$, $r = 0.01$, $\delta = 0.5$, for parameters not varied in a run of simulations. Figure 3 summarizes these results. When biased imitation can maintain stable behavioral differences in the face of migration, stable marker differences evolve provided that (1) recombination (r) is not too strong and (2) individuals interact sufficiently often with individuals like themselves (e is not too high). There are no cases in which behavioral differences fail to evolve and marker differences manage to become stable.

2. *Spatial structure is needed to generate ethnic markers but not to maintain them.* Migration between groups generates the initial covariance essential for the evolution of ethnic markers. However, if individuals are able to use markers to assort accurately ($e \approx 1$), spatial structure is no longer necessary to maintain ethnic markers once such covariance arises (fig. 4) and groups end up mixed together in space, but high covariance between markers and behaviors remains. This configuration can only be a stable equilibrium if r and e are very small. However, for somewhat larger values of r and e, there is a long transition period during which two ethnically marked types are present without spatial variation. A more complex model in which groups occupied different niches would likely be able to sustain spatially mixed ethnically marked groups in a wider range of circumstances. Also, we will demonstrate later that natural selection would reduce values of r and e if at all possible. This makes the possibility of the evolution of such spatially blended systems more likely. Such situations are an interesting and unexpected outcome of our model.

3. *Increasing the number of populations increases the range of initial conditions that give rise to ethnic markers.* Random starting conditions (random frequencies of behavior and marker in each group) often lead to the evolution of behaviorally different and marked groups, and this result becomes more likely as more groups are added to the system (fig. 5). The two-group system is most sensitive to starting conditions, as this case has the highest chance of randomly generating all groups with similar initial behavior frequencies.

4. *Group differences are strongest at boundaries.* When more than two groups are arrayed in space, the correlation between marker and behavior ($R = D_k/\sqrt{U_k V_k}$) is greatest at the boundaries between culture areas. Figure 6 shows the steady state in ten populations

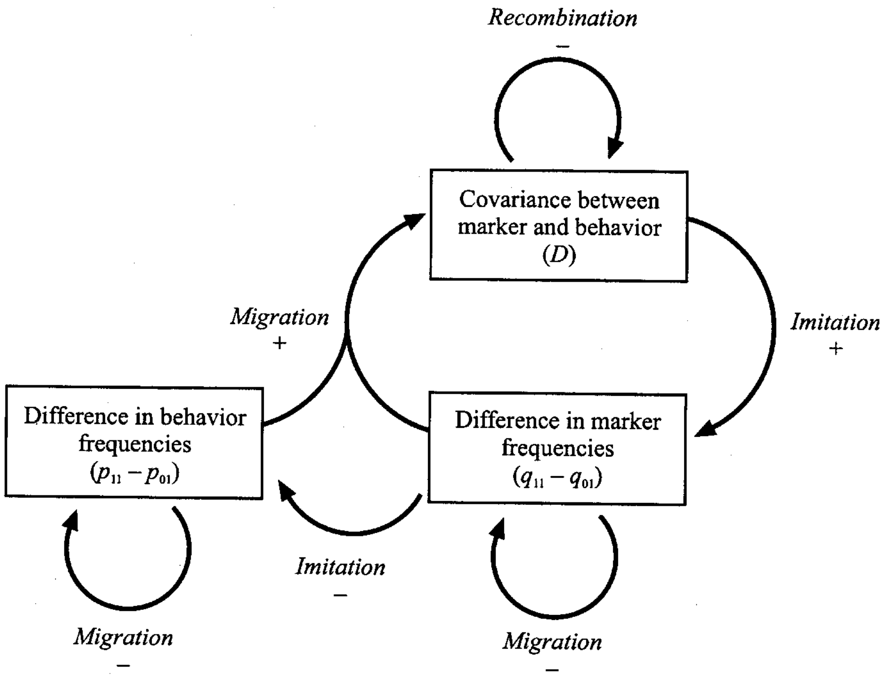

FIG. 2. *The feedback process that generates marked groups and the forces that oppose this process.*

arranged in a stepping-stone ring. This steady state results from an initial clinal distribution of behavior and marker frequencies with zero correlation between behavior and marker in each population. There is a region of three populations in the middle in which the frequency of marker 1 and behavior 1 is low and a region of three populations at the edges in which these frequencies are high (remember that the populations wrap around so that population 1 exchanges migrants with population 10). In both of these regions there is little or no correlation between marker and behavior. In between these regions are boundary areas in which frequencies

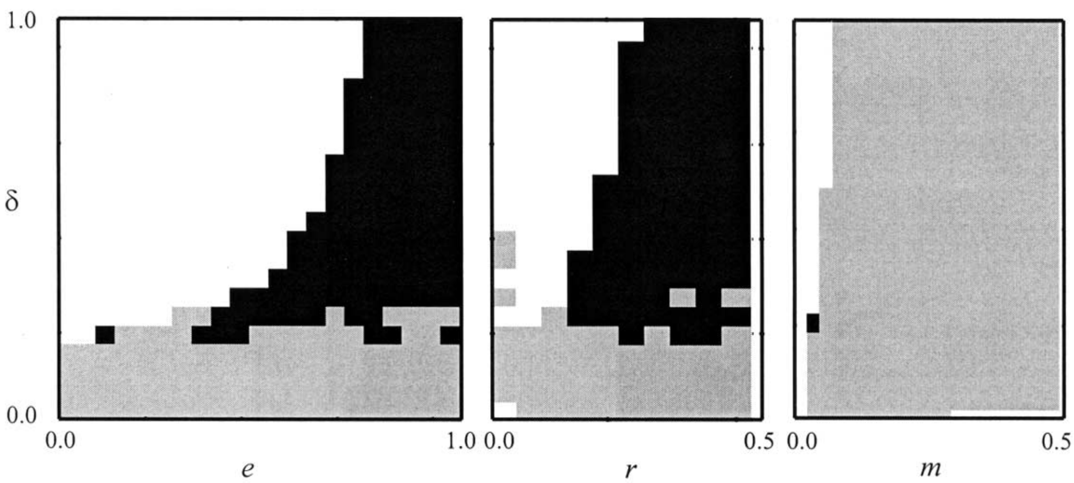

FIG. 3. *The evolution of stable marker differences.* White regions, *combinations of parameter values that produced both stable behavioral and marker differences (that is, these populations became ethnically marked).* Black regions, *cases in which behavioral differences were stable but marker differences were not (that is, these populations became culturally different but without ethnic markers).* Gray regions, *cases in which behavioral differences failed to evolve, typically because of strong migration.*

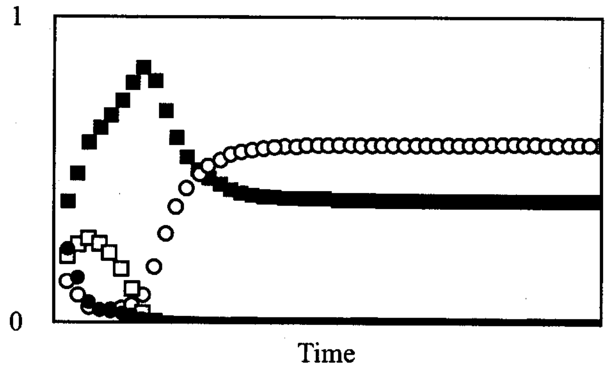

FIG. 4. *The frequencies of each the four combinations of behavior and marker over time in each of two populations. The behaviors are denoted by the shape of the symbol,* circle (= *0*) or square (= *1*), *and the markers are denoted by color,* black (= *0*) or white (= *1*). *The initial conditions and value of* m *are the same as in figure 1, but now assortment is perfect,* e = *0.0, and there is no recombination,* r = *0.0. As before, at first, rare-type disadvantage causes the behavior 1 to become more common in population 1 and behavior 0 in population 2, and migration generates a positive covariance between marker 1 and behavior 1 (equation 4). However, because there is no recombination, this covariance builds up much more rapidly, especially in population* 1, *in which the initially relatively more common marker was also absolutely more common. The high correlation between marker and behavior combined with the accurate assortment eliminates rare-type disadvantage, and migration mixes the two groups until they are identical. Because the covariance increases more rapidly in population 1, the marker-behavior variant in population 2 experiences a transient advantage that is preserved at equilibrium.*

are intermediate and there is substantial correlation between marker and behavior.

5. *A more general model of social interaction leads to similar results.* So far we have assumed that social interaction can be modeled by a game of pure coordination with equal average payoffs for both equilibria. Symmetric, pure coordination games are very special because the basins of attraction of the two equilibria are the same size. To test whether our results were sensitive to this assumption, we ran a number of simulations in which we varied the parameters of the completely general two-person coordination game shown in table 2.

The results indicate that the system regularly evolves toward marked, behaviorally distinct groups even when there are large deviations from the perfect coordination structure. Thus our results do not depend in a sensitive way on the perfect nature of the game structure we have chosen. This suggests that any stable behavioral equilibria, regardless of their relative consequences for group or individual welfare, may become marked.

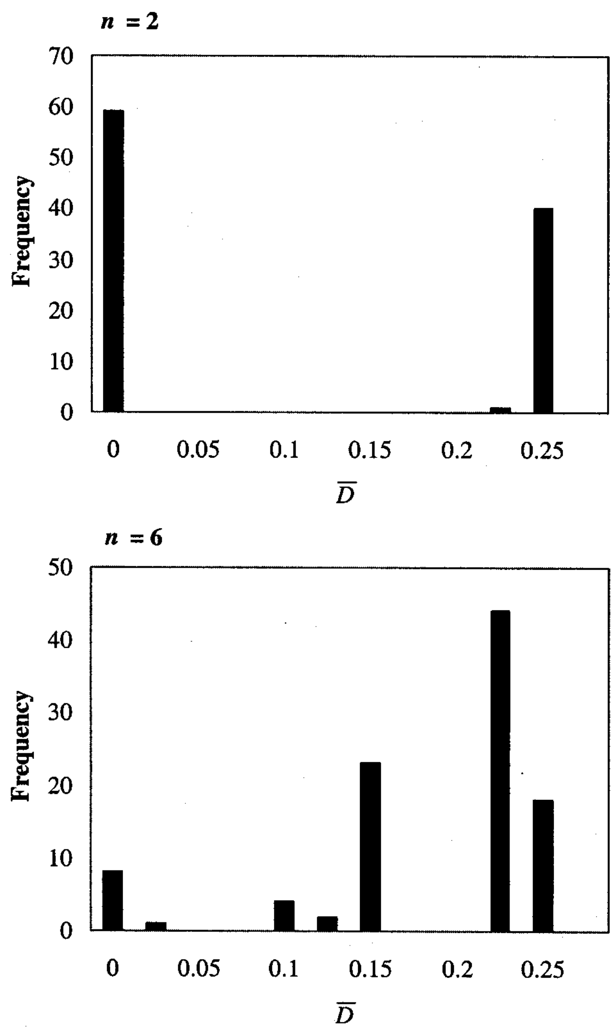

FIG. 5. *Equilibrium absolute values of* $\overline{\text{D}}$ *(covariance in the population as a whole) for simulations involving two groups* (top, *100 simulations) and six groups* (bottom, *100 simulations*). *Starting conditions were random with parameter values* m = *0.025,* r = *0.10,* e = *0.30,* δ = *0.50. High* $\overline{\text{D}}$ *becomes more likely as the number of groups increases.*

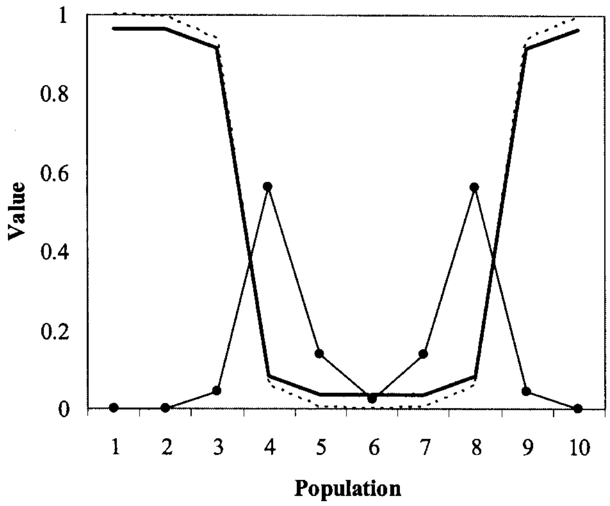

FIG. 6. *The steady state that arises from slightly clinal initial distributions of the frequencies of marker 1 and behavior 1 in ten populations arranged in a ring.* Broken line, p_1; heavy solid line, q_1; light solid line, R.

TABLE 2
Payoffs in a General Two-Person Game with Two Stable Equilibria

	Player 2's Behavior	
Player 1's Behavior	1	0
1	$1 + \delta + g$	$1 - h$
0	1	$1 + \delta$

NOTE: Payoffs shown for player 1; δ, g, and h are assumed to be positive.

EVOLUTIONARY STABILITY OF THE PARAMETERS

This model depends on four parameters: m, δ, r, and e. The first two formalize assumptions about the ecology of the evolving populations. The second pair of parameters represents assumptions about human psychology. The simulation results indicate that social interactions in which common behaviors have high payoff will lead to the evolution of ethnic markers if both e and r are small, or, in other words, if people have a psychology that predisposes them to interact with individuals with the same marker as themselves and to acquire some markers and behaviors as a package. Natural selection will, all other things being equal, favor such a psychology (that is, selection will favor mutations that reduce the values of e and r). However, selection on other aspects of social learning and demands on interaction may restrict the extent to which selection can reduce these parameters.

DISCUSSION

We have argued that ethnic markers do not function to allow individuals to direct altruism to others like themselves because such a system cannot resist invasion by cheaters who signal altruistic intent but then do not deliver. In contrast, ethnic markers can signal one's behavioral type when social interactions have a coordination structure because in such situations there is nothing to be gained from cheating. Both parties in the coordination setting gain the most when they honestly advertise their strategy, and as a result both the behavior and its advertisement spread when the successful are imitated. Axtell, Epstein, and Young (1999) have analyzed another model that is quite different structurally but works for similar reasons.

The intuition that ethnic markers and cooperation are related is not, however, without merit. Humans are peculiar in that we often cooperate with large numbers of unrelated individuals. As we have argued, the existence of ethnic markers alone cannot explain the scale of human cooperation. Yet we have shown that markers may evolve when individuals interact in a two-person coordination game, and we believe that any process that leads groups to occupy multiple stable equilibria may produce the same result. Two of us have argued at length elsewhere that human cooperation results from norms enforced by socially created rewards and punishments (Boyd and Richerson 1990, 1992; Soltis, Boyd, and Richerson 1995; Richerson and Boyd 1998, 1999). If punishment is sufficiently costly, such systems can stabilize a very wide range of behavior. Then, competition between groups will lead to the spread of moral systems that enhance group survival, welfare, and expansion, including norms that lead to enhanced cooperation in economic and military activities.

As a result, we expect that systems of moral norms, some of which create group-beneficial cooperation, should come to be marked by ethnic markers by the process described above. Punishment transforms the prisoner's dilemma structure of a cooperation problem into a coordination structure. The process we have described here can then lead to individuals' selecting individuals with whom to cooperate on the basis of markers, but the markers themselves do not stabilize the cooperation.

COROLLARIES AND PREDICTIONS

The goal of this kind of modeling study is to demonstrate the cogency of a deductive argument linking assumptions about microlevel social interactions to the empirically observable macrolevel social patterns that result. Accordingly, we conclude by describing several testable predictions of the model.

Our analysis of the evolutionary stability of e and r makes two predictions about the psychological tendencies of human beings:

1. *Individuals in marked communities should prefer interaction with similarly marked individuals.* Our

analysis of the evolution of e, the rate at which individuals interact at random with respect to markers, suggests that natural selection or an analogous process operating on cultural rules for interaction should reduce e to zero, if possible. Thus, to the extent that e represents a psychological bias toward interacting with those who look like oneself rather than the ability or freedom to interact with ones like oneself, we expect members of marked communities to prefer individuals marked like themselves, at least when it comes to coordination interactions.

2. *Individuals in marked communities should acquire bundles of at least some norm and marker traits*. While the model does not suggest anything about the social learning of noncoordination behaviors and social markers, our analysis of the evolution of r, the rate of recombination of behavior and marker traits, predicts that, for our model to be relevant, individuals should acquire norm and marker traits as a bundle. They should also preserve these associations throughout substantial portions of their life spans. If this is not true, the process we describe here is unlikely to work.

The model makes three clear predictions about the nature of the distributions of marker traits and their relations to ethnic groups and their histories:

1. *Ethnic differences should be stronger at boundary regions than deep within ethnic territories.* Hodder (1977) suggests that this is true for some ethno-archeological data from the Lake Baringo region of Kenya, but the data are inadequate to test this prediction. The appropriate test would be examination of a large ethnic group, such as the Kikuyu of Kenya, which interacted at many border areas with a number of different ethnic groups. Another setting that holds promise for testing this prediction is fragmentary migration that brings smaller units of a larger ethnic population into contact with other ethnic groups. If these groups are on average more marked than their source populations, we may be able to conclude that interaction with the other ethnic groups has increased selection on markers and magnified initial differences in those settings.

2. *Norm and marker boundaries should coincide, while the distributions of other culture items may map onto one another differently*. Our model makes no predictions about the nature of all cultural traits and the distribution of ethnic markers. However, if this model is correct, a number of norm differences—on beliefs in inheritance, child rearing, household labor, and other categories of human life in which there are multiple coordinated solutions to the same problem—should correspond to the distributions of marker differences.

3. *Potential marker traits with the greatest initial differences should become marked first*. One test of this prediction would be to examine ethnographic settings in which two isolated source populations have contributed migrant groups that have since been in contact for some time. The source populations provide estimates of the initial differences present in the migrant groups when they came into contact. The migrant groups provide estimates of the differences that might have grown from those initial differences. This prediction will earn support if the traits with greater differences between source populations appear to have led to marked traits in the contact groups.

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Preeclampsia/Eclampsia and the Evolution of the Human Brain

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Among mammals, the human species presents an apparent "extravagant" sexuality: most human copulations occur at the wrong time to result in fertilization. Copulation takes place all year long rather than in a period of oestrus, and ovulation is concealed from male partner(s) and often even from females themselves (Diamond 2000 [1992]). Further, although extramarital sexuality exists in human societies, the human female does not employ the reproductive strategy of her mammalian counterparts, placing the sperm of different males in competition at the time of ovulation. Marriage is an institution in almost all human societies, inducing longer average fidelity in reproductive couples than in many other mammalian species (Diamond 2000 [1992], Kaplan et al. 2000). At the same time, the human female displays a rather low rate of fertility, 25% per cycle at the age of maximum fertility. It can easily be calculated that in order to conceive a human couple needs on the average (albeit there are numerous individual exceptions) about 100 acts of intercourse. At the level of populations, demographers calculate a mean time until conception in couples without contraception of seven to eight months after the beginning of sexual relations (Léridon 1993). This is astonishing compared with the situation of other mammals, whose sexual relationships during oestrus are very fertile. Incidentally, it can be added that once having conceived, the human female has a naturally high rate of spontaneous miscarriage (15%). At first glance, these facts might suggest that the human female is at some reproductive disadvantage compared with her nonhuman mammal counterparts (Léridon 1993). This report will develop the argument that these apparent disadvantages may, on the contrary, be an adaptive biological process.

1. We thank Gunther Eble for reviewing the manuscript.

The human female's exposure to sperm many times before conception (in fact, the life expectancy of sperm being three or four days in the female genital tract, even with intercourse twice a week she is constantly exposed) over a relatively long period (seven to eight months), her constant exposure to the sperm of a particular male partner, and many pregnancies with this same partner may be a biological adaptation to the risk of preeclampsia/eclampsia. Preeclampsia, usually defined as new-onset hypertension and albuminuria (abnormal loss of protein by the kidneys due to renal damage) developing after 20 weeks of gestation in the human female (Walker 2000), is a consequence of a defect in the normal human-specific deep endovascular invasion of the trophoblast required by the extensive nutritional needs of the fetal brain (Cunnane, Harbige, and Crawford 1993, Martin 1996, Robillard, Dekker, and Hulsey 2002). Thus it may be an apomorphy (innovation) directly linked to the great increase of cranial capacity in *H. sapiens*. Further, the large cranial capacity of *H. neanderthalensis* may have been incompatible with adequate fetal nutritional possibilities at so primitive a stage of craniofacial contraction and ontogeny and may be implicated in the disappearance of the species. With the following we hope to stimulate interest in this disease on the part of demographers, palaeoanthropologists, ethnographers, geneticists, zoologists, and others.

PREECLAMPSIA/ECLAMPSIA

Preeclampsia/eclampsia is a hypertensive disorder of pregnancy that occurs in 10% of human births: a young woman previously normotensive will present high blood pressure in the last trimester of pregnancy and recover her normotensive status after delivery. In roughly 7% of pregnancies, women will present simple pregnancy-induced hypertension (mild preeclampsia). In 3% of pregnancies, this condition will be complicated by generalized endothelial cell disease that induces damage to the kidneys (proteinuria) or the liver (the HELLP syndrome: hemolysis, elevated liver enzymes, and low platelet count), or severe preeclampsia. Finally, in 1% of pregnancies, this generalized endothelial cell activation will result in cerebral vasculopathy and induce epileptic seizures. In the recent past, without modern medical intervention, at least a third of these cases ended in the death of the mother and a much larger proportion in the death of the fetus in utero or of the newborn, and this situation holds in developing countries today. All these troubles have in common that their only known definitive cure is delivery by whatever means (induced labor, cesarean section), making preeclampsia the most important cause of medically induced prematurity. The long-term survival of these newborns depends on modern neonatology (Brown 1997).

Preeclampsia is not only harmful to the mother but also a catastrophe for the fetus. Because of poor maternal-fetal vascular exchange, it is the primary documented cause of intrauterine growth retardation, resulting in affected women's giving birth to "small for gestational age" low-birthweight (less than 2,500 g) newborns even at full term. Throughout the history of humankind, these newborns have paid the highest price of infant mortality (Levene 1985).

In epidemiological terms, hypertensive disorders of pregnancy are one of the plagues of human reproduction. There is no real established natural animal model other than some suggestions in primates (patas monkeys [Palmer et al. 1979] and lowland gorillas [Baird 1981]). These very isolated reports on single cases of epilepsy during delivery do not seem to be associated with a prevalence of the disease as high as the 1% of total births reported for humans (in rare cases, mammals may present epileptic seizures at delivery because of, for example, intense hemorrhage or hypoglycemia).

Could preliterate human populations have been aware of this disease even in prehistoric times? Yes. Eclampsia was probably interpreted as a curse on the pregnancy in question. We use the term "curse" in view of the fact that, in all human cultures and for 99% of the existence of our species, epilepsy has been associated with possession. Eclampsia appears in the medical literature as early as 4,200 years ago (Lindheimer et al. 1999). Further, our ancestors may have been able to make the connection between preeclampsia and eclampsia, having observed, first, that young women with oedema (abnormal accumulation of liquid in the tissues) at the end of pregnancy were likely to develop eclampsia at delivery and, second, that the pregnancies of those who did not produced tiny newborns.

The Pathophysiology of Preeclampsia

In human pregnancy, in contrast with that of other mammals, implantation of the embryo occurs by two physiological invasions by the cytotrophoblast inside the uterine wall: (*a*) at the beginning of pregnancy after fecundation (as in all mammals) and (*b*) at the end of first trimester of gestation, this one a very deep (one-third of the uterine wall) invasion (Pijnenborg 1996, Zhou, Damsky, and Fisher 1997). Preeclampsia is the failure of this second invasion, which induces poor vascular exchanges between the mother and the placenta. The increase in blood pressure in the mother is a compensatory mechanism aimed at increasing the exchange and maintaining supplies to the fetus. This human-specific two-phase endovascular trophoblast invasion represents a remarkable immunological maternal-fetal interaction. The cytotrophoblast, being a half foreign tissue by virtue of its paternal antigens, can be considered to represent a natural allograft in the uterine wall (Claman 1993, Dekker, Robillard, and Hulsey 1998). The human female is the only mammal that requires this second deep trophoblast invasion, and this fact is most likely why preeclampsia does not exist in other mammals (Robillard, Dekker, and Hulsey 2002). In severe preeclampsia and eclampsia, in addition, a cascade of events leads to global endothelial cell dysfunction in mothers with or by oxidative stress (a phenomenon understood only since the late 1980s) (Roberts et al. 1989, Taylor et al. 1998). The factor X leading to this global endothelial cell dysfunction might well be the inositol phosphate glycans P abnormally produced by the preeclamptic placenta (Kunjara et al. 2000), which, like bacterial endotoxins, are very irritating to endothelial cells and, as do all lipopolysaccharides, induce an immediate defense reaction in the maternal immune system that may explain the histological vasculopathy found in the kidneys, liver, and brain.

Protective Factors

Preeclampsia/eclampsia is a disease of first pregnancies in humans and seldom recurs in subsequent ones (Chesley 2000). It has been recognized for more than a century that any kind of previous pregnancy (completed or not, i.e., spontaneous miscarriages or volunteer abortions) is protective against preeclampsia in successive pregnancies (MacGillivray 1983, Seidman et al. 1989). In the late 1970s a protective effect (confirmed in the mid-1990s) was described in cases of first pregnancies: primigravid women who conceived after long sexual cohabitation in a reproductive couple were quite free of these complications (Marti and Herrman 1977). The same phenomenon has been described in multigravid women who have changed male partners. Preeclampsia occurred in approximately 40% of couples with less than 4 months of cohabitation before conception, 25% those with 5 to 8 months, 15% of those with 9 to 12 months, and 5% of those of more than 12 months (and the same father in multigravidae) (Robillard et al. 1994, Robillard and Hulsey 1996).

In summary, to reduce the risk of preeclampsia/eclampsia, it is better for the human female (1) to wait some time before conception of a first child with a particular father and (2) to stay with this same father for additional pregnancies. Biological explanations of these epidemiological observations remain unclear, but the idea of preeclampsia/eclampsia's being a graft rejection of the fetal-maternal allograft is a promising trail. The human female has to tolerate the half-foreign graft through the father's antigens, and this is easy to do after the immunological stimulation of a first pregnancy. In the case of a first pregnancy with a particular father, she is able to tolerate it given a long, constant exposure to the father's antigens through his sperm (Dekker, Robillard, and Hulsey 1998, Tubbergen et al. 1999, Robillard, Dekker, and Hulsey 2002).

Evolutionary Considerations

Craniofacial contraction in primates. One of the major evolutionary trends in primate and hominid evolution is an increase in cranial capacity accompanied by craniofacial contractions. Deniker (1886) was the first to notice the significance of flexure of the skull base, and many observers including Biegert (1936, 1957), Schultz (1926, 1936, 1955, 1960), Anthony (1952), who emphasized the anterior migration of the *foramen magnum*, Delattre (1952, 1958), and Delattre and Fenart (1954, 1956, 1960) picked up on this idea. These shape changes were reported but not quantified. The two last-named researchers showed that cranial ontogenesis in higher apes and humans was characterized by varying degrees of occipital flexion and prognathism depending on the genus and the degree of bipedalism. Despite this work, the dynamic unity of the skull and the face was not yet clear. A fundamental discovery was that the three-dimensional organization of basicraniofacial architecture is controlled by the processes of flexure at the base of the skull, and this affects the morphogenesis of the two stages of the face, the maxilla and the mandible (Deshayes 1986, 1988, 1991; Deshayes and Dambricourt Malassé 1990; Dambricourt Malassé and Deshayes 1992). This phenomenon, reviewed by Dambricourt Malassé (1987, 1988, 1993), is found in all primates and in mammals generally. Gudin (1952) pioneered a global architectural analysis in the sagittal plane, showing an arrangement of straight lines from the base of the skull to the face that reflects the dynamics of skull construction in this plane. He drew a pantograph (see Dambricourt Malassé et al. 1999 for applications) for humans and apes and was able to propose an early geometric model for quantifying morphological differences and to show that mandibles recorded craniofacial contraction. The pantograph demonstrated that flexure at the base of the skull corresponded to the face's riding over the frontal bone. This morphogenetic pattern is found in many living apes and also in the evolutionary phenomenon of hominization. Comparing present-day and fossil mandibles, Dambricourt Malassé (1987, 1988) distinguishes at least five distinctive *Baupläne* (structural designs) among extant and fossil primates in terms of increasing intensity of embryonic craniofacial contraction and increase in cranial capacity. Craniofacial contraction is minimal in fossil (adapiforms) and extant prosimians, more substantial in monkeys (cercopithecids), even more so in great apes (*Pongo, Gorilla, Pan*) and australopithecines (*Australopithecus*), and maximal in humans. It is the embryonic amplitude of craniofacial contraction that differs among the various present-day primates rather than the nature of the process itself.

Shape changes in the cranium and increase in cranial capacity. In recent papers (Millet 1997, Penin 1997, Chaline et al. 1998), differences in the shape of the cranium in some species of great apes, australopithecines, fossil hominids, and modern humans have been quantified in the three orthogonal views of the skull of geometric morphometry (Sneath 1967, Felsenstein 1990, Rohlf and Bookstein 1990, David and Laurin 1992). The method used here quantifies these shape changes independently of the trend toward increased size and confirms the existence of craniofacial contractions (angular correlations in three dimensions), which occur by significant statistical leaps. It is shown that the great ape, australopithecine, and *Homo* cranial *Baupläne* are significantly different. The *Homo* plan, derived from the australopithecine, encompasses primitive humans and three ancient African fossil species or subspecies (*habilis, ergaster*, and *rudolfensis*) followed by more recent *erectus, heidelbergensis*, and *neanderthalensis* in Europe, *soloensis* (evolved *erectus*) in Indonesia, and modern humans (*H. sapiens*) in Africa. It is characterized by occipital rotation, with the *foramen magnum* being shifted anteriorly and inclined, and posterior extension of the skull and broadening of the frontal bone, resulting in increased cranial capacity. The Neandertalization of *H. erectus* forms in Eurasia involved a renewed posterior expansion of the skull, with cranial capacity reaching 1,600 cm^3. The transition from *H. erectus* to modern humans (*H. sapiens*) in Africa was marked by a new occipital rotation, the obvious elevation of the cranial vault and lowering of the base of the skull (which augmented cranial capacity), and the shortening of the face, which became vertical. The final simian characters, such as the browridge, also vanished. The morphological differences between primitive and modern humans look like a small leap within a trend in the *Homo Bauplan* but are not statistically significant. Cranial capacity ranges from 282 to 454 cm^3 in chimpanzees, from 350 to 752 cm^3 in gorillas (Schultz 1965), from 400 to 550 cm^3 in australopithecines, from 510 to 1,600 cm^3 in archaic *Homo*, and from 1,100 to more than 2,000 cm^3 in *H. sapiens*.

For eclampsia implications, it is interesting to link increased cranial capacity in the *Homo* lineage with ontogeny. The craniofacial contraction process starts very early in ontogeny and is contemporaneous with organogenesis—the implementation of the craniosacral embryonic plan. It is defined in scope and duration by embryogenesis, which represents the first eight weeks after fertilization in humans and a little less in other primates (e.g., nearly two weeks in chimpanzees). During this period, neurons duplicate at the rate of 5,000 neurons/second. The extension of this period in humans thus brings about hypertrophy ($\times$ 4) of the brain. It is suggested that from fossil great apes to modern man there have been numerous heterochronies (*sensu* Reilly, Wiley, and Meinhart 1997) in the course of ontogeny, resulting in the increased cranial capacity of primitive forms of *Homo* and the disappearance of simian characters associated with further increase in cranial capacity in modern humans (Chaline et al. 1998).

According to this view of cranial capacity increase, it is clear that the very deep trophoblastic implantation occurring in humans as a two-phase process may be explained in terms of increased fetal nutritional needs compared with those in mammals with smaller cranial capacities. The human embryo requires 60% of total fetal nutritional supplies for the growth of the brain during the fetal phase (third trimester) while other mammalian fetal brains require only 20% (Cunnane, Harbige, and Crawford 1993, Martin 1996). Thus, the appearance of preeclampsia in humans seems to be linked to the development of a large brain in *Homo*. The most archaic species of the human lineage (*habilis, ergaster, rudolfensis, erectus, heidelbergensis, neanderthalensis*) exhibit less craniofacial contraction and smaller cranial capacity than *H. sapiens*. The large increase in cranial capacity observed in *H. sapiens* suggests that preeclampsia could be a by-product of natural selection for that trait.

These considerations suggest a new hypothesis for the disappearance of *H. neanderthalensis* some 30,000 years ago. Within the archaic *Homo Bauplan*, characterized by reduced craniofacial contraction compared with *H. sapiens, H. neanderthalensis* exhibits the largest increase in cranial capacity of the group, reaching 1,600 cm^3—a value that falls within the range of variability of *H. sapiens*. We may ask whether this large cranial capacity was compatible with fetal nutritional possibilities at such a primitive stage of craniofacial contraction and ontogeny. A single-phase process of trophoblastic implantation may have been inadequate for this large increase in cranial capacity, and this phenomenon may help to explain, at least in part, the disappearance of the Neandertals. The two-phase process of very deep trophoblastic implantation in *H. sapiens* may have been an evolutionary solution, a new character or apomorphy allowing the extended fetal nutrition required by the large increase in cranial capacity.

Biological and Cultural Adaptations to the Preeclampsia Risk

Reducing the risk of preeclampsia created both biological and social cultural requirements. On the biological side, the human female, needing some degree of exposure to the sperm of a particular male partner before a first pregnancy, had to be sexually attractive continually (concealed ovulation, absence of oestrus) but at the same time had to avoid being fertilized too soon (very low fertility rate and significant incidence of spontaneous miscarriage). All human cultures have imposed marriages inducing rather long fidelity in reproductive couples (Diamond 2000 [1992]), and the vast majority of human groups prohibit systematic polyandry for their females (Deliège 1996). Further, the risk of preeclampsia may have been an important contributing factor to the prohibition of incest in all human cultures. These ideas are developed elsewhere (Robillard, Dekker, and Hulsey 2002).

Because of the importance of eclampsia in humans, the association between delivery and seizures should be recorded in one way or another in the human memory (myths, tales). The morals of these stories should be very instructive with regard to their interpretations of these convulsions in childbirth. Particularly, it would be interesting to investigate whether this "curse" is directed toward the mother only or toward the couple. If the latter is the case, it may be that "primitive" cultures had noticed facts that modern medicine has taken a long time to rediscover.

Conclusion

The human female's apparent extravagant sexuality, absence of oestrus, concealed ovulation, constant sexual attractiveness, very low fertility rate, and very high rate of spontaneous miscarriage and at least some long fidelity in couples in all human cultures may be interpreted as a biological and cultural adaptation to the human reproductive burden of preeclampsia. The large increase of cranial capacity in *H. sapiens* suggests that preeclampsia may be a by-product of natural selection for that trait. It is also possible that the disappearance of *H. neanderthalensis*, which acquired a large cranial capacity within the archaic *Homo* lineage characterized by less embryonic craniofacial contraction, could be linked to inadequate fetal nutrition.

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