



Toward Peace: Foreign Arms and Indigenous Institutions in a Papua New Guinea Society
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26. $^{13}\text{C}\{^1\text{H}\}$ chemical-shift calculations indicate that the $\text{Rh}\cdots\text{HC}$ signals occur at $\delta +31.2/+33.3$ [3] and $\delta +38.9$ [2]. We observe a signal at $\delta +31$ in the $^{13}\text{C}\{^1\text{H}\}$ SSNMR for **2**. For the mixture of **3** and **4**, signals due to $\text{Rh}\cdots\text{HC}$ could well be coincident with the ^1Bu signals that are observed in the range of $\delta+28$ to $+20$.
27. Data were collected as described in the supplementary materials, solved with SuperFlip (37), and refined with CRYSTALS (38, 39). Complexes **1**, **2**, and **3** all occupy a position on a crystallographic twofold axis imposing disorder in the alkane/alkene fragment. See the supplementary materials (24) for full data collection and refinement details.
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Supplementary Materials

www.sciencemag.org/cgi/content/full/science.1225028/DC1
Materials and Methods
Supplementary Text
Figs. S1 to S33
Tables S1 to S7
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Toward Peace: Foreign Arms and Indigenous Institutions in a Papua New Guinea Society

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In 1990, shotguns and M-16s were adopted into Enga warfare, setting off some 15 years of devastation as youths (~17 to 28) took charge of interclan warfare. In response, people called on elder leaders to adapt customary institutions to restore peace; subsequently, war deaths and the frequency of war declined radically. Data from precolonial warfare, 501 recent wars, and 129 customary court sessions allow us to consider (i) the principles and values behind customary institutions for peace, (ii) their effectiveness, (iii) how they interact with and compare to state institutions of today, and (iv) how such institutions might have shaped our human behavioral repertoire to make life in state societies possible.

In 1990, the Enga of Papua New Guinea (PNG), who number between 400,000 and 500,000 people today, adopted new technologies: shotguns, M-16s, and other semi-automatic rifles to replace bows and arrows in interclan conflicts. Even to the Enga it seemed like the beginning of a never-ending story as two decades of runaway warfare ensued, fueled by a “youth bulge” (1, 2). The age-based power hierarchy of males was overturned; gangs of mercenaries reigned; death tolls soared; trees were razed; gardens uprooted; and houses, and schools, and missions burned to ash. Between 1991 and 2005, Enga fought more than 250 wars (3): organized armed conflicts between political communities, in which the ends were defined by peace agreements (4). From 2006 on, interviews and observations of village court sessions indicated gradual changes in attitudes and practices. Exhausted by war, Enga were calling on local village courts,

sanctioned but not steered by the state, to solve conflicts peacefully through customary institutions. The number of deaths and the duration of wars declined steadily; by 2010 and 2011, few wars were fought in Enga province. Social technology from generations past was adapted to contain the impact of adopted modern technology.

In a recent, important work, Pinker (5) has chronicled the big picture of the decline in violence over human history brought about by developments in our cultural institutions and material milieu that differentially engaged “the demons and angels of our nature.” Violence declines steadily from the anarchy of simple societies as the state achieves a monopoly on the use of force to serve justice. Historians will have their say on the recorded past; however, there is little quantitative evidence on levels of violence for small-scale societies beyond ethnographic snapshots and prehistoric graveyards (6, 7). Certainly, prestate societies have institutions to tame violence (8) ranging from nurturing socialization (9–11) to dispersal (12), duels (13), and compensation (14, 15). Could it be that these did not suffice when small-scale societies evolved into

larger polities, causing a descent into a trough of atrocity during early state formation? After all, our “better angels” (16, 17) must have come about in part through social selection (18, 19), to wit, being penalized or favored by others for partnerships, positions, and privilege via institutional frameworks.

The Enga case provides a rare opportunity to examine the construction and adaptation of institutions to promote peace as well as quantitative measures of their effectiveness. It allows us to address the question of how institutions in small-scale societies counter desires for revenge and tame demons. What are their underlying principles and values? How might they have contributed to shaping our behavioral repertoire to make life in state societies possible? Why are the Enga, who resisted pacification by colonial powers, now eschewing more effective weapons and turning toward peace? Will they be able to do so in the future as they become further integrated into an emerging nation and global economy?

The Enga are highland horticulturalists of PNG who depend on the sweet potato to feed large human and pig populations (20, 21). Men compete passionately in politics, warfare, and the ceremonial distribution of wealth. Women devote themselves to family and subsistence agriculture; when war breaks out, they retreat to their natal clans with their children and pigs. Exogamous clans of 350 to 1000 are the units for most political action including war.

The Enga regarded warfare as a last resort for solving problems; it served to avenge insult or injury, to display strength, and to reestablish balance of power (22). There is little indication that Enga fought largely over land (23). After the sweet potato arrived some 350 years ago (24), there were major population shifts followed by raging wars that altered the social landscape. Subsequently, ceremonial exchange systems called *Tee* arose to reconfigure networks of trade and exchange disrupted by warfare; new religious cults broke cycles of violence (25, 26).

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Around 1850, compensation, formerly paid to allies, was expanded to make peace with the enemy. Clans could and did fight, resolve conflicts, and stay put, reducing migration after warfare (3). Compensation cost precious pigs and valuables, providing a strong incentive to establish rules to contain warfare. When well-organized by skilled leaders, warfare and peace-making had economic motivations: to reestablish ties, balance of power, and respect between clans so that wealth for the many forms of ceremonial exchange called *Tee* could continue to flow freely (25, 26). Warfare and exchange thus became entwined.

The Australian Colonial Administration's pacification of PNG societies (15, 27) reached Enga in the 1950s and 1960s, making way for missions and new economic opportunities. Many traditions waned, including bachelors' cults, ancestral cults, and separate men's and women's houses. The last great *Tee* cycle of enchainment exchange was held in 1978 to 1979 (25), ending one close link between warfare and exchange. Guns in the hands of the colonial administration brought peace; Enga turned to "fighting in court" (28). A few years before independence, warfare resurged as social inequalities grew. The western justice system had failed to restore relations by mediation and material compensation and ignored local politics and future relationships (28).

In 1974, the Village Court Act came into effect to serve parochial judicial needs by harnessing existing local potential (22). Village courts were to apply "custom" to achieve substantial justice. Custom was imprecisely defined and changeable; community harmony was prioritized (29). Respected local leaders elected as magistrates found themselves part of the national legal system with little training beyond instruction about the limits of their jurisdiction (29). State support was limited to minimum wages, clerks to keep records, provision of uniforms, a provincial office, and sporadic police support. In 1982, a branch of the village courts, Operation Mekim Save (OMS), was established to settle tribal wars; initially OMS favored judicial arbitration by village court magistrates backed by punitive police power (28).

Enga see village courts as their own institutions because they choose their own magistrates and because decisions are not steered, supervised, or enforced by the state. Village courts often dodge the limits of jurisdiction by hearing serious crimes and mediating until the opposing parties reach a settlement. Enga communities have taken the initiative to create a lower echelon of courts that fall outside of the national justice system: *wari* (worry) courts. One or two community leaders mediate disputes on the spot in *wari* courts (22); if mediation fails, complaints are taken to village courts.

Throughout the 1980s, OMS left much to be desired with slow response and often-brutal police raids favoring one side (29, 30). Discontent festered in a weak state (31). In 1990, guns, formerly rejected in warfare to avoid carnage (21), were adopted by some hot-headed youths to the

dismay of the majority, igniting an arms race (22). High-powered rifles were obtained from businessmen and politicians or "acquired" via the police and army (32). The key triggering incidents of recent wars remained similar to those of the past: murder, revenge, theft, and land disputes (table S1).

Guns altered the leadership, tactics, and outcomes of war. Ambushes and raids, executed outside the control of elder clan leaders and OMS replaced pitched battles. Warring clans employed mercenaries skilled in the use of semiautomatic weapons, called "Rambos" or "hiremen," who fought largely for brotherhood and fame and to "carry out justice where government had failed" (supplementary text). In the late 1990s, warriors formed "teams" of peers led by Rambos that cross-cut clan boundaries (3), similar to some inner-city gangs (33). Men who had never cooperated before were bonded through oaths of loyalty, rituals of confession, traditional fight magic, and victory celebrations. Over time, teams colonized the problems of surrounding clans to fight out their own vendettas, accelerating warfare (3). The last vestige of state control over warfare, police support for preventative orders, was withdrawn in most cases because police were no match for warriors with similar arms and superior experience, knowledge of terrain, language, and people (34).

As guns spread, the number of wars in Enga increased rapidly (Table 1); the number of deaths per war rose from a mean of 3.7 (21) in precolonial times to 17.8 between 1991 and 2000. Wars can last from weeks to several years. When both sides are exhausted, elder leaders with economic means and political skills take over peace

negotiations. Unable to hold and use land vacated, winners request a moderate payment from the losers to recognize defeat and let them resettle. Formerly, wars reestablished balance of power (23, 30) so that exchange could flow; recent wars leave imbalance, widespread destruction, and thousands of refugees (3). Refugees are adequately provided for by hosting clans but nonetheless incur deep emotional scars. Public servants fear venturing into rural areas to initiate development projects; in cities, men from enemy clans are targets for payback murders.

Starting around 2005, Enga began to resist entrapment in runaway violence. Attitudes changed. This did not happen over night, for there were two opposing forces at work. Rambos and teams aggressively sought to colonize the problems of others taking advantage of the frenzy around the 2007 elections and the 2009 tension-fraught bi-election in district A. The number of wars increased from 94 in 2004 to 2006 to 149 in 2007 to 2009 (Table 2). Simultaneously war-weary citizens began to withdraw support for warriors and to turn to OMS to put an end to armed conflicts soon after they broke out. Consequently number of deaths before wars were ended decreased (Table 1): from 1991 to 1995, 23% of wars were ended after one to five deaths, whereas from 2006 to 2010 74% of wars were ended after one to five deaths. By 2010 and 2011, citizens prevailed, and war was widely rejected as a solution to solve problems (Table 2).

Why the turn toward peace? Three factors prevailed: exhaustion and economic hardship, church influence, and an effective OMS. Tradi-

Table 1. Number of wars, deaths per war, and deaths before war ended by five year interval from 1991 to 2010.

Deaths before war ended	1991–1995		1996–2000		2001–2005		2006–2010	
	n wars	% wars	n wars	% wars	n wars	% wars	n wars	% wars
1–5	10	23%	34	40%	83	58%	168	74%
6–10	17	39%	24	28%	25	17%	32	14%
11–50	13	29%	20	23%	33	23%	25	11%
51–300	4	9%	8	9%	3	2%	1	1%
Total	44	100%	86	100%	144	100%	226	100%
Total number of deaths	836		1475		1363		1142	
Average number of deaths per war	19		17		10		5	

Table 2. Number of wars and mean number of deaths per war from 2001 to 2011. The Porgera district has been omitted. District C had no wars in 2011.

	2001–2003		2004–2006		2007–2009		2010–2011	
	Total wars	Average no. deaths	Total wars	Average no. deaths	Total wars	Average no. deaths	Total wars	Average no. deaths
District A	13	13	27	5	59	5	3	6.7
District B	31	6	17	6	26	7.3	7	6.3
District C	18	10	19	6	18	3.6	13	5
District D	21	26	17	7	39	2.8	2	2
District E	17	7	14	2	7	2	3	3
Total	100	12	94	5	149	4.5	28	5.1

tionally, Enga fought to restore balance so that exchange could flow. Most Enga who have experienced recent wars have incurred unprecedented losses with no gains for exchange. Exhaustion and imbalance prevail. Even youths from the initial cohort of modern warriors have matured into family men with more assets to lose. Lastly, the Enga provincial government has prioritized education, giving youths new visions of prosperity for the future. Without social and material rewards, the enthusiasm of warriors wanes (supplementary text).

Church influence in promoting peace has been strong since the 1950s, with a phase of proactive peace initiatives in the 1980s and early 1990s (35, 36) that floundered as warfare with modern weapons intensified. Churches provide a legitimate institution, ideology, and fellowship for those who eschew warfare, even though the Enga norm, “Do unto others as they do unto you,” persists together with new norms such as “Money is life.” The charisma of locally led religious celebrations, with their colorful regalia, music, and festivities, disrupts cycles of vengeance and prepares the emotional landscape for peace. Nonetheless, no Rambo interviewed felt that Christianity had convinced him to stop fighting nor would do so if need arose. Women’s peace movements have not been as prominent as elsewhere in the PNG highlands (37, 38).

Lastly, OMS is key for peace-making because as third parties they have the ability and authority to mediate emotional, social, and material solutions to intergroup conflicts. Armed with cell phones and better transport to reach trouble spots in time, OMS has become more effective in the past years. In a sense, OMS gained when police backing dwindled; people had to turn to OMS to contain wars knowing that no outside force would intervene. OMS magistrates sidestep their limits of jurisdiction by mediating compensation for serious crimes. Legal authorities do not object because the state is not autonomous from local social forces (29, 39); if peace can be achieved, development will succeed, and that success, in turn, will lead to a more stable peace.

What makes OMS so effective? Legitimization by the state gives authority; lack of supervision allows OMS magistrates to work under few constraints. OMS magistrates say that they “speak the language, know the hearts of people, and do not just read from some law book.”

Magistrates weather the rain, the sun, and the occasional raucous drunk or pig while people air complaints in public and the crowd responds. They organize evidence into a settlement that is sensitive to current conditions, emotions, and values. OMS magistrates receive the privileges of high standing in the community for their hard work, including protection from violence.

Table 3 compares outcomes for serious criminal cases that were brought to the district court with those heard by the OMS village court in the provincial capitol of Wabag (22). Ninety-eight percent of OMS cases reached or approached resolution via compensation as a means of restorative justice. Only 10% of district court cases concluded with a jail sentence; the rest were struck out when witnesses did not appear or the case was withdrawn by the plaintiff and taken to OMS. Jail sentences do not satisfy as material reparations do.

What are the principles that quell emotions and resolve serious disputes? For 45 serious cases, magistrates gave one or more of the following justifications (22): 16 cases, lack of respect for the emotions of the complainant; 13 cases, breach of respect for property; 5 cases, untruths; 13 cases, failing to meet traditional obligations; and 12 cases, failure to exercise restraint under rage or intoxication. These norms and values are expressed in precontact maxims that guide village court decisions today (supplementary text). Kinship ties were called on to settle matters peacefully in 33% of the cases. In 26% of the cases, parties were encouraged to go home, “drink Coca-Cola,” and first try to resolve the dispute by themselves (40). Christian values or human rights principles were not explicitly cited to justify decisions; magistrates did cite women’s rights, a prominent theme in the current media.

In paying compensation, the offender accepts liability, acknowledges the pain of loss, and compensates materially. Kin outside the clan assist donor clans in assembling wealth; politicians and businessmen donate large sums to increase their popularity. When done well, compensation changes hearts so that people let go and proceed with productive relations; when poorly done, hostilities resume. The cost of paying compensation is mitigated by anticipated social and political gains for those who honor financial responsibilities, show respect, and refrain from

violent retribution. Those who cost the clan repeated compensation or fail to contribute are marginalized as “rubbish men” (supplementary text). Peace-making provides the framework for social selection of behavioral predispositions that are the building blocks for the modern state (41).

This short exposition excludes many important aspects of war and peace-making to be explored in future publications to provide deeper understanding. These include the role of history, cultural context, the state, religion, leadership, oratory, war magic, and above all, insights that can be gained from comparison with other PNG societies (15). Nonetheless, it is possible to propose some answers to the opening questions. Local Enga institutions were indeed effective in containing violence and restoring order in two tumultuous periods. The first was precolonial, when peace-making was devised to allow clans to fight, pay reparations, stay put, and renew ties of cooperation. The reduction of subsequent postwar migrations attests to its effectiveness (3, 25). The second was postcolonial, when the state’s sanctioning of indigenous peace-making together with the influences of Christianity yielded similar success. Death rates in war per 100,000 per annum were 81 in 1990 when guns were adopted, 91 in 2000 when wars with modern weapons raged, and 19 in 2011 when Enga sought peace (22). The inclusion of nonwar homicides per year from 2006 to 2011 from OMS records yields 103 deaths per 100,000 for 1990, 110 for 2000, and 32 for 2011. These figures are lower than Pinker’s (5) estimate of an average of 524 deaths per 100,000 and Keeley’s (6) of 500, underscoring the variation in nature and effectiveness of peace institutions in tribal societies.

New institutions build on former rules, norms, and values; history matters (42, 43). The Enga are fortunate to have the legacy of compensation to reduce violence that could be integrated into the legal system of a democracy (15). However, Enga compensation is based on relationships of a small-scale society and has drawbacks as scale increases. In a world of drugs, alcohol, cell phone affairs, and high mobility, responsible citizens must cover for the crimes of the irresponsible. Compensation is expensive: an average of 26 pigs and K1239 (~U.S. \$500) per death since 1991 (3). Formerly, clan members contributed to repair the wrongs of “brothers,” moved by life-long co-residence, emotional bonds, and the need for a strong, protective corporate group. In a society of growing scale and mobility, clan members are often brothers by name alone. Strapped by monetary needs for education and modern amenities, responsibility is narrowing to extended family members and politicians seeking to gain popularity through contributions. Many Enga question if and how compensation will continue to be effective in the future outside of internal village disputes or major threats.

Recent trends suggest that interclan warfare as a response to insult or injury may soon be a practice of the past; people have experienced

Table 3. Outcomes of cases heard in district and village courts in 2011. Cases for both courts include a similar proportion of charges concerning murder, rape, assault and property (22).

Decision	District court		OMS village court	
	<i>n</i>	%	<i>n</i>	%
Fine or jail sentence	4	10%	1	2%
Struck out	18	43%	0	0%
Withdrawn	20	47%	0	0%
Compensation order	0	0%	17	40%
Compensation settlement mediated	0	0%	9	29%
Mediated agreement reached to settle out of court	0	0%	12	29%
Total	42	100%	39	100%

modern war and recognized its futility. In the face of rapid change, the future is hard to predict. If the large sums of income from natural resources and foreign aid are applied to development during this time of relative peace, the people of Enga will have more to lose and may continue to turn away from war. However, there is a burgeoning population of discontented youths, and politics are heating up as multinationals invest billions to extract the resources of an otherwise poorly developed PNG. Perks for those in power are many. In some areas, gangs are already serving the interests of politicians (30); a new round of warfare could erupt over the politics of tangible resources. If this happens, local institutions founded on principles of kinship, respect, and restorative justice will not suffice, and the Enga may find themselves in another cycle of violence as the scale of their society increases. This was true for many societies in the past (5, 44) and is still the case for societies in similar transitions today.

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Supplementary Materials

www.sciencemag.org/cgi/content/full/337/6102/1651/DC1
Materials and Methods
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Adaptive Sleep Loss in Polygynous Pectoral Sandpipers

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The functions of sleep remain elusive. Extensive evidence suggests that sleep performs restorative processes that sustain waking brain performance. An alternative view proposes that sleep simply enforces adaptive inactivity to conserve energy when activity is unproductive. Under this hypothesis, animals may evolve the ability to dispense with sleep when ecological demands favor wakefulness. Here, we show that male pectoral sandpipers (*Calidris melanotos*), a polygynous Arctic breeding shorebird, are able to maintain high neurobehavioral performance despite greatly reducing their time spent sleeping during a 3-week period of intense male-male competition for access to fertile females. Males that slept the least sired the most offspring. Our results challenge the view that decreased performance is an inescapable outcome of sleep loss.

Sleep is a prominent yet enigmatic part of animal life (1). In humans, and other mammals, sleep restriction and fragmentation

diminish waking neurobehavioral performance (such as attention, motivation, sensory-motor processing, and memory), often with adverse con-

sequences for the individual and society (2–5). Sleep loss even impairs the performance of innate behavioral displays (6). These findings suggest that sleep performs essential restorative processes that sustain adaptive brain performance (1). An alternative view posits that sleep may be simply a state of adaptive inactivity that conserves energy when activity is not beneficial (7). This adaptive inactivity hypothesis proposes that the marked

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