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The Indo-European Homeland from Linguistic and Archaeological Perspectives

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Abstract

Archaeological evidence and linguistic evidence converge in support of an origin of Indo-European languages on the Pontic-Caspian steppes around 4,000 years BCE. The evidence is so strong that arguments in support of other hypotheses should be reexamined.

1. INTRODUCTION

For two centuries, the identification of the "homeland" of the Indo-European (IE) languages and the details of the family's diversification and expansion have remained unsolved problems. One reason is the difficulty of linking linguistic evidence with archaeological evidence in the absence of archaeological finds of writing; another is that the problem's solution requires an interdisciplinary effort in an age of increasing specialization. We were trained in European archaeology (Anthony) and IE historical linguistics (Ringe), and we have both had to educate ourselves in related disciplines in order to pursue our work. However, collaboration between specialists eventually becomes necessary. It is not just a matter of avoiding elementary errors; in a case such as the IE homeland problem, a broadly satisfying solution must be global, applying methods from all relevant disciplines to act as checks on solutions that satisfy only a selected range of data. We believe that such an integrated solution is finally attainable.

Readers might reasonably ask whether a reconstructed prehistoric language such as Proto-Indo-European (PIE) is "real enough" to be linked to the archaeological record. Most historical linguists would say yes—with qualifications.

It is true that we can recover only part of any prehistoric language: a larger or smaller portion of its lexicon and a larger or smaller fragment of its grammar, depending on how much inherited material is preserved by the actually attested daughter languages. Some details may remain unrecoverable, and our reconstructions are sometimes temporally "out of focus," including slightly older and slightly less old details in the same reconstruction.

However, each protolanguage that we reconstruct must be an approximation of some real language spoken by a real community, for two different reasons. One basis of our confidence is the nature of the "comparative method" by which we reconstruct protolanguages: It exploits the observed regularity of sound change by means of simple mathematics, yielding categorical results that can be replicated by other researchers and checked both for internal consistency and against information from other sources. (The classic exposition is Hoenigswald 1960.) The other reason for our confidence is the Uniformitarian Principle (UP), familiar from other historical sciences such as paleontology. As usually applied in linguistics, the UP holds that unless external conditions can be shown to have changed in some way that can be proved to have an impact on human language, we must assume that the structures of past languages, the way they were acquired by children, the changes they underwent, the distribution of linguistic variation in their speech communities, and so on fell within the same ranges as those of languages that can still be observed and studied. Thus, the UP is usually invoked to flesh out the impoverished language data that survive from the past and our necessarily limited reconstructions of protolanguages. But it can also be used to make a different argument: If straightforward mathematical reconstruction yields a grammar fragment that falls within the observed range for modern native languages, we can reasonably infer that it corresponds to some real language of the past spoken by some real speech community, because experience shows that living languages do not exist apart from native speech communities. Because the grammar fragment, phonological system, and lexemes that are reconstructible for PIE reveal a coherent, unremarkable human language, the UP suggests that the PIE-speaking community might, given the correct integrative methods, be correlated with the reality recovered by archaeology.

These general arguments acquire much more force from the details of (some) reconstructed protolanguages. The more complexly integrated the grammar fragment of a protolanguage is, the more implausible the suggestion that it is some kind of artifact of our methods; the more internally coherent the grammar fragment is, the smaller the temporal window that it must represent, given that changes over time replace details of grammar with different alternatives. We who work on PIE

are lucky: We can reconstruct a complex and intricate grammar in which the alternatives that (probably) resulted from development over time are relatively few and limited.

One fact especially makes the connection of prehistoric languages with prehistoric material cultures worth pursuing. Some of the words that we can reconstruct for protolanguages have very specific meanings, and a few refer to technological developments that can be dated independently and correlated with the archaeological record. That is crucial because, in the absence of writing, archaeology yields no direct evidence for the language spoken by the people who made a particular group of artifacts. Under most circumstances, only the indirect correlation of datable artifacts and the words that refer to them can connect linguistic prehistory with archaeology. In this respect, too, PIE is a fortunate case (see below).

2. PROTO-INDO-EUROPEAN SUBGROUPING AND ITS IMPLICATIONS

However, one complication has major consequences for the correlation of reconstructed PIE with the archaeological record. Ten groups of IE languages, none closely related to the others, are well attested. Determining the order in which they diverged from each other, called subgrouping, has proved surprisingly difficult (e.g., Ringe et al. 2002), but a consensus is emerging. It seems clear that the ancestor of the Anatolian subgroup (which includes Hittite) separated from the other dialects of PIE first, so from a cladistic point of view Anatolian is half the IE family (e.g., Jasanoff 2003). Within the non-Anatolian half, it appears that the ancestor of the Tocharian subgroup (whose attested languages were spoken in Xinjiang, today in western China, until approximately the tenth century CE) separated from the other dialects before the latter had diverged much (e.g., Winter 1998, Ringe 2000). It follows that an item inherited by two or more of the daughter subgroups can be reconstructed for "early" PIE only if it is attested in at least one Anatolian language and at least one non-Anatolian language, and such an item can be reconstructed for the ancestor of the non-Anatolian subgroups only if it is attested in one or both of the Tocharian languages and in some other IE language. This observation is relevant below.

For want of better terms, "early" PIE is used here for the last common ancestor of the Anatolian and non-Anatolian IE branches; "post-Anatolian" PIE is used for the last common ancestor of the non-Anatolian PIE languages, including Tocharian. Because it seems clear that there was still a more or less unified group of PIE dialects after Anatolian and Tocharian had split off, "late" PIE is used for the common ancestor of all other IE branches. Within this late group, Italic and Celtic are generally thought to have split off early (Schmidt 1991, Ringe et al. 2002).

3. THE WHEEL AND THE DATE OF PROTO-INDO-EUROPEAN

The late PIE word for 'axle' is unproblematically reconstructible as *$h_2$ék^{h}s- (e.g., Mallory & Adams 2006, p. 248). All its descendants, called cognates, retained the meaning 'axle' in Indo-Iranian, Balto-Slavic, Germanic, Celtic, Italic, and Greek. Some cognates are attested very early (e.g., in Latin, Ancient Greek, and Sanskrit). This is a protolexeme with an established meaning (as defined by Clackson 2007, pp. 186–89). It is difficult to explain the shared meaning except by inheritance from late PIE; so also the shared sequence of sounds, which can be shown to have evolved into the attested cognates from an ancestral form *$h_2$ék^{h}s- by regular rules of sound change for each language. Axles cannot exist apart from wheeled vehicles, so a word meaning 'axle' in late PIE is evidence that wheeled vehicles existed during the period when late PIE was spoken. The invention of the wheel-and-axle principle, which first made wagons and carts possible, is solidly dated by radiocarbon after 4000–3500 BCE, a very well studied external fact (Bakker et al. 1999,

Fansa & Burmeister 2004, Anthony 2007). This external fact ties late PIE to a real-world date after wheeled vehicles were invented, that is, after 4000–3500 BCE.

*$h_2$ék*s- need not bear the weight of this argument alone. The reconstructible PIE wheeled-vehicle vocabulary contains at least five words referring to parts of wheeled vehicles—a semantic field of five lexemes, all with established meanings. There are two PIE words meaning 'wheel,' one for 'axle,' one for 'thill' (i.e., 'harness-pole'), and a verb 'to transport in a vehicle' (**Table 1**) (**Figure 1**). One 'wheel' word is solidly attested in Tocharian, so wheeled vehicles were familiar to post-Anatolian PIE speakers before the ancestor of Tocharian broke away. Other possible PIE roots for wheeled vehicles in Tocharian underwent semantic shifts; for instance, Tocharian B *retke* 'army' could be derived from **Hrot-ó-s* 'wheel' through *'chariotry' (Mallory & Adams 2006, p. 248), but the semantic shift obscures the derivation. Anatolian shares only 'thill,' which might be used with a plow or sledge, so Anatolian might have separated before wheels were invented; that is consistent with other evidence for archaism in Anatolian (e.g., Fortson 2010, pp. 171–72).

The PIE status of a vocabulary for wheeled vehicles is critically important in resolving the long argument over where and when PIE was spoken. If post-Anatolian PIE contained a vocabulary for wheeled vehicles and their parts, then the parent of the non-Anatolian branches remained a single language after wheeled vehicles were invented, or after 4000–3500 BCE. A homeland for PIE in the western Eurasian steppes of what is today Ukraine and southern Russia has a long history of support (Schrader 1890; Gimbutas 1970, 1977; Mallory 1989; Kortlandt 1990; Anthony 2007), initially because the reconstructed PIE vocabulary seemed to be a vocabulary of pastoralists (wool, horses, livestock, dairy foods) rather than farmers; and later because horses, domesticated in the steppes before 3500 BCE (Outram et al. 2009, Anthony & Brown 2011), played a prominent role in IE ritual practices in almost every IE branch, and horses are native to and were frequently exploited by people in the Eurasian steppes. The steppe theory of PIE origins is consistent with a date for post-Anatolian PIE after 4000–3500 BCE because the adoption of wheeled vehicles transformed steppe economies after this date, encouraging the rise and spread of a new form of highly mobile pastoralism that is thought to be associated with the spread of the IE languages.

Neolithic Anatolia, 7000–6000 BCE, is today the principal alternative to the steppe theory for the homeland of PIE. Gamkrelidze & Ivanov (1995) supported a homeland in eastern Anatolia and a dispersal after 4000 BCE, but their interpretation was based on a particular theory of IE phonology, the glottalic hypothesis, that is disputed (Diakonoff 1988); and it lacked clear support from archaeology, which revealed no clear cultural shifts or migrations that issued out of eastern Anatolia at that time. A new and different Anatolian hypothesis was proposed by Renfrew (1987, 2002a), who linked the spread and diversification of the IE languages to the archaeologically attested expansion of agricultural economies out of central and western Anatolia into Greece and the rest of Europe beginning about 6500 BCE. Renfrew's PIE homeland would have been in Anatolia at 7000–6500 BCE, and diversification of the daughter branches would have started with the migration of the first farmers from Anatolia to Greece around 6500 BCE, and continued with migrations to the western Mediterranean around 5800 BCE (with what is known to archaeologists as the Cardial Neolithic), to southeastern Europe at about 6000 BCE (or Old Europe), and to northern Europe about 5500 BCE (with the Linear Pottery or LBK culture). The Anatolian-farming hypothesis was strengthened when Bouckaert et al. (2012), refining methods first developed by Gray & Atkinson (2003), proposed a cladistic model of PIE origins with a root in Neolithic Anatolia at about 6500 BCE.

The Anatolian-farming hypothesis requires the diversification of PIE to have started almost three millennia before wheels were invented, so it does not appear to be consistent with the presence of shared, solidly attested cognates for words referring to wheeled vehicles in all

Table 1 Indo-European wheeled-vehicle vocabulary[a]

Indo-European language branches	*k^{w}é-k^{w}l-o-s 'wheel,' collective *k^{w}e-k^{w}l-é-h_2	*Hrot-ó-s 'wheel,' collective *Hrót-e-h_2	*$h_{2/3}$éyH-os 'thill,' collective *$h_{2/3}$iH-s-éh_2	*h_2eḱs- 'axle'	*wégʰ-e-ti '(s)he transports (it) in a vehicle'
Anatolian	—	—	Hittite *hissas*	—	—
Tocharian	B *kokale*, A *kukäl*, 'chariot'	—	—	—	Derivative B *yakne*, A *wkäṃ* 'way'
Celtic	—	Old Irish *roth*, Welsh *rhod*	—	Middle Welsh *echel*	Old Irish derivative *fén* 'wagon'
Italic	—	Latin *rota*	—	Latin *axis*	Latin *vehit*
Greek	κύκλος /kúklos/, pl. κύκλα /kúkla/	—	—	ἄξων /áksɔ:n/	Pamphylian imperative 3SG ϝεχετο /wekʰeto:/
Germanic	Old English *hwēol*, Old Norse *hvél*	Old High German *rad*, Old Frisian *reth*	—	Old English *eax*, Old High German *ahsa*, Old Norse *ǫxull*	Inf. Old English, Old High German *wegan*, Old Norse *vega*, all 'move'
Balto-Slavic	—	Lithuanian *rãtas*	Slovene *ojȇ*, pl. *ojêsa*	Lithuanian *ašìs*, Old Church Slavonic *osĭ*	Lithuanian *vẽža*, Old Church Slavonic *vezetŭ*
Indo-Iranian	Sanskrit *cakrám*, Avestan *caxrō*	Sanskrit derivative *ráthas* 'chariot'	Sanskrit *īṣā́*	Sanskrit *ákṣas*	Sanskrit *váhati*, Avestan *vazaiti*

[a]Empty cells indicate that a cognate is not attested in the subfamily in question.

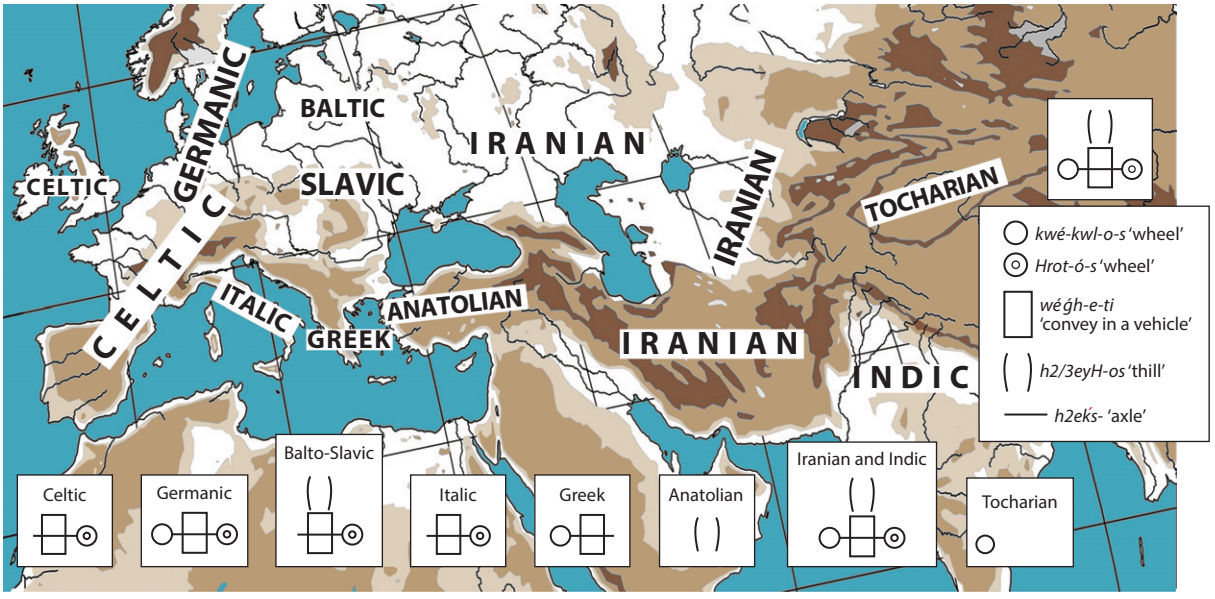


Figure 1

Wheel terms found in Indo-European language branches. Modified with permission from Anthony (1995).

post-Anatolian PIE branches. Gray & Atkinson's (2005) online comments about this chronological problem suggested that because most of the wheeled-vehicle vocabulary is based on IE roots—and thus was not borrowed from a non-IE language—the separate daughter languages could have independently chosen the same PIE roots to designate wheels and other vehicle parts after they were invented; alternatively, the words for wheeled vehicles could have been widely borrowed after 3500 BCE and then "naturalized" within each daughter branch so that linguists could not detect the borrowing.

Let us examine what these explanations require. The first suggestion, that the separate daughters chose the same roots after differentiation had occurred, requires the dispersed daughter languages to have independently selected the same five IE roots to refer to the same five newly introduced wagon parts. Gray & Atkinson (2005) suggested that it was a "natural" choice to select the verbal root *k^wel-, 'turn' or 'revolve,' as the root for *$k^wék^wlos$, 'wheel, thing that turns' (for example); but there are at least four different verb roots that are reconstructible for PIE with the meaning 'turn' or 'revolve' (*k^wel-, *h_2werg-, *$wert$-, *wel-),[1] so the motivation for the specific sharing of a 'wheel' word based on *k^wel- was not natural but cultural. Moreover, the two words for 'wheel,' at least, are analyzable derivatives of verb roots; so to make this explanation work, they would have to have survived with little enough phonological change to make identical derivations feasible, and the old derivational patterns would have to have been used—not once, but in each daughter branch in which the words survive—some three millennia after the languages had split, when wheeled vehicles and axles finally were invented. In addition, those constraints must have affected only the words that would later be used for the wheel vocabulary: Other innovations that

[1]Note that words for 'wheel' were formed from *h_2werg- in Hittite and (independently) Tocharian, but because they are not shared by other branches of the family they do not establish that wheels were known before the separation of Anatolian from the other branches.

occurred after the IE dispersal, things like *spoke*, *iron*, *tin*, *chicken*, and *glass*, were named differently in the dispersed daughter languages. One of the basic postulates of linguistics is that the relation between word and thing is cultural and arbitrary, as the diverse lexemes for the same referent show in this short list of things invented after the IE dispersal. But Gray & Atkinson's (2005) solution implies that we should accept multiple parallel choices of the same roots and even the same derivatives for utterly new things in a continent-wide coincidence—but only for words that would later be employed for wheels and wagons.

The scenario just sketched is already obviously improbable; the formation of the word **k^{w}ék^{w}los* 'wheel' makes it more improbable still. Like many PIE nouns, this one was derived from a verb root by adding a suffix and altering the shape of the root. In this noun, the suffix is the thematic vowel **-e-~*-o-* (**-e-* in a few forms but **-o-* in most), which is immediately followed by the case-and-number endings. Also, the root **k^{w}el-* has been reduplicated—that is, its initial consonant has been doubled and the copy is followed by the vowel **e*. Finally, the root is in the "zero grade"—that is, its internal vowel has been dropped. Thus, the structure of the citation form given above, **k^{w}é-k^{w}l-o-s*, is (reduplication + zero-grade root + thematic vowel + nominative singular ending). That specific formation was very unusual for nouns derived from verbs in the PIE period. For instance, in the list of reduplicated nouns in the older IE languages in Brugmann (1906, p. 129), most occur in only one daughter and are obviously post-PIE innovations; most of the few that show resemblances from daughter to daughter are not formally identical and cannot be reconstructed for PIE with any confidence. The only comparable noun in the list is **b^{h}e-b^{h}r-ú-s* 'beaver'; but (*a*) the suffix vowel **-ú-* is not the thematic vowel; (*b*) the root **b^{h}er-* is not a verb root, but an adjective root meaning 'brown'; and (*c*) the status of that root is somewhat shaky—it never seems to occur without unusual suffixation or modification. In short, the formation of **k^{w}ék^{w}los* is virtually unique in PIE. Fortson (2010, p. 130) suggests that **k^{w}ék^{w}los* was "an expressive neologism for a new gadget," which is a reasonable speculation. The proposal that a noun was formed from a verb in this highly unusual manner numerous times, independently, is practically impossible.

The same argument does not apply to the other PIE lexeme for 'wheel,' **Hrotós*, so decisively; it is an agent noun meaning 'runner,' which might have been coined more than once. But the first type of argument adduced above does apply: There were at least five PIE roots meaning 'run' (**Hret-*, **dreh$_2$-*, **d^{h}reg^{h}-*, **d^{h}ew-*, **tek^{w}-*), yet only this one appears in many daughters as the basis for a shared word meaning 'wheel.'

The second suggestion of Gray & Atkinson (2005)—that the wheel words might have been borrowed across Europe and Asia after wheels were invented, or after 3500 BCE, but that linguists are unable to recognize them as borrowed because the borrowing happened so long ago—takes no account of the basic facts of language change. Each language undergoes idiosyncratic regular changes in its sounds in each generation, and the regular sound changes peculiar to each language are discoverable by comparison of related languages. Words are detectable as inheritances or borrowings according to which regular sound changes they have undergone and which (if any) they have failed to undergo. Although it is occasionally difficult for the comparative method to detect ancient borrowings between IE languages, many have in fact been detected. For a few centuries, two related languages in contact—a "lending" language and a "borrowing" language—might fail to undergo any diagnostic sound changes that would make a few loanwords recognizable; in that case, those loanwords could be mistaken for a common inheritance. But that all the daughters of PIE could have failed for more than two millennia to undergo any sound changes that would make any of five quite different words undetectable as borrowings is a statistical absurdity.

Moreover, the borrowing scenario, even if it were statistically respectable, raises more specific questions that have to be answered. Which 3,000-year-old IE daughter branch created the wheeled-vehicle vocabulary? If it was, say, Greek or Celtic, why can't we see any trace of Greek or Celtic phonology in the vocabulary in any of the other IE branches? Presumably in Proto-Greek the root would have been pronounced not as PIE *$k^wék^wlos$ but as something closer to Greek /kúklos/. But Proto-Germanic *h^weh^wlaz, the ancestor of Old English *hwēol*, cannot be descended from /kúklos/ (or *$k^wók^wlos$, or any other likely intermediate preform of the Greek word).

In sum, the date of the Neolithic agricultural dispersal is an insuperable obstacle to accepting it as the vector for the differentiation of PIE. Neither Anatolian nor Greek nor Linear Pottery Neolithic farmers had wheeled vehicles; the speakers of post-Anatolian PIE did. Another indication that early PIE, the ancestor of both Anatolian and later PIE, cannot have existed so early is that the attested Anatolian and non-Anatolian IE languages are similar enough to make the reconstruction of PIE unproblematic. The early phase of PIE from which Anatolian was derived might have been spoken before wheels were invented, but if so, that early phase must have been in the millennium immediately before wheels were invented, the fifth millennium BCE, and more comfortably late in that millennium.

The languages of the first farmers who migrated from Anatolia to Greece about 6700–6500 BCE must have belonged to a non-Indo-European family, of which several are known to have been present in Anatolia in antiquity. Hattic and Hurrian, representing two distinct non-IE language families, were dominant in central and eastern Anatolia before the appearance of the IE languages there; Hattic names were recorded in Assyrian documents about 1900–1800 BCE (roughly contemporary with the oldest attested Hittite names), and the attestation of Hurrian begins significantly earlier (Kammenhuber 1969, p. 430; Wilhelm 2004, p. 95). Specialists regard the IE Hittite and Luvian languages as intrusive in their parts of Anatolia and strongly affected by borrowing from non-IE indigenous superstrates and substrates (Diakonoff 1985, 1988; Melchert 2001; Yakubovich 2010). These indications of the primacy of non-IE language families in the core Hittite region have always made Anatolia an awkward location for a PIE homeland dated 4,500 years before the Hittites (also see Mallory 1998, pp. 177–78), particularly in view of the probability that the Anatolian languages belonged to a single IE subfamily in 1900–1800 BCE, no more diverse than twentieth-century Welsh and Irish (Melchert 2001). Where was the linguistic diversity that we would expect to have evolved in Anatolia during the presumed 4,500-year gap between Hittite and Anatolian PIE, the same span of time that separates us from the Late Neolithic Bell Beaker culture?[2]

4. URALIC BORROWINGS AND OTHER GEOGRAPHIC ADVANTAGES OF THE STEPPE PROTO-INDO-EUROPEAN HOMELAND

The strongest geographic indicator of the location where PIE was spoken is the fact that PIE and Proto-Uralic (PU) appear to have been geographic neighbors. They had core vocabulary items that look suspiciously similar ('name,' 'water') and similar-looking pronouns (Ringe 1997; Janhunen 2000, 2001; Koivulehto 2001; Kallio 2001; Salminen 2001; Witzel 2003; Parpola 2012). One kind of relationship between PIE and PU that would account for the apparently shared pronouns, noun endings, and basic vocabulary would be ancestral: The two protolanguages could have shared a very ancient common ancestor, perhaps a broadly related set of intergrading dialects spoken by hunters at the end of the Pleistocene. Nichols (1997) called this kind of very deep, apparently

[2]For further problems with the Anatolian-origin theory, see Lewis & Pereltsvaig (2012), who wrote 43 referenced essays describing flaws found in Bouckaert et al. (2012), including 103 errors in language mapping.

genetic grouping a quasi-stock. Unfortunately, relationships that deep cannot be demonstrated with any confidence even by state-of-the-art statistical assessment (Kessler & Lehtonen 2006).

But regardless of whether "Indo-Uralic" is a valid language family, it is widely accepted among specialists there were cultural links between PIE and PU: At a minimum, PIE words for 'sell' and 'wash' were borrowed into PU, and PIE words for 'price' and 'draw, lead' were borrowed into Proto-Finno-Ugric, a first-order daughter of PU (Koivulehto 2001, pp. 235–38), conceivably through the intermediary of a trade jargon. PU was a language of forest-zone foragers, unfamiliar with domesticated animals except dogs; word borrowing from the richer material culture of PIE is exactly the kind of contact phenomenon expected.

These two kinds of linguistic relationship—a possible common ancestral origin and clear interlanguage borrowings—suggest that the PIE homeland was situated near the homeland of PU. The location of the PU homeland is debated, but the forest zone several hundred kilometers on either side of the Ural Mountains is a consensus place to look. Mallory (2001) suggested that the expansion of the Uralic languages across the northern forest zone might have been stimulated by organizational changes within Ural-region forager societies resulting partly from interaction with more complex, hierarchical PIE and (later) Indo-Iranian pastoral societies at the steppe/forest-steppe ecological border. The relationship between PIE and PU pulls the PIE homeland north toward the forest zone and away from Anatolia.

PIE also exhibits lexical loans to or from Caucasian languages, particularly Proto-Kartvelian (PK), suggesting a location adjoining the Caucasus (Harris 1991, Gamkrelidze & Ivanov 1995, Nichols 1997). The Pontic-Caspian steppes lie directly between the Caucasus and the Uralic forest zone, a plausible location for PIE given these internal clues from shared loans and/or inheritances with neighbors. The additional constraints that PIE speakers were familiar with cattle and sheep herding, dairy foods, woolen textiles, agriculture, wagons, honey and mead, and horses would suggest a location west of the Urals at any time before 2500 BCE, because horse-sheep-and-cattle pastoralism was not practiced east of the Urals before this date. (The Botai culture had no domesticates except horses and dogs.) The most favored wild honey bee habitat, lime and oak forests, also ended east of the southern Urals (Carpelan & Parpola 2001). A homeland in the steppes north of the Caucasus and west of the Urals, bordering the northern forest zone, fits all of these internal criteria. A chronological window between 4500 and 2500 BCE and a geographic location in the Pontic-Caspian steppes are consistent with the evidence in the PIE vocabulary for wheeled vehicles, and with loans from PIE into PU and from PK into PIE or vice versa.

Other considerations lead to the same geographic conclusion. Mallory (1997) suggested five tests that any PIE-homeland solution must pass, and three of his tests include geographical elements. The first is temporal-spatial plausibility, a test that the Anatolian-Neolithic-PIE hypothesis fails to meet temporally because of the wheel vocabulary and spatially because no Anatolian-Neolithic language had any relations with PU.

Mallory's third principle, the relationship principle, requires that the proposed homeland exhibit a set of regional and interregional archaeological–cultural relationships that can be accommodated to the known linguistic relationships between the branches of the IE tree. The Anatolian homeland encounters difficulties here because the Neolithic migration pattern, beginning with the Neolithic colonization of Greece from Anatolia, suggests that Greek should be closely related to Anatolian; the western Mediterranean Neolithic languages (ancestral to Italic and/or Celtic?) should be closely related to Greek; and Greek should be quite distant from Indo-Iranian. None of those suggested relationships is true of the actual relationships between these branches: Greek and Anatolian are not close, Greek is not close to Celtic or Italic, and Greek and Indo-Iranian share so many traits that the term Greco-Aryan (or Indo-Greek) is sometimes used to describe their relationship.

In contrast, the Pontic-Caspian homeland can be accommodated to the known relationships between the IE daughter branches because migrations are archaeologically documented to have occurred out of the Pontic-Caspian steppes into neighboring regions in the sequence and direction (**Figure 2**) that are demanded by the oldest three branchings of the IE tree (Ringe et al. 2002, p. 90). Pre-Anatolian separated to the west, into southeastern Europe, about 4200–4000 BCE with the Suvorovo migration, the first archaeologically visible migration out of the steppes (Bicbaev 2010). Then Pre-Tocharian separated to the east, with the Afanasievo migration into the western Altai Mountains beginning about 3300 BCE, the second archaeologically visible migration out of the Pontic-Caspian steppes, matching Ringe et al.'s and Winter's (1998) expectation that Tocharian was the second branch to separate. After that, a cluster of western European branches separated to the west, into the Danube valley on the south side of the Carpathians with the Yamnaya migration up the Danube about 3100–2800 BCE, and into southern Poland on the northern side of the Carpathians with the expansions of the Usatovo and the Tripolye C2 cultures about 3300–3000 BCE (Ecsedy 1994, Mallory 1998, Klochko & Kośko 2009, Heyd 2011, Anthony 2013). These last separations match the proposal that the ancestors of Italic and Celtic (and perhaps pre-Germanic) could have separated in a rather complex phase of migrations and language spreads. The later spread of Indo-Iranian languages into Central Asia, Iran, and South Asia from the steppes after 2000 BCE is the same in our hypothesis and in Plan B by Renfrew (1987, pp. 197–205), which he prefers (Renfrew 2002b, p. 6). A steppe homeland satisfies the archaeology-and-language relationship test by exhibiting archaeological evidence for migrations in the direction and sequence suggested by linguistic evidence.

Mallory's final test, archaeological plausibility, requires that there should be some materially visible archaeological break or economic shift or prestige-elaboration trajectory that might have been the vector for language shift. This is the strongest advantage of the Anatolian-Neolithic-PIE hypothesis: It is linked to a clear, archaeologically visible, genetically supported (in human, cattle, and wheat DNA; see Deguilloux et al. 2012 and Scheu et al. 2012), and broadly plausible scenario for massive language shift across Europe, a language shift that almost certainly happened but probably disseminated a non-Indo-European family of Neolithic languages.

After the Neolithic, the next large-scale shift in economic and social patterns was not as clearly expressed across all geographic parts of Europe, but it occurred about 3000–2500 BCE—connected with the transition to more mobile societies and more ephemeral domestic settings; coinciding with the introduction of wheeled vehicles, domesticated horses, woolen textiles, copper metallurgy in western Europe, single graves under mounds, the symbolic elevation of drinking cups (and presumably of feasting culture), and weapons in rich single graves; expressed archaeologically in the Yamnaya, Corded Ware, Single-Grave, and Bell Beaker horizons. At the same time, European Neolithic DNA markers declined, and new DNA markers characteristic of steppe populations spread with the Corded Ware culture into central Europe from the east, creating the foundation for modern European genetic structures (Brandt et al. 2013). The innovations in transportation, woolen textiles, metallurgy, settlement mobility, subsistence economy, political structure, and warfare were the central part of what Sherratt (1997) recognized as the Secondary Products and Drinking Revolution, but do not require his theory of an Asian origin. We suggest that the late PIE dialects spread westward during this period of change partly because the steppe societies of the Early Bronze Age had developed, before other European cultures did, a political and ritual adaptation to high mobility, to the maintenance of social life at a distance. Early IE societies developed a set of customs that were adapted to maintaining social relations through reputation and occasional meetings rather than through continuous face-to-face relationships in nucleated population centers. The evidence for this new set of institutions is contained in the PIE vocabulary, to which we return below.

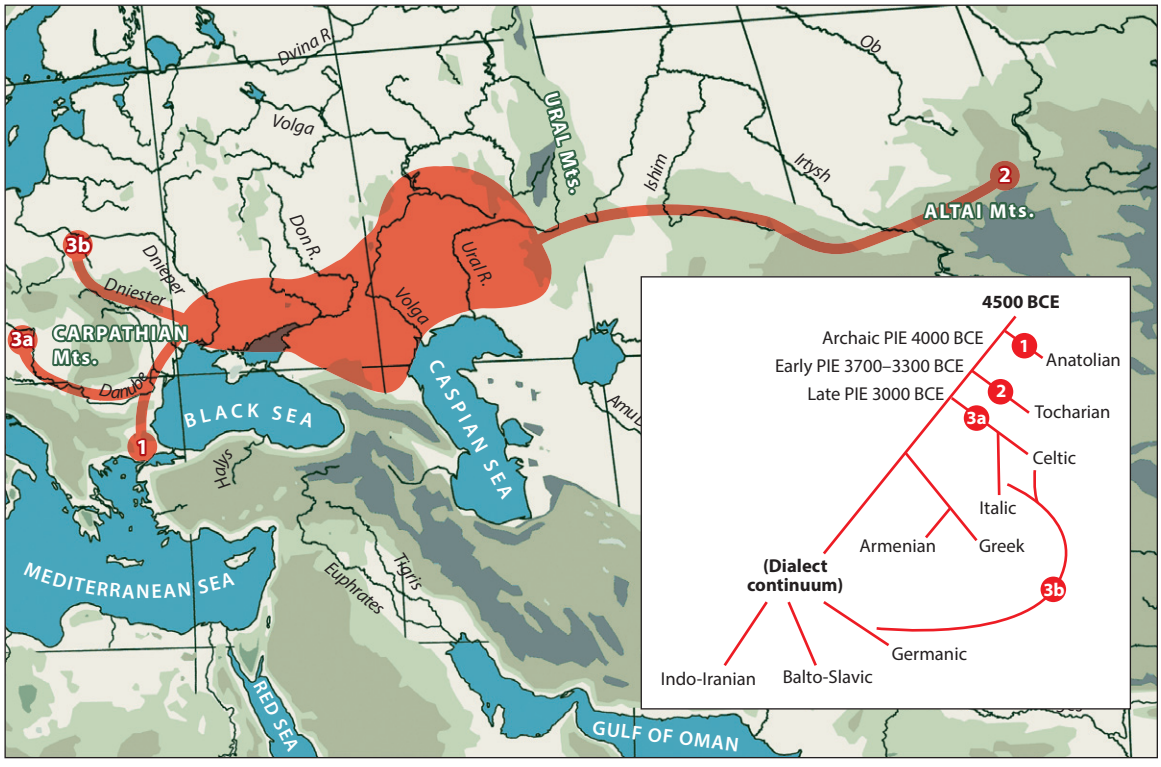


Figure 2

The Proto-Indo-European homeland, with migrations outward at about 4200 BCE (1), 3300 BCE (2), and 3000 BCE (3*a* and 3*b*). A tree diagram (*inset*) shows the pre-Germanic split as unresolved. Modified from Anthony (2013).

5. THE ARCHAEOLOGICAL IMPLICATIONS OF A STEPPE HOMELAND

The steppe-origin and Anatolia-origin hypotheses differ not only in time and place, but also in the complexity of their associated social explanations. Farmers' languages have often spread with their economy, replacing hunter-gatherer languages in a wavelike process driven by the demographic advantages of sedentary life in farming communities (Bellwood & Renfrew 2002, Bellwood 2013). The Anatolian-origin theory explains the success of the IE languages as one example of a global process of language shift that accompanied the expansion of farming. However, as Mallory (1998, p. 180) recognized, the agricultural transition never explained all the language shifts in the Anatolian-origin theory, because in Renfrew's Plan B, the Indo-Iranian languages had to enter Central Asia, Iran, and South Asia through the conquest of farming communities or something like it—through "elite dominance," in Renfrew's phrase (Renfrew 1987, p. 95). Only the European languages could have expanded with agriculture. A Neolithic origin for the European IE languages seemed a simple and elegant solution, but as discussed above, a Neolithic breakup of PIE is too early—and elite dominance is still required to account for the spread of the Asian IE languages.

A later spread from the steppes requires, for Europe as well as Asia, a more complicated sociolinguistic model of language shift. Long-established agricultural communities must have given up their non-IE languages and shifted to IE languages in the absence of empire or conquest. Military conquest is not a viable vector of language shift in the Bronze Age, because there were no

empires and no administrative structures to effectively extract wealth from distant territories among the competing armed chiefdoms of Bronze Age Europe. The sociopolitical context would have been small-scale tribes and clans, mobile in some places and settled in others, arranged in shifting alliances between regional chiefs and armed with weapons displayed prominently in graves and in ritual hoards. During the Bronze Age, after 3300 BCE, in the Pontic-Caspian steppes, and during the Late Neolithic, after 2800 BCE, in much of Central and Western Europe, status-associated weapons became more common in Yamnaya, Usatovo, Corded Ware, and Bell Beaker graves, and warfare was both glorified and institutionalized with the emergence of formal warrior identities in many regions (Vandkilde 2006, Mercer 2007). Archaeological evidence alone does not show how the kaleidoscope of competing European chiefdoms conceived of political power and clientship, which are highly relevant to language shift. But information about political power and clientship is contained in the PIE vocabulary (**Table 2**) as well as in early Indo-European poetics (Watkins 1995), elements of which have already been used in discussions of Bronze Age politics (Kristiansen & Larsson 2005).

The mechanism driving language shift through such a complex social matrix must have depended little if at all on demographic advantages, as no strong demographic advantage can be assigned to any particular region in Copper and Bronze Age Europe, with the possible exception of southeastern Europe. The cultures of Eneolithic Old Europe might have had a denser population than elsewhere in Europe before 4000 BCE, and most steppe-origin scenarios for the IE expansion begin with the shift of this large Old European population to IE languages. But steppe herders certainly held no demographic advantage over the Old European population, and a demographic advantage cannot explain expansion beyond Old Europe. Language shift on anything like the required scale must have resulted from some combination of prestige, opportunities for economic advancement, and/or protection from violence associated with speakers of IE languages in many strategic places, and must have proceeded through choices concerning which language to use in which situation, rather than through conquest and direct dominance. Those choices were affected by new institutions of social and political recruitment, described in the next section.

Whatever model we choose to explain language shift, it probably occurred in a geographically patchy manner. Scanning the epigraphic evidence dated before and during the rise of the Roman Empire in the Mediterranean and in southern Europe, Ringe (2009) counted 10 or 12 IE languages (mostly in the Greek, Italic, and Celtic branches), but also 10 surviving non-IE languages, belonging to an unknown number of non-IE language families. Some of the non-IE languages were recorded in inscriptions on the Mediterranean islands (Linear A, Eteo-Cretan, Elymian, Lemnian), but most of the pre-Roman non-IE inscriptions are from Italy (Etruscan and the language of the stele of Novilara in northeastern Italy), the Alps (Raetic), and Iberia (Iberian and Tartessian—plus Basque, recorded only in names in Latin inscriptions). If inscriptions were available from northern Europe at this time, say 700–200 BCE, we might find additional regions of surviving non-IE speech there, given the variety of non-IE languages in the well-documented Mediterranean. To account for such a pattern, we cannot invoke the so-called wave-of-advance model of language spread that often is associated with the Anatolian-Neolithic-PIE hypothesis. Instead, IE languages must have spread through Late Neolithic/Copper/Bronze Age societies in a patchy, incident-inspired, opportunistic manner, leaving many "islands" of non-IE languages.

6. THE MECHANISM OF SPREAD

What social mechanism caused non-IE speakers to shift to IE languages? Archaeological evidence suggests at least three phases of migration out of the Pontic-Caspian steppes between 4200 and 3300 BCE (**Figure 2**), each with its own circumstances and dynamics. A fine-grained sociolinguistic

Table 2 Late Proto-Indo-European patronage vocabulary[a]

Patrons	*Hr̥ḗǵs 'headman, king,' *wéyḱs pótis 'village headman,' *gʰosti-potis 'host' (lit. 'lord of guests')
Client	*sókʷh₂ō (lit. 'follower')
Service	*dékos (lit. 'what is acceptable')
Wealth	*h₃ep-
Hospitality	*gʰóstis 'guest-friend' (reciprocal[b])
Feast	*deh₂p- 'to cut up (meat),' *dh₂pn̥óm 'a meal'
Sacrifice	*spend- 'to pour a libation,' *Hyaǵ- 'to sacrifice'
To milk	*h₂melǵ-
Cattle	*gʷṓws
Praise	*h₁erkʷ- 'song of praise'
Fame	*kléwos

[a]Table based on Mallory & Adams (2006, pp. 266–86).
[b]From Fortson (2010, p. 23).

explanation of language shift should be linked to the local conditions affecting each of these movements: the first that carried Pre-Anatolian into southeastern Europe about 4200–4000 BCE, coinciding with the Suvorovo–to–Cernavoda I migration and the sudden end of the tell cultures of Old Europe; the second that carried Pre-Tocharian into the western Altai Mountains about 3300 BCE, coinciding with the Yamnaya-to-Afanasievo migration and the beginning of pastoralism in the western Altai; and the third, a complex series of movements that dispersed a cluster of late PIE dialects westward, up the Danube and into the Carpathian Basin about 3100–2800 BCE with the Yamnaya-to-Hungary migration and, also about 3300 BCE, around the northern side of the Carpathians into southeastern Poland with the Usatovo/Tripolye C2 expansion, which could have carried IE dialects into the region that gave birth to the Corded Ware horizon (Furholt 2003).

Steppe economies underwent a revolutionary change between the first and second migrations, or between 4200 and 3300 BCE: a shift from a partial reliance on herding in the steppe Eneolithic, when domesticated animals probably were used principally as a ritual currency for public sacrifices, as at Khvalynsk, to a later regular dietary dependence on cattle and either sheep or goat meat and dairy products, shown by changing stable isotopes in human bones (Anthony 2007, 2013). This dietary shift to full dependence on pastoral products correlated with the initial adoption of a nomadic, wagon-based, equestrian form of pastoralism, made possible by the combination of bulk transport by wagon and rapid transport by horseback, beginning about 3300 BCE with the Yamnaya culture, which ushered in these changes in the steppes and reflected their consolidation as a revolutionary way of exploiting grazing animals and grasslands. The first and second migrations issued from significantly different kinds of steppe economies: The first was somewhat settled and less dependent on domesticated animals, and the second was nomadic and fully dependent on domesticated animals and their dairy products. Yet in terms of social organization and the dynamics of language shift, the first and third migrations, westward into densely populated regions, shared key dynamics that did not apply to the second migration, the expansion of a wagon-based herding economy into a region (the Altai Mountains) occupied by foragers. So the three migrations were quite different and distinct events, but they shared certain key political institutions.

Two central features linked the political economies of all of these steppe societies: (*a*) the presence of a rich–poor social hierarchy expressed prominently in dress, body decoration, and weaponry at funerals and (*b*) the sacrifice of cattle, horses, and either sheep or goats, interpreted as the remains of feasts, at funerals and presumably at other events (unattested archaeologically) such as births or marriages. Feasting could have been an important vector for expansion of the IE languages, and it is a link between the archaeological and linguistic evidence. Dietler & Hayden (2001), Hayden (2001), and Hayden & Villeneuve (2012) have argued that the emergence of political hierarchy is almost always associated with the unequal mobilization of labor and resources by self-aggrandizing individuals who underwrite and promote public feasts, usually connected with ritual events, at which their wealth and power are advertised, celebrated, and secured. Rivals compete publicly through the size and complexity of the feasts they sponsor. Alliances are confirmed by gift-giving and promises at public feasts. Long-distance trade can be stimulated by the need for exotic gifts that chiefs can present to allies in order to secure their support, particularly for warfare against other chiefs (Vehik 2002). Almost all chiefdoms seem to have maintained themselves at least partly through public feasting, and this form of political economy seems to have been adopted in the steppes in the Eneolithic soon after domesticated animals were accepted. Of course the ideologies and cultural models attached to feasting traditions differed, and feasting also occurred in the absence of political hierarchy. The public feasting associated with the Neolithic cultures of northern and western Europe, from LBK (Marciniak 2008) to the various megalithic societies (Bakker 2011), seems to have been intended to celebrate the social collective, symbolized by the household, and perhaps by its male elders as a group (Thomas 2010, Parker-Pearson & Willis 2011), rather than glorifying single individuals or young warriors, or aggrandizing chiefs (Furholt & Müller 2011). In the steppes, by contrast, beginning with Khvalynsk and the Dnieper-Azov cemeteries (Nikol'skoe, Mariupol) about 4500 BCE, a minority of richly decorated single graves—enriched partly by copper items imported from southeastern Europe but also featuring numerous ornaments of shell and boar's tusk, flint blades and projectile points, and polished stone maces—stood in stark contrast to the majority of poorly outfitted graves (Mallory 1989, pp. 206–10; Anthony 2007, pp. 179–86). Some richly costumed graves were also distinguished by the earliest steppe burial mounds, as at Suvorovo north of the Danube.

How do the animal sacrifices and social hierarchies of the steppes square with PIE vocabulary? PIE had lexemes related to gift-giving and gift-taking (Benveniste 1973, pp. 61–63; Markey 1990; Mallory & Adams 2006, pp. 270–72), interpreted as referring to feasts meant to honor the gods and to secure from them the blessings of "...glory [PIE **kléwos*], victory [PIE **ségʰos*], booty [PIE **sóru*], rain, wide pastures, sons, cattle, and riches; in one word: prosperity," (Zimmer 2009, p. 184; PIE lexemes added). The host of the feast was, in PIE, the **ghosti-potis*, the 'lord of the guests,' who honored the immortal gods and his mortal guests with gifts of food, drink, and poetry (Zimmer 2009, p. 183). PIE had words for the full circle of giving: 'give,' 'bestow,' 'what is bestowed,' 'what is distributed,' 'apportion,' 'reward/prize,' and on the other side, 'to take/accept legally.' Praise poetry encouraged generosity. Watkins (1995, pp. 73–84) identified a lexeme for a special kind of song, PIE **h*$_1$*erk*^{w}- 'praise of the gift,' with cognates in Anatolian, Tocharian, Vedic, and Armenian. Praise poems proclaimed the generosity of the gods or of a patron and enumerated their gifts, expanding the patron's fame (**kléwos*), the path to immortality (otherwise attainable for mortals, to judge from shared motifs in later IE texts, only through conspicuous acts of war or piety).

The generosity of the patron was embedded in an accepted social hierarchy. PIE **h*$_3$*ep*- 'wealth, possessions' is securely reconstructible [cf. Hittite *happina*(*nt*)- 'rich,' Latin *opēs* 'wealth'], and there were PIE roots meaning 'to lack' or 'to be in need,' as well as words meaning 'servant'

(Mallory & Adams 2006, pp. 267–77), so a hierarchy of wealth and poverty was recognized. Clients, literally 'followers' (PIE **sókʷh₂oyes*), might have contributed animals to feasts, given that some words meaning 'sacrifice' in the daughter languages are transparent compounds of **bʰer-* 'carry,' referring to the act of bringing animals for offerings. A good chief would accept the offerings graciously (**dék-* 'accept ritually'), with cognates in Latin, Greek, and Sanskrit (Mallory & Adams 2006, p. 271). Feasts were occasions for patrons to acquire prestige and display wealth while sharing it with others in an honorable way. Linguistic evidence for PIE political economy fits with the steppe archaeological evidence better than it does with the archaeological evidence from the Neolithic.

At the same time, the PIE vocabulary suggests that vertical power differences were partly balanced by horizontal mutual obligations of hospitality between guest and hosts (**gʰóstis*), a reciprocal relationship that obligated the host to offer hospitality, protection, and gifts to his guest and obligated the guest to return the favor in the future. This was a relationship of reciprocity, unlike the patron–client relationship. Violations of the guest–host institution were considered "illegal, immoral, and unholy" (Fortson 2010, p. 23). The guest–host institution could extend reciprocal protection to nonkin and strangers. It would have been very useful as a social adaptation to mobility, maintaining social life at a distance and defusing potentially hostile acts between strangers who interacted more frequently as human mobility increased across Europe after 3500 BCE, after wheels appeared. Later, during the IE expansion, the guest–host relationship could incorporate outsiders as people with clearly defined rights and protections [as illustrated repeatedly from *The Odyssey* to the Middle Ages (Kristiansen & Larsson 2005, p. 238)]. Patron–client and guest–host institutions were maintained and elaborated in the languages and mythologies of the IE daughters, demonstrating their importance in securing and maintaining power and perhaps in attracting and recruiting new followers—a potential mechanism of language shift.

If patron-sponsored public feasts and guest–host relationships were the attractive factors in recruiting followers, a more coercive PIE institution could have compelled outsiders to seek protection with IE-speaking patrons. That institution was the war-band of newly initiated youths (**kóryos*). Comparative mythology suggests that PIE boys were initiated, perhaps as an age-set, into roaming war-bands of youths described as violent, thieving, and promiscuous, in which they served for a number of years before returning home to adopt more respectable identities as mature men (Falk 1986, McCone 1987, Lincoln 1991, Kershaw 2000, Das & Meiser 2003). The Germanic *Männerbünde*, Italic *sodales* and *luperci*, Celtic *fianna*, Greek *ephebes*, and Vedic *Vrātyas* and *Maruts* present parallel linkages between youth, raiding/community defense, landlessness, promiscuity, and liminality. Youthful war-bands apparently operated on the frontiers of IE societies, wore animal skins to appear like wolves or dogs, and bore names containing the word 'wolf' or 'dog,' each a symbol of death and war in IE mythologies (Bremer 1982, p. 141; McCone 1987; Lincoln 1991). Bremer (1982, pp. 136–37, 145) observed that the legends of early Rome, revolving around young brothers, wolves, and roving landless young men, might suggest that youthful war-bands were implicated in the foundation of that city. The recent archaeological discovery of midwinter dog and wolf sacrifices dated 1900–1700 BCE at the Srubnaya (or Timber-Grave) settlement of Krasnosamarskoe in the middle Volga steppes of Russia (**Figure 3**) establishes the practice at that site, uniquely, of a winter-season ritual of transgressive liminality involving the sacrifice and consumption of at least 51 dogs and 7 wolves, probably the remains of a series of winter initiations into a status represented metaphorically by dogs and wolves (Powell 2013), like the youthful war-bands of IE mythology.

The war-band institution could have driven people who were not protected by the social umbrella to move under it to be safe from thieving or to obtain restitution. Two verbs for making restitution are reconstructible for PIE. One, **serk-* 'make restitution, compensate,' survives in

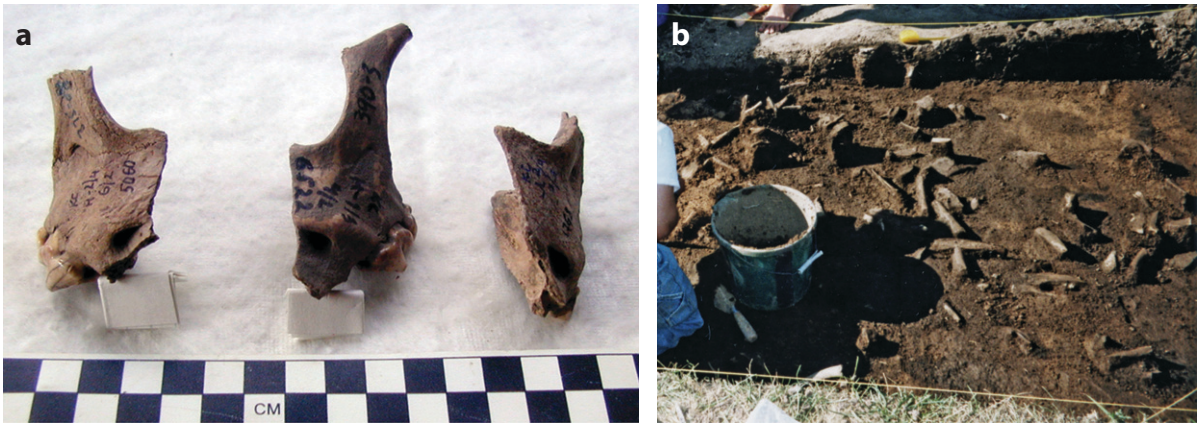


Figure 3

Excavations at Krasnosamarskoe, Russia, revealed remains of a Late Bronze Age Srubnaya-culture midwinter ritual in which dogs and wolves were killed and eaten and their bones and heads were chopped into small regularized pieces as part of a rite of passage in which the initiates metaphorically became dogs and wolves. (*a*) Chopped dog-skull fragments showing a standardized eye orbit/maxilla cut. (*b*) Excavations found thousands of burned and chopped animal-bone fragments strewn across the floor of a structure. Modified from Powell (2013). Data from research by D.W. Anthony and D. Brown, based on interviews by Powell.

Hittite *sarnikzi* 'makes restitution' (Mallory & Adams 2006, p. 277). The descendants of the other, $*k^{w}ey$-, have meanings that center on 'pay, compensate' but also include 'blood-price,' 'vengeance,' 'requite,' 'pay a fine,' and 'guilt,' suggesting that this verb might apply specifically to restitution for theft or violence. Language shift during the Bronze Age could have been motivated partly by the desire for compensation from an IE-speaking patron/chief for damages caused by his war-band. In this situation, the language of the "court" was an IE language, and the institutions that recognized and validated compensation as a just demand were IE institutions.

All these institutions could have provided the framework for recruiting outsiders into IE-speaking societies in social positions offering vertical mobility, horizontal reciprocity, and the possibility of immortality through poetry, made more attractive by generosity at feasts. The threat of violence from war-bands and the possibility of restitution for damages could have added some compulsion. A new, more productive, and mobile herding economy and long-distance trade in metals and other valuables (salt, in some regions) probably brought prestige and power to IE-speaking societies after 3300 BCE. These mechanisms, reconstructible through the PIE vocabulary and consistent with archaeological discoveries, made possible the integration of outsiders as clients without shaming them or assigning them permanently submissive roles. All these factors, taken together, suggest that the spread of IE languages was probably more like a franchising operation than an invasion. Although the initial penetration of a new region required an actual migration and military confrontations, once it began to produce new patron–client agreements (franchises) its connection to the original steppe immigrants became remote, while the myths, rituals, and institutions that maintained the system were reproduced, using inherited words, down the generations.

7. COMPUTATIONAL MODELING OF LANGUAGE TREES

Several attempts to model the diversification of IE computationally have been made, but most teams of researchers have not attempted to determine the date of PIE or of any of its unattested

daughters. An exception is the work of Gray & Atkinson (2003), who propose a date for PIE so early that it cannot be reconciled with the archaeological and linguistic evidence presented above. There are several reasons that their results deserve further scrutiny.[3]

Many computer scientists are skeptical about the attempt to date protolanguages, on the grounds that we would need more information about linguistic prehistory than we can have in order to reconstruct in detail the processes that have generated a complex observed outcome (Evans et al. 2006). To determine dates for a tree's internal nodes, we would need to know at least the initial state, the change process(es) that gave rise to the observed states, and the rates at which the change(s) have operated. Unfortunately, the initial state is never better than an approximation, because all linguistic reconstructions are necessarily incomplete. Worse, rates of word replacement show extreme and unpredictable variation, as has been known for 50 years (e.g., Bergsland & Vogt 1962). There is also an inherent uncertainty in calculating rates of vocabulary replacement. If we find that a word present in language A no longer appears in the same meaning in its direct descendant B, we can infer only that it has been replaced at least once; we cannot exclude the possibility that it has been replaced more than once, even several times. Estimated rates of replacement are therefore approximations whose degree of accuracy is actually unknown and possibly unknowable. Statistical methods can mitigate these problems, but corroboration from other disciplines, such as archaeology, makes a much stronger case.

In addition, IE word lists present special challenges, and the work of Gray and colleagues raises further unanswered questions. The most important points are the following.

1. Modern languages preserve (on average) less material inherited from PIE than do ancient ones, magnifying the problem of multiple replacement (see immediately above) and raising the level of statistical uncertainty in calculations based on them. However, to the extent that standard literary dialects are used, the rate of vocabulary replacement can be underestimated because such dialects tend to retain words that are no longer the usual expressions in vernacular dialects. Because some IE languages are attested only from recent centuries, whereas others are known only from ancient "official" documents, these problems compound the uncertainties.
2. The coding of characters used by Gray & Atkinson (2003) raises technical questions. Each semantically defined multistate character is broken down into a suite of binary characters, one for each cognate class, so that the resulting binary characters code for presence or absence of a given cognate class in a given language in a given meaning. This coding leads inexorably to one of two problems: The binary characters are not independent of one another, and if only one binary character derived from each multistate character is chosen for each iteration of the software (to obviate that problem), some information in the data set is suppressed in each iteration. The effect of this strategy on calculations of dates is unclear.
3. The algorithm used to calculate the dates of internal nodes is guaranteed to give a correct result only if the data evolve according to a "lexical clock" (Nichols & Warnow 2008, pp. 790–92) whereby words are replaced at a more or less steady rate, at least within particular subsets of the vocabulary (as it has long been known that words of some meanings are more resistant to loss than others). But in the real world such an assumption does not hold; we cannot even assume that, if word X is twice as likely

[3]We are grateful to Robert Berwick, Andrew Garrett, Mark Liberman, and Tandy Warnow for helpful discussion regarding this section.

to be lost as Y in one lineage, the same will hold in all lineages (even if the rates are different). Choosing different rates at random from a well-behaved distribution does not solve the problem, because unpredictable, extreme differences in the rate of word loss do occur (see above). Use of a "relaxed" clock is more realistic, but whether it is realistic enough has not been investigated rigorously.

But the most compelling reason to want further study is that completely independent teams have not replicated Gray and Atkinson's results. Work currently in progress by the team of Chang, Hall, Cathcart, and Garrett promises to fill that gap.

DISCLOSURE STATEMENT

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