

speakers at the Theory Workshop (who without exception belong to the younger generation) regard this session as a success. This assessment includes the interest shown in the workshop's exhibition in the conference foyer to mark the 100th birthday of the philosopher Walter Benjamin, who in 1942 committed suicide in the Pyrenees whilst fleeing from the Nazis. The renewed German interest in Benjamin (who, incidentally, was the first to use material culture and excavation as metaphors in the analysis of historical and personal developments) coincides with his appearance as a strong influence in recent British post-processualist writing.

The papers given at Rostock will be published in Germany as a book. A seminar on Marxism in archaeology will be held in early 1993. For the next archaeological congress at Siegen in June 1993, a panel discussion on the effects of unification and "evaluation" on eastern German archaeology is planned. The topic proposed for the 1994 workshop session is ethno-archaeology. Given the anti-theoretical climate of German archaeology, it will take a good deal of determination to continue the debate and extend it to other aspects of archaeological theory, but the very fact that for the first time an open forum has been created for this purpose may entitle us to some optimism. International interest in this venture and links with the British and Scandinavian TAGs may also prove critical to the future of the German debate.

## References Cited

- HÄRKE, H. 1989. The Unkel Symposia: The beginnings of a debate in West German archaeology? *CURRENT ANTHROPOLOGY* 30:406-10.
- . 1991. "All quiet on the western front? Paradigms, methods, and approaches in West German archaeology," in *Archaeological theory in Europe: The last three decades*. Edited by I. Hodder, pp. 187-222. London and New York: Routledge.
- WOLFRAM, S. 1991. Eine neue Arbeitsgemeinschaft: Die Theorie-AG. *Archäologische Informationen* 14(1):103-5.
- argue that it is only in the Upper Palaeolithic that the material remains left by our ancestors show a level of sophistication that would presuppose symbolic verbal communication. An important corollary of this viewpoint is that human language is radically different not only from the communication systems of pre-Upper Palaeolithic hominids but also from those of non-hominid primates. The alternative point of view suggests that human language evolved earlier than the Upper Palaeolithic and that it has a good deal in common with the communication systems of earlier hominids as well as non-hominid primates (Bradshaw 1991, Foley 1991). Supporters of this point of view argue for a gradual development of modern human symbolic language as well as for a relatively early appearance of this trend. They base their arguments on a variety of different lines of evidence including the anatomy and development of the brain (Holloway and de la Coste-Lareymondie 1982; Falk 1980; Tobias 1987, 1991; Calvin 1983), archaeology and developmental psychology (Wynn 1991), and comparative primate ethology and cognition (Parker and Gibson 1979, Savage-Rumbaugh 1986). Some of this debate involves disagreement over what language is and whether it should be defined in such a way as to emphasize the differences between modern human and ape vocal communication or to recognize their similarities (see Noble and Davidson 1991). However, the deeper roots of the debate lie in a controversy over the fundamental function of language and the evolutionary pressures which were responsible for producing it.

In this context, we propose a model derived from comparative primate morphology and ethology which suggests that the need for large groups among our early ancestors was the driving force behind not only the evolution of language but also hominid encephalization (Dunbar 1992, n.d.). The close relationship between encephalization and group size allows us to predict the point in hominid evolution at which groups became so large that language would have been necessary to maintain social cohesion. When this model is applied to the hominid fossil record, it suggests that the necessity for both large groups and (at least rudimentary) language appeared early in the evolution of the genus *Homo* and began to increase rapidly in the second half of the Middle Pleistocene. It provides no evidence for the relatively sudden appearance of a radically novel communication system in the Upper Palaeolithic (about 40,000 years ago).

This hypothesis is based on a close statistical relationship between relative neocortex size, group size, and the amount of time devoted to social grooming among non-human primates (Dunbar 1992). In extending these results to anatomically modern humans, Dunbar (n.d.) argues that the time required to service the relationships in the large groups predicted for modern humans would have been too great to be sustained by the methods normally employed by non-human primates (namely, social grooming). The conclusion is that language evolved as a form of bonding mechanism in order to use social time more efficiently.

## Neocortex Size, Group Size, and the Evolution of Language<sup>1</sup>

LESLIE C. AIELLO AND R. I. M. DUNBAR  
Department of Anthropology, University College  
London, Gower St., London WC1 6BT, England.  
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Over the past few years, the origin of human language has become a contentious issue (Gibson 1991). One faction argues that fully developed symbolic language is a recent occurrence, coinciding with the appearance of the Upper Palaeolithic approximately 40,000 years ago (White 1982, Chase and Dibble 1987, Mellars 1991, Noble and Davidson 1991). Supporters of this point of view

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A number of analyses have independently demonstrated a relationship between neocortex size and group size in primates (Sawaguchi and Kudo 1990, Dunbar 1992). They suggest that group size is limited by the number of relationships that an individual animal can successfully monitor and that this in turn is limited by the relative size of its neocortex. In this respect, the best predictor of group size turns out to be the neocortex ratio (defined as the ratio of neocortex volume to the volume of the rest of the brain) (Dunbar 1992). The reduced-major-axis equation for this relationship is:

$$\text{Log}_{10}[N] = 0.093 + 3.389 \text{Log}_{10}[C_R] \quad (1)$$

( $r^2 = 0.764$ ,  $N = 35$ ,  $P < 0.001$ ), where  $N$  is the mean group size for a given taxon and  $C_R$  is its neocortex ratio.

These results were extended to anatomically modern humans, for whom a group size of 148 was predicted (95% confidence limits = 101–231, Dunbar n.d.). There is considerable evidence that groupings of this size occur frequently in modern and historical human societies. Census data for 20 hunter-gatherer populations support this prediction by revealing an average group size of 153 individuals (range 90–220), intermediate between the widely recognized smaller band-type groups of 25–50 individuals and the larger tribal groupings in excess of 500 individuals. The smaller and larger groupings are well established in the anthropological literature (Stewart 1955, Service 1962, Birdsell 1970); in contrast, the intermediate-level groupings, though often discussed, have not been widely censused.

When groups significantly exceed this intermediate size, it becomes increasingly difficult to co-ordinate their members' behaviour through personal contacts alone. At this point they can no longer be egalitarian in their organization but must increasingly develop stratification involving specialized roles relating to social control (Naroll 1956, Forge 1972). This problem can only be avoided by splitting the group before it reaches the critical level of about 150, as happens among Hutterite communities in the U.S.A. and Canada. Similar constraints appear to operate, for example, in the case of modern professional armies, where the smallest independent unit (the company) averages 180 individuals (MacDonald 1955), and also in the case of research specializations in the sciences, which typically consist of up to 200 individuals but rarely more (Price and Beaver 1966). All of these values lie within the 95% confidence limits for group size predicted for modern humans by relative neocortex size (see Dunbar n.d.).

In non-human primates, group cohesion is maintained largely by social grooming, which is used to service the key relationships between individuals on which the stability of the group depends. Dunbar (1991) has shown that there is a significant linear relationship between group size and the amount of time devoted to social grooming each day among primates (especially catarrhine primates). For catarrhine species that do not have a fission-fusion social system (see Dunbar 1991), the reduced-major-axis equation for grooming time plotted

against group size is

$$G = -0.772 + 0.287N \quad (2)$$

( $r^2 = 0.589$ ,  $N = 22$ ,  $P < 0.001$ ), where  $G$  is the percentage of daytime devoted to social grooming.

On this basis, contemporary humans would have to spend 30–45% of daytime in social grooming in order to maintain the cohesion of the groups predicted on the basis of their neocortex ratio. It seems unlikely that any species could sustain this level of time investment in social grooming if it had to pursue a conventional foraging strategy. A shift to a form of social interaction that was more efficient than grooming in its use of time would thus have been required to facilitate the cohesion of such large groups. It has been suggested (Dunbar n.d.) that language uniquely fulfilled this requirement by allowing hominids to exchange information about individuals not immediately present.

In principle, then, we should be able to apply the equations derived from these analyses to the hominid fossil record in order to identify the point in time at which language would have had to evolve. Since individual populations of extant primates can spend up to 20% of their day in social grooming without compromising their time budgets, the crisis point for the evolution of enhanced verbal communication must lie at some higher value (perhaps 25–30% of the day).

In order to determine mean group sizes for fossil populations, we need to be able to determine neocortex sizes. Given a simple equation relating neocortex size to brain size for living primates, we can estimate neocortex size for fossil species directly. For present purposes, it is sufficient to regress neocortex ratio directly onto brain volume. The relationship between these two variables for data given by Stephan, Frahm, and Baron (1981) is remarkably close (fig. 1), with a clear grade difference between strepsirrhine and haplorhine primates. The reduced-major-axis equation for the haplorhine primates (including anatomically modern humans) is

$$\text{Log}_{10}[C_R] = -0.618 + 0.200 \text{Log}_{10}[B] \quad (3)$$

( $r^2 = 0.857$ ,  $P < 0.001$ ,  $N = 26$ ), where  $C_R$  is the neocortex ratio and  $B$  the total brain size ( $\text{mm}^3$ ).

One problem with applying equation 3 to the fossil specimens is that Stephan et al. measured the net volumes of neural tissue, excluding the ventricular and other spaces within the cranium. The only measure available for the fossil specimens is, of course, gross cranial capacity, and this cannot simply be substituted for brain volume. Fortunately, Martin (1989) gives data on cranial capacities for a number of the taxa listed in the Stephan et al. sample. When these are plotted against each other (fig. 2), it is clear that there is a simple linear relationship between them. The reduced-major-axis equation is

$$\text{Log}_{10}[B] = 3.015 + 0.986 \text{Log}_{10}[C] \quad (4)$$

( $r^2 = 0.995$ ,  $N = 36$ ,  $P < 0.001$ ; confidence limits for the slope = 0.984–0.988), where  $C$  is the internal cra-

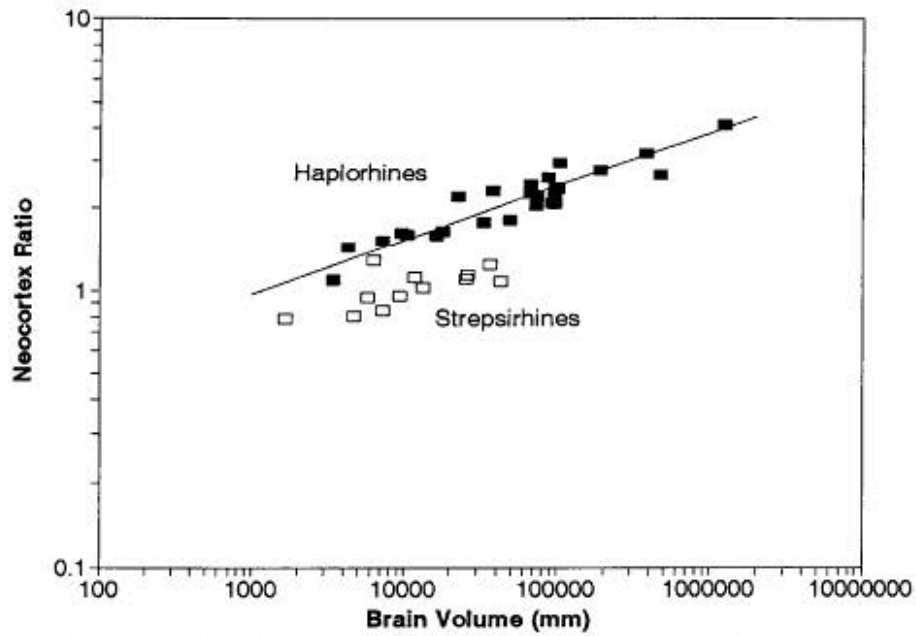


FIG. 1. Neocortex ratio and brain size in strepsirhine and haplorhine primates including modern humans.

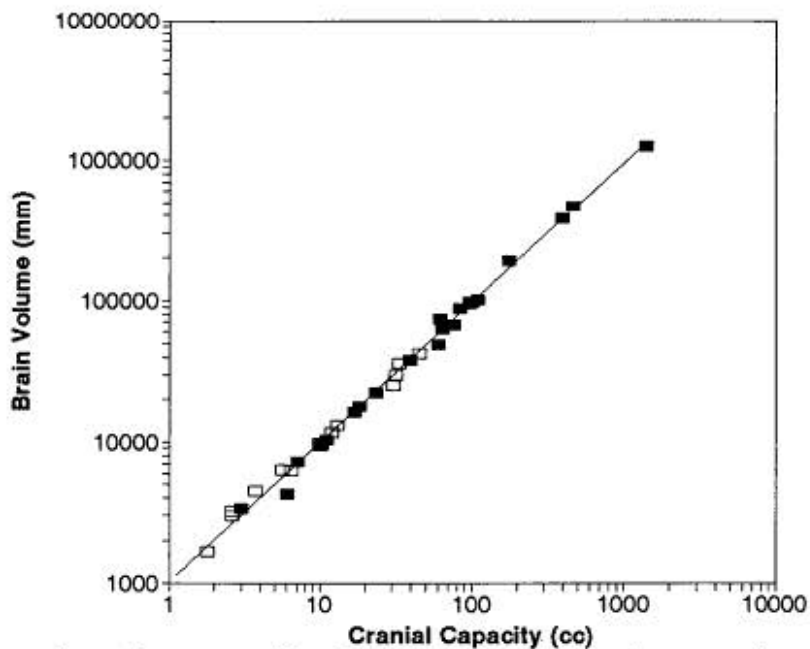


FIG. 2. Brain size and cranial capacity in all available primates (N = 22 spp.). □, strepsirhine primates (N = 14); ■, haplorhine primates (N = 22).

nial capacity (measured in cc). Although the difference seems slight, the scaling effects in equations 3 and 4 are sufficient to introduce significant biases into the results for haplorhine primates unless this initial correction is made. Such effects become markedly more prominent with the larger-brained hominids.

The values for group size and therefore grooming time predicted for australopithecines are below the limit found in living primates (table 1, fig. 3). For archaic *H. sapiens*, grooming time is well within the range of modern humans. The grooming time requirements predicted for the Neanderthals (*H. s. neanderthalensis*) are similar to those predicted for both archaic and modern humans. Finally, *H. habilis/rudolfensis* has an average predicted grooming time requirement (23%) that is close to the highest values observed in living primate populations (20% in one group of *T. gelada* [Iwamoto and Dunbar 1983]). Until the middle part of the Middle Pleistocene (ca. 300,000 years ago) the percentage grooming time remains below the inferred modern human range. From this point on, percentage grooming time increases steadily towards the predicted level for modern humans.

These results imply that the evolution of human language involved a gradual and continuous transition from non-human primate communication systems. If there is any evidence at all for a Rubicon in the evolution of language, it is in the middle part of the Middle Pleistocene rather than in the more recent Upper Palaeolithic.

These data can thus be interpreted in terms of a progressive need to supplement existing forms of social cohesion with more efficient vocally based ones as group sizes increased. At the earliest stage, tone and emotion would be the essential components of vocalization; information content would not necessarily be important. The function of this type of enhanced vocalization would be vocal grooming, an expression of mutual interest and commitment that could be simultaneously shared with more than one individual. In fact, this process is already observable at a rudimentary level in extant primates [Dunbar n.d.]. Richman [1976, 1978, 1987] has pointed out that gelada vocalization has a number of features that were once considered distinctive features of human speech: fricatives, plosives, and nasals, labials, dentals and velars, as well as rhythmic, melodic, and conversational properties involving highly synchronised bouts with intense emotional overtones. It may be no coincidence that geladas live in the largest naturally occurring groups of any non-human primate (mean group size 115 animals [Iwamoto and Dunbar 1983]). These vocal properties, which converge so uncannily on human speech, appear to supplement grooming as a mechanism for social bonding [Dunbar n.d.]. Although geladas cannot be said to have evolved language, they may provide a model for the earliest stages in its development.

Since the gelada's neocortex is no larger than that of other baboons (and may even be significantly smaller), this suggests that the basic cognitive foundations for at least this rudimentary stage of language do not require unusual neocortical development and may thus have al-

ready been available in the more advanced non-human primates (see also Bradshaw 1991). The evolution of vocal communication may also have been facilitated by facial geometry: it was pointed out over 20 years ago that geladas are similar to humans in possessing relatively short, deep faces and broad, fleshy tongues [Jolly 1970]. This facial geometry, resulting ultimately from dietary factors, may facilitate the production of human-like speech sounds in these primates by giving the muscles that move the tongue a better lever advantage (see Duchin 1990). Using this as a springboard, a more advanced vocal communication might be expected to have developed if there was both an increase in neocortex size and an improvement in the apparatus of speech production. The increase in neocortex size would have increased the capacity of the brain for close integration and elaboration of the basic cognitive foundations for speech and language, while changes in facial geometry as well as in the position of the larynx within the throat would greatly have facilitated phonation [Lieberman 1989].

These analyses provide no grounds for suggesting that the australopithecines would have needed any more sophisticated means of social cohesion than that found in the living great apes (fig. 3, table 2). There would, therefore, be no need for any type of enhanced vocal communication in these early hominids. However, *H. habilis/rudolfensis*, with a mean predicted grooming requirement approaching 23% of its time budget, would, like the geladas, have been under some pressure to augment grooming with vocal interaction as a means of maintaining social cohesion in its increasingly large social groups. It is significant that it is at this stage of hominid evolution that we have the first clear evidence for a human pattern of brain asymmetry [Falk 1980, 1983; Tobias 1987, 1991]. This may have provided an important early step in the elaboration of linguistically related cognitive function, while the tendency towards a shorter face would have facilitated the production of a variety of sounds. Brain asymmetry has been associated not only with handedness (for which there is independent evidence at this stage from associated stone tools [Toth 1985]) but also with cerebral specialization involving visuospatial and symbolic understanding, speech recognition, and speech production [Falk 1980, 1983; Holloway and de la Coste-Lareymondie 1982].

It is only with the appearance of archaic *H. sapiens* in the second half of the Middle Pleistocene that, according to this model, the early hominids would have been put under the same pressure as that found in modern human societies in relation to social bonding. There is no significant difference in either inferred group sizes or percentage time spent grooming between archaic *H. sapiens*, the Neanderthals, and modern humans (table 2). It is of interest that archaic *H. sapiens* is the first hominid for which there is some suggestion of a modern human vocal tract characterized by a low larynx and an ascending pharynx [Laitman, Haimbuch, and Crelin 1979; Lieberman 1989]. Although this work might also suggest that the Neanderthals had later lost the ability to pro-

**TABLE 1**  
Cranial Capacity and Predicted Brain Volume, Neocortex Ratio, Group Size, and Percentage Grooming Time for Fossil Hominids and Living Humans and Apes

Fossil	Estimated Age (mya)	Cranial Capacity (mm <sup>3</sup> )	Brain Volume (Eq. 4)	Neocortex Ratio (Eq. 3)	Group Size (Eq. 1)	% Grooming Time (Eq. 2)
<b>Australopithecines</b>						
<i>Australopithecus afarensis</i> <sup>a</sup>						
AL333-45	3.100	500,000	474,443	3.29	70.13	19.36
AL162-28	3.100	400,000	380,742	3.15	60.42	16.57
AL333-105J	3.100	400,000	380,742	3.15	60.42	16.57
<i>A. africanus</i>						
Sts 5 <sup>b</sup>	2.750	485,000	460,406	3.27	68.72	18.95
Sts 19/58	2.750	436,000	414,509	3.20	64.00	17.60
Sts 60	2.750	428,000	407,009	3.19	63.21	17.37
Sts 71 <sup>b</sup>	2.750	428,000	407,009	3.19	63.21	17.37
MLD I	3.000	500,000	474,443	3.29	70.13	19.36
MLD 37/38	3.000	435,000	413,571	3.20	63.90	17.57
<i>A. robustus</i> and <i>boisei</i>						
KNM ER 406	1.700	510,000	483,798	3.30	71.07	19.62
KNM ER 732	1.700	500,000	474,443	3.29	70.13	19.36
SK 1585	1.750	530,000	502,500	3.33	72.92	20.16
OH 5	1.800	530,000	502,500	3.33	72.92	20.16
KNM ER 407 <sup>c</sup>	1.850	506,000	480,057	3.30	70.69	19.52
KNM ER 13750 <sup>c</sup>	1.880	475,000	451,045	3.26	67.77	18.68
KNM WT 17000 <sup>c</sup>	2.500	410,000	390,126	3.16	61.42	16.86
<b>Early Homo</b>						
<i>H. habilis</i> and <i>rudolfensis</i>						
OH 13	1.500	673,000	635,950	3.49	85.54	23.78
OH 16	1.700	638,000	603,328	3.45	82.54	22.92
OH 7	1.800	674,000	636,882	3.49	85.62	23.80
OH 24	1.800	594,000	562,281	3.40	78.69	21.81
KNM ER 1805 <sup>c</sup>	1.850	582,000	551,079	3.39	77.62	21.51
KNM ER 1470 <sup>c</sup>	1.890	752,000	709,497	3.57	92.12	25.67
KNM ER 1813 <sup>c</sup>	1.890	509,000	482,863	3.30	70.97	19.60
<i>H. erectus</i>						
<b>Africa</b>						
Salé	0.250	880,000	828,438	3.68	102.33	28.60
OH 12	0.700	750,000	707,637	3.56	91.96	25.62
OH 9	1.230	1,067,000	1,001,775	3.82	116.39	32.63
KNM ER 3883 <sup>c</sup>	1.570	804,000	757,849	3.61	96.33	26.88
KNM ER 3733 <sup>c</sup>	1.780	850,000	800,584	3.65	99.98	27.92
<b>Java</b>						
Ngandong 1 <sup>d</sup>	0.250	1,172,000	1,098,911	3.89	123.93	34.79
Ngandong 4 <sup>d</sup>	0.250	1,251,000	1,171,914	3.94	129.45	36.38
Ngandong 6 <sup>d</sup>	0.250	1,013,000	951,768	3.78	112.42	31.49
Ngandong 9 <sup>d</sup>	0.250	1,135,000	1,064,697	3.87	121.30	34.04
Ngandong 10 <sup>d</sup>	0.250	1,231,000	1,153,438	3.93	128.06	35.98
Ngandong 11 <sup>d</sup>	0.250	1,090,000	1,023,063	3.84	118.06	33.11
Sambungmachan	0.420	1,035,000	972,145	3.80	114.05	31.96
Trinil 2	0.620	940,000	884,105	3.73	106.94	29.92
Sangiran 10	0.620	855,000	805,227	3.66	100.38	28.04
Sangiran 12	0.620	1,059,000	994,369	3.82	115.81	32.46
Sangiran 17	0.620	1,004,000	943,429	3.78	111.75	31.30
Sangiran 2	0.760	813,000	766,213	3.62	97.05	27.08
Sangiran 4	0.930	908,000	854,422	3.70	104.49	29.22
<b>China</b>						
Hexian	0.250	1,025,000	962,883	3.79	113.31	31.75
Zhoukoudian 2	0.420	1,030,000	967,515	3.79	113.68	31.85
Zhoukoudian 3	0.420	913,000	860,917	3.71	105.03	29.37
Zhoukoudian 5	0.420	1,140,000	1,069,321	3.87	121.65	34.14
Zhoukoudian 6	0.420	850,000	800,584	3.65	99.98	27.92
Zhoukoudian 10	0.420	1,225,000	1,147,895	3.93	127.64	35.86
Zhoukoudian 11	0.420	1,015,000	953,620	3.78	112.57	31.54
Zhoukoudian 21	0.420	1,030,000	967,515	3.79	113.68	31.85
Lantian	0.800	780,000	735,538	3.59	94.40	26.32
<b>Archaic H. sapiens</b>						
Arago 21	0.400	1,200,000	1,124,793	3.91	125.90	35.36
Irhoud 1 <sup>e</sup>	0.090	1,305,000	1,221,777	3.98	133.16	37.44
Irhoud 2 <sup>e</sup>	0.090	1,450,000	1,355,529	4.06	142.87	40.23
Singa <sup>f</sup>	0.097	1,400,000	1,309,430	4.03	139.56	39.28
Petralona	0.200	1,230,000	1,152,515	3.93	127.99	35.96
Kabwe	0.150	1,285,000	1,203,313	3.96	131.79	37.05



TABLE I  
(Continued)

Fossil	Estimated Age (mys)	Cranial Capacity (mm <sup>3</sup> )	Brain Volume (Eq. 4)	Neocortex Ratio (Eq. 3)	Group Size (Eq. 1)	% Grooming Time (Eq. 2)
Elandsfontein <sup>a</sup>	0.350	1,225,000	1,147,895	3.93	127.64	35.86
Dali	0.300	1,120,000	1,050,822	3.86	120.22	33.73
Florisbad <sup>b</sup>	0.100	1,280,000	1,198,696	3.96	131.45	36.95
Omoo <sup>c</sup>	0.130	1,430,000	1,337,092	4.05	141.55	39.85
Laetoli 18	0.125	1,367,000	1,278,992	4.01	137.35	38.65
Ndutu	0.400	1,100,000	1,032,317	3.84	118.78	33.32
Steinheim	0.350	1,100,000	1,032,317	3.84	118.78	33.32
Swanscombe	0.250	1,325,000	1,240,237	3.99	134.52	37.83
Vértesszöllös 2 <sup>d</sup>	0.210	1,300,000	1,217,161	3.97	132.81	37.35
Neanderthals						
Amud 1 <sup>e</sup>	0.041	1,750,000	1,631,682	4.21	162.00	45.72
Le Moustier <sup>c</sup>	0.041	1,565,000	1,461,474	4.12	150.35	42.38
La Chapelle <sup>c</sup>	0.047	1,625,000	1,516,706	4.15	154.17	43.48
Neanderthal	0.050	1,525,000	1,424,636	4.10	147.77	41.64
Gibraltar 1	0.050	1,200,000	1,124,793	3.91	125.90	35.36
Sbanidar 1 <sup>f</sup>	0.050	1,600,000	1,493,696	4.14	152.59	43.02
Guattari 1 <sup>e</sup>	0.050	1,550,000	1,447,662	4.11	149.38	42.10
La Quina 5	0.064	1,350,000	1,263,308	4.00	136.21	38.32
Spy 1	0.068	1,305,000	1,221,777	3.98	133.16	37.44
Spy 2	0.068	1,553,000	1,450,424	4.11	149.58	42.16
La Ferrassie 1	0.070	1,689,000	1,575,589	4.18	158.21	44.63
Krapina B	0.100	1,450,000	1,355,329	4.06	142.87	40.23
Tabún C1 <sup>g</sup>	0.100	1,270,000	1,189,462	3.95	130.76	36.76
Saccopastore 1	0.120	1,245,000	1,166,372	3.94	129.03	36.26
Saccopastore 2	0.120	1,300,000	1,217,161	3.97	132.81	37.35
Early modern <i>H. sapiens</i>						
Cro-Magnon <sup>h</sup>	0.030	1,600,000	1,493,696	4.14	152.59	43.02
Skhül 4 <sup>i</sup>	0.080	1,555,000	1,452,266	4.12	149.70	42.19
Skhül 5 <sup>i</sup>	0.080	1,520,000	1,420,031	4.10	147.44	41.54
Skhül 6 <sup>i</sup>	0.080	1,585,000	1,479,888	4.13	151.63	42.75
Qafzeh 6 <sup>i</sup>	0.100	1,570,000	1,466,078	4.12	150.67	42.47
Living humans <sup>j</sup>						
Males						
Mean		1,467,000	1,371,198	4.07	143.99	40.55
-2 SD		1,211,000	1,134,959	3.92	126.67	35.58
+2 SD		1,723,000	1,606,857	4.20	160.33	45.24
Females						
Mean		1,299,000	1,216,238	3.97	132.75	37.33
-2 SD		1,089,000	1,022,138	3.84	117.99	33.09
+2 SD		1,509,000	1,409,898	4.09	146.73	41.34
Living apes <sup>k</sup>						
Chimpanzee						
Mean		400,000	380,742	3.15	60.42	16.57
-2 SD		391,000	372,204	3.13	59.50	16.31
+2 SD		409,000	389,188	3.16	61.32	16.83
Gorilla						
Mean		469,000	445,427	3.25	67.20	18.51
-2 SD		452,000	429,503	3.23	65.56	18.04
+2 SD		486,000	461,342	3.27	68.81	18.98
Orang-utan						
Mean		397,000	377,927	3.14	60.11	16.48
-2 SD		385,000	366,661	3.13	58.89	16.13
+2 SD		409,000	389,188	3.16	61.32	16.83

SOURCES: Unless otherwise indicated, cranial capacities are from Aiello and Dean (1990) and estimated geological ages from Leig<sup>l</sup> (1992).

<sup>a</sup>Klein (1989). The date of 3.1 is an average taking into consideration the dating anomalies of the Hadar Formation.

<sup>b</sup>Vrba (1985). The age of Sterkfontein Mb4 is given as midpoint of the range for this member (2.4–3.0 million years ago).

<sup>c</sup>Feibel, Brown, and McDougall (1989).

<sup>d</sup>The dates for the Ngandong fossils may be considerably younger (Bartstra et al. 1988).

<sup>e</sup>Grün and Stringer (1991).

<sup>f</sup>Stringer (1979) for estimated cranial capacity.

<sup>g</sup>Klein (1989).

<sup>h</sup>Clarke (1985).

<sup>i</sup>Trinkaus (1983).

<sup>j</sup>Martin (1986).

<sup>k</sup>Ashton and Spence (1958).

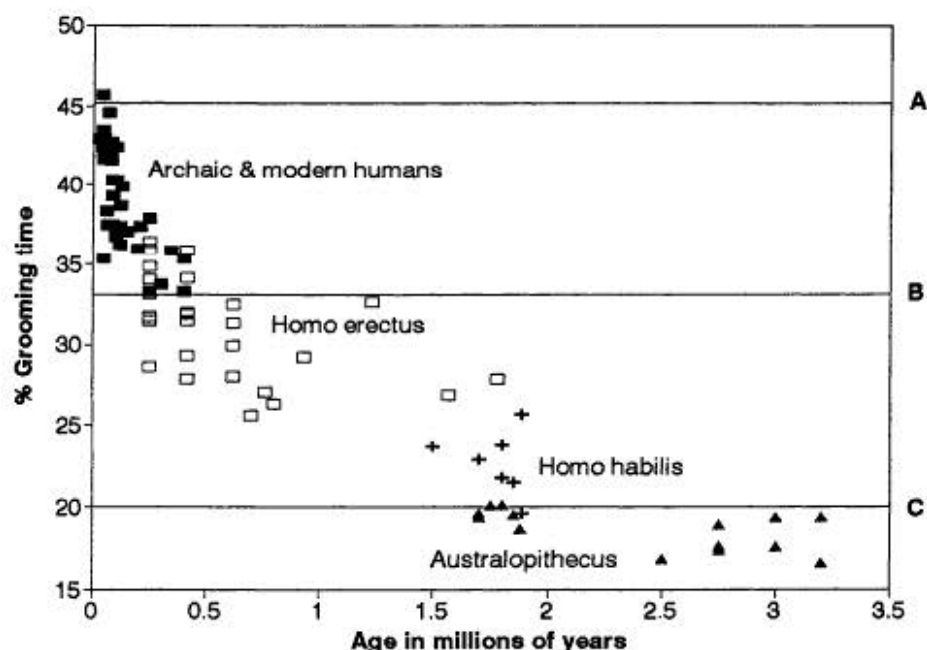


FIG. 3. Predicted grooming time requirement and time.  $\blacktriangle$ , australopithecines; +, *H. habilis/rudolfensis*;  $\square$ , *H. erectus*;  $\blacksquare$ , archaic *H. sapiens*, Neanderthals, early modern *H. sapiens*. A and B, 95% confidence limits for predicted grooming time in living humans (A = two standard deviations above the modern human mean for males; B = two standard deviations below the modern human mean for females). C, maximum percentage grooming time observed in living primates (20%).

duce fully articulate human speech, it does indicate that hominids as early as Kabwe in Africa and Steinheim in Europe (ca. 250,000 years ago) would have had vocal tracts capable of producing the full range of modern speech sounds.

It is at this stage of hominid evolution that vocal grooming alone would not have been sufficient. In groups of the size typical of non-human primates (and

of "vocal-grooming" hominids), social knowledge is acquired by direct, first-hand interaction between individuals. This would not be possible in the large groups characteristic of modern humans, where cohesion can only be maintained if individuals are able to exchange information about behaviour and relationships of other group members. By the later part of the Middle Pleistocene (about 250,000 years ago), groups would have become so large that language with a significant social information content would have been essential.

This is not necessarily to suggest, however, that there was a sudden appearance of fully developed symbolic language at the archaic *H. sapiens* stage of hominid evolution. Rather, modern symbolic communication might be expected to have emerged gradually in response to continuing pressures for more efficient social cohesion and would likely have been associated with the development of codified kinship systems and religion. Although the current analysis cannot suggest precisely when fully modern symbolic language evolved, it does suggest that it was a gradual outgrowth of the evolution of enhanced vocal communication that first got under way almost 2 million years ago with the earliest members of the genus *Homo*.

If this account is correct, then the question becomes why the ancestral humans should have needed to evolve such large groups. Within the primates, predation risk

TABLE 2  
Predicted Percentage Grooming Time for Fossil and Modern Hominids

Taxon	N	Mean	S <sub>2</sub>
<i>Australopithecus</i>	16	18.44*	1.54
<i>H. habilis/rudolfensis</i>	7	22.73*	3.29
<i>H. erectus</i>	23	30.97*	9.85
Archaic <i>H. sapiens</i>	18	37.88	8.98
Neanderthals	15	40.46	10.15
Modern <i>H. sapiens</i> (females)	120	37.33	4.37
Modern <i>H. sapiens</i> (males)	541	40.55	5.95

NOTE: Specimens included in each fossil taxon are indicated in table 1. S<sub>2</sub>, variance; N, sample size.

\* Significantly different from modern human females at  $P < 0.05$ .

seems to be the main factor dictating group size (see van Schaik 1983, Dunbar 1988; but, for a contrary view, see Wrangham 1980). However, given that many of the terrestrial Old World monkeys and apes are able to circumvent the problems posed by high predation risk with groups of only moderate size, it seems implausible that hominids required groups nearly three times larger when their intrinsic risk of predation would in any case have been lower by virtue of their larger body size (see Struhsaker 1967, Dunbar 1988).

There would appear to be only three plausible explanations for the development of such large human groups. One is that the habitats they occupied presented proportionately higher risks of predation than those typically occupied by baboons, macaques, and chimpanzees today. The fact that baboons and chimpanzees are primarily forest-edge or woodland species whereas the ancestral hominid niche may have been more open grassland would lend some support to this suggestion. Baboon groups inhabiting more open habitats are significantly larger than those occupying more wooded habitats (Dunbar 1988: fig. 7.6), though they still do not approach the size of human groups. However, the only primate that preferentially occupies open grassland habitats (the gelada) does exhibit a level of grouping that is unusually large by primate standards—populations as large as 270 having been recorded (Dunbar 1984). That increasing aridity of the East African environment coincides with the appearance of early members of the genus *Homo* (*habilis*, *rudolfensis*, and *erectus*) (Behrensmeyer and Cooke 1984) may explain the relatively large groups predicted for these hominids, but it is unlikely that the even larger groups that appear to be typical for early *H. sapiens* could have the same origin.

The second possibility is that human groups are in fact larger than necessary to provide protection against predators because they are designed to provide protection against other human groups (a suggestion originally mooted by Darwin 1981 [1871] and elaborated more recently by Alexander 1989). Competition for access to resources might be expected to lead to an evolutionary arms race because the larger groups would always win. Some evidence to support this suggestion may lie in the fact that competitive aggression of this kind resulting in intraspecific murder has been noted in only one other taxon besides humans, namely, chimpanzees (see Manson and Wrangham 1991). Increased body size might also be interpreted as a response to increased intraspecific competition.

The third possibility has to do more with the dispersed nature of traditional human societies and their associated nomadic life-style. Given that large-scale migration seems to be a major human adaptation, it may have been necessary to ensure that migrating groups had ready access to water holes and food sources over a very wide area. One way of doing this might have been to ensure that social relationships could be maintained among many neighbouring groups of more conventional size. Such an explanation would mesh well with the conventional picture of hunter-gatherer societies living

in marginal habitats (see, e.g., Lee 1982, Johnson and Earle 1987) and would explain why such societies often consist of smaller groups (bands or night camps) embedded in larger units (regional groupings). This would also explain why the major stages in the evolution of human brain size appear to coincide with major episodes of migration. *H. erectus* (with brain size, inferred group size, and percentage grooming time halfway between the apes and modern humans) was the first hominid to spread out of Africa. There is also accumulating anatomical evidence for increased population movement, particularly into eastern Asia, at the archaic *H. sapiens* level (Aiello 1993).

Unfortunately, until we can determine the ecological factors determining the exact size of primate groups, this problem appears to be insoluble. What is clear, however, is that the evolution of larger groups and the concomitant development of effective vocal communication with an increasing symbolic content were probably relatively slow and gradual and need not have had the same cause or combination of causes throughout their course. In the earlier stages, predation (or predation in combination with increasing migration) may have been most important. In the later stages, intergroup conflict (which could well have been associated with continuing large-scale population movement) may have become the dominant factor. The basic point, however, is that pressure for large groups seems to be the driving factor behind the evolution of human language and all of the cultural manifestations associated with it.

This model avoids many of the pitfalls that have plagued other theories of the origin of language. Not only does it allow us to predict when language began to evolve but also it provides us with a selective pressure for enhanced vocal communication that does not presuppose cognitive capacities themselves dependent on linguistic ability. Specifically, it emphasizes the social context of the emergence of language without presupposing the prior existence of social categories which themselves depend on linguistic constructs. The postulated necessity for larger groups and consequently enhanced vocal communication as an efficient social bonding mechanism also provides a selective pressure that would affect the relative fitness of individuals within the context of the broader ecological constraints which they faced. Furthermore, this model is consistent with other lines of evidence from diverse fields (e.g., palaeoneurology, comparative anatomy, developmental psychology, and primate cognition) supporting a relatively early occurrence of enhanced vocal communication in the hominid line and emphasizing the points of similarity and continuity between modern human symbolic language and non-human primate vocalization.

## References Cited

- AIELLO, L. C. 1993. The origin of modern humans: The fossil evidence. *American Anthropologist*. In press.
- AIELLO, L. C., AND M. C. DEAN. 1990. *An introduction to human evolutionary anatomy*. London: Academic Press.



- ALEXANDER, R. D. 1989. "Evolution of the human psyche," in *The human revolution*. Edited by P. Mellars and C. B. Stringer, pp. 455-513. Edinburgh: Edinburgh University Press.
- ASHTON, E. H., AND T. F. SPENCE. 1958. Age changes in the cranial capacity and foramen magnum of hominoids. *Proceedings of the Zoological Society of London* 130:169-81.
- BARTSTRA, G.-J., S. SOEGONDHO, AND A. VAN DER WIJK. 1988. Ngandong man: Age and artifacts. *Journal of Human Evolution* 17:325-37.
- BEHRENSMEYER, A. K., AND H. B. S. COOKE. 1984. "Paleoenvironments, stratigraphy, and taphonomy in the African Pliocene and Early Pleistocene," in *Ancestors: The hard evidence*. Edited by E. Delson, pp. 60-62. New York: Alan R. Liss.
- BIRDSELL, J. B. 1970. Local group composition among the Australian Aborigines: A critique of the evidence from fieldwork conducted since 1930. *CURRENT ANTHROPOLOGY* 11:115-42.
- BRADSHAW, J. L. 1991. Animal asymmetry and human heredity: Dextrality, tool use, and language in evolution, 10 years after Walker (1980). *British Journal of Psychology* 82:39-59.
- CALVIN, W. H. 1983. A stone's throw and its launch window: Timing, precision, and its implications for language and the hominid brain. *Journal of Theoretical Biology* 104:121-35.
- CHASE, P. G., AND H. L. DIBBLE. 1987. Middle Paleolithic symbolism: A review of current evidence and interpretations. *Journal of Anthropological Archaeology* 6:263-96.
- CLARKE, R. I. 1985. "A new reconstruction of the Florisbad cranium, with notes on the site," in *Ancestors: The hard evidence*. Edited by E. Delson, pp. 301-5. New York: Alan R. Liss.
- DARWIN, C. 1981 [1871]. *The descent of man*. Princeton: Princeton University Press.
- DUCHIN, L. E. 1990. The evolution of articulate speech: Comparative anatomy of the oral cavity in *Pan* and *Homo*. *Journal of Human Evolution* 19:687-98.
- DUNBAR, R. I. M. 1984. *Reproductive decisions: An economic analysis of the social strategies of gelada baboons*. Princeton: Princeton University Press.
- . 1988. *Primate social systems*. London: Chapman and Hall.
- . 1991. Functional significance of social grooming in primates. *Folia Primatologica* 57:121-31.
- . 1992. Neocortex size as a constraint on group size in primates. *Journal of Human Evolution* 22:469-93.
- . n.d. Co-evolution of neocortex size, group size, and language in humans. *Behavior and Brain Sciences*. In press.
- FALL, D. 1980. Hominid brain evolution: The approach from paleoneurology. *Yearbook of Physical Anthropology* 23:93-107.
- . 1983. Cerebral cortices of East African early hominids. *Science* 221:1072-74.
- FEIBEL, C. S., F. H. BROWN, AND I. MCDUGALL. 1989. Stratigraphic context of fossil hominids from the Omo group deposits: Northern Turkana Basin, Kenya and Ethiopia. *American Journal of Physical Anthropology* 78:595-622.
- FOLLY, R. A. 1991. Language origins: The silence of the past. *Nature* 353:114-15.
- FORGE, A. 1972. "Normative factors in the settlement size of Neolithic cultivators (New Guinea)," in *Man, settlement, and urbanism*. Edited by P. Ucko, R. Tringham, and G. Dimbleby, pp. 363-76. London: Duckworth.
- GIBSON, K. 1991. Tools, languages, and intelligence: Evolutionary implications. *Man* 26:255-64.
- GRÖN, R., AND C. B. STRINGER. 1991. Electron spin resonance dating and the evolution of modern humans. *Archaeometry* 33:153-99.
- HOLLOWAY, R., AND C. DE LA COSTE-LAREYMONDIE. 1982. Brain endocast asymmetry in pongids and hominids: Some preliminary findings on the paleontology of cerebral dominance. *American Journal of Physical Anthropology* 58:101-10.
- IWAMOTO, T., AND R. DUNBAR. 1983. Thermoregulation, habitat quality, and the behavioural ecology of gelada baboons. *Journal of Animal Ecology* 52:357-66.
- JOHNSON, A. W., AND T. EARLE. 1987. *The evolution of human societies: From foraging group to agrarian state*. Stanford: Stanford University Press.
- JOLLY, C. 1970. The seed-eaters: A new model of hominid differentiation based on a baboon analogy. *Man* 5:5.
- KLEIN, R. 1989. *The human career*. Chicago: University of Chicago Press.
- LAITMAN, J. T., R. C. HEIMBUCH, AND E. S. CRELIN. 1979. The basicranium of fossil hominids as an indicator of their upper respiratory systems. *American Journal of Physical Anthropology* 51:15-34.
- LEE, R. B. 1982. *The !Kung San: Men, women, and work in a foraging society*. Cambridge: Cambridge University Press.
- LEIGH, S. R. 1992. Cranial capacity evolution in *Homo erectus* and early *Homo sapiens*. *American Journal of Physical Anthropology* 87:1-14.
- LIEBERMAN, P. 1989. "The origins of some aspects of human language and cognition," in *The human revolution*. Edited by P. Mellars and C. B. Stringer, pp. 391-414. Edinburgh: Edinburgh University Press.
- MAC DONALD, C. B. 1955. "Company," in *Encyclopedia Britannica*, 14th edition, 6:143-44.
- MANSON, J. H., AND R. W. WRANGHAM. 1991. Intergroup aggression in chimpanzees and humans. *CURRENT ANTHROPOLOGY* 32:369-90.
- MARTIN, R. D. 1986. "Ontogenetic and phylogenetic aspects of human brain size," in *Définition et origines de l'Homme*, pp. 325-41. Paris: CNRS.
- . 1989. *Primate origins and evolution*. London: Chapman and Hall.
- MELLARS, P. 1991. Cognitive changes and the emergence of modern humans. *Cambridge Archaeological Journal* 1:63-76.
- NAROLL, R. 1956. A preliminary index of social development. *American Anthropologist* 58:687-715.
- NOBLE, W., AND I. DAVIDSON. 1991. The evolutionary emergence of modern human behaviour: Language and its archaeology. *Man* 26:222-53.
- PARKER, J. T., AND K. R. GIBSON. 1979. A developmental model for the evolution of language and intelligence in early hominids. *Behavioral and Brain Sciences* 2:367-407.
- PRICE, D., AND D. BEAVER. 1966. Collaboration in an invisible college. *American Psychologist* 21:1011-18.
- RICHMAN, B. 1976. Some vocal distinctive features used by gelada monkeys. *Journal of the Acoustic Society of America* 60:718-24.
- . 1978. The synchronisation of voices by gelada monkeys. *Primates* 19:569-81.
- . 1987. Rhythm and melody in gelada vocal exchanges. *Primates* 28:199-223.
- SAVAGE-RUMBAUGH, E. S. 1986. *Ape language: From conditional response to symbol*. Oxford: Oxford University Press.
- SAWAGUCHI, T., AND H. KUDO. 1990. Neocortical development and social structure in primates. *Primates* 31:283-90.
- SERVICE, F. R. 1962. *Primitive social organization: An evolutionary perspective*. New York: Random House.
- STEPHAN, H., H. FRAHM, AND G. BARON. 1981. New and revised data on volumes of brain structures in insectivores and primates. *Folia Primatologica* 35:1-29.
- STEWART, J. H. 1955. *Theory of culture change: The methodology of multilineal evolution*. Urbana: University of Illinois Press.
- STRINGER, C. B. 1979. A re-evaluation of the fossil human calvaria from Singa, Sudan. *Bulletin of the British Museum of Natural History (Geology)* 32:77-83.
- STRUHSAKER, T. T. 1967. Ecology of vervet monkeys (*Cercopithecus aethiops*) in the Masai-Amboseli Game Reserve, Kenya. *Ecology* 48:891-904.
- TOBIAS, P. 1987. The brain of *Homo habilis*: A new level of organization in cerebral evolution. *Journal of Human Evolution* 16:741-62.
- . 1991. *Olduvai Gorge*. Vol. 4. *The skulls, endocasts, and*

- teeth of *Homo habilis*. Cambridge: Cambridge University Press.
- TOTH, N. 1985. Archaeological evidence for preferential right-handedness in the Lower and Middle Pleistocene, and its possible implications. *Journal of Human Evolution* 14:607-14.
- TRINKAUS, E. 1983. *The Shanidar Neandertals*. New York: Academic Press.
- VAN SCHAIK, C. P. 1983. Why are diurnal primates living in groups? *Behaviour* 87:120-44.
- VRBA, E. S. 1985. "Early hominids in southern Africa: Updated observations on chronological and ecological background," in *Hominid evolution: Past, present, and future*. Edited by P. V. Tobias, pp. 195-200. New York: Alan R. Liss.
- WHITE, R. 1982. Rethinking the Middle/Upper Paleolithic transition. *CURRENT ANTHROPOLOGY* 23:169-92.
- WRANGHAM, R. W. 1980. An ecological model of female-bonded primate groups. *Behaviour* 75:262-300.
- WYNN, T. 1991. "Archaeological evidence for modern intelligence," in *The origins of human behaviour*. Edited by R. A. Foley, pp. 52-66. London: Unwin Hyman.

## Calendar

1993

- April 11-16. Asociación de Lingüística y Filología de la América Latina, 10th International Congress, Veracruz, Mexico. Write: Juan López Chávez, Facultad de Filosofía y Letras, Torre de Humanidades I, 3er. piso, cubículo 20, Universidad Nacional Autónoma de México, México, D.F., Mexico.
- April 14-17. American Association of Physical Anthropologists, Annual Meeting, Toronto, Ont., Canada. Write: Jere Haas, Division of Nutritional Sciences, 211 Savage Hall, Cornell University, Ithaca, N.Y. 14853-6301, U.S.A.
- April 23-24. Society for Economic Anthropology, Annual Meeting, Durham, N.H., U.S.A. Theme: Economic Analysis beyond the Local System. Write: Richard Blanton, Sociology-Anthropology, Purdue University, West Lafayette, Ind. 47907, U.S.A.
- April 29-May 1. International Round Table on Highland-Zone Exploitation in Southern Europe, Brescia, Italy. Write: Paolo Biagi, Museo Civico di Scienze Naturali, Via Ozzanum 4, I-25128 Brescia, or John G. Nandris, Institute of Archaeology, University College, 31-34 Gordon Square, London WC1H 0PY, England.
- June 3-6. International Society for the Comparative Study of Civilizations, Annual Meeting, Scranton, Pa., U.S.A. Write: Raymond Lewis, Department of Social Science, Eastern Kentucky University, Richmond, Ky. 40475-3119, U.S.A.
- June 4-7. Nordic Anthropological Film Association, 13th International Conference, Reykjavik, Iceland. Theme: The Construction of the Viewer. Write: S. B. Hafsteinsson, Faculty of Social Science, University of Iceland, 101 Reykjavik, Iceland.
- June 11-15. International Association for Impact Assessment, 12th Annual Meeting, Shanghai, China. Theme: Development and the Environment. Write: Zhou Liang-Yi, Shanghai Institute of Science and Technology Management, Shanghai 201900, China; Alan L. Porter, Industrial and Systems Engineering, Georgia Institute of Technology, Atlanta, Ga. 30332-0205, U.S.A.; or, for sessions on Cultural Resources and Remote Sensing, E. Pendleton Banks, Wake Forest University, P.O. Box 7807, Winston-Salem, N.C. 27109, U.S.A.
- June 26-July 1. *Pithecanthropus* Centennial: International Congress and Exhibition, Leiden, The Netherlands. Theme: Human Evolution in Its Ecological Context. Write: Hans Beijer, Geological Survey of the Netherlands, P.O. Box 157, NL-2000 AD Haarlem, The Netherlands.
- July 22-27. 4th World Conference on Human Ecology, Mérida, Yucatán, Mexico. Theme: *Homo sapiens*, an Endangered Species: Toward a Global Strategy for Survival. Write: Centro de Investigación y de Estudios Avanzados del IPN-Unidad Mérida, Sección de Ecología Humana, Km 6 Antigua Carretera a Progreso, A.P. 73 "Cordemex," C.P. 97310 Mérida, Yucatán, Mexico.
- July 26-30. Association of Social Anthropologists of the Commonwealth, 4th Decennial Conference, Oxford, England. Theme: The Uses of Knowledge: Global and Local Relations. Write: Wendy James, Institute of Social Anthropology, University of Oxford, 51 Banbury Rd., Oxford OX2 6PF, England (programme details and booking) or Marilyn Strathern, Department of Social Anthropology, University of Manchester, Brunswick St., Manchester M13 9PL, England (for information about organising sections to run parallel to the ASA programme).
- July 28-August 5. International Union of Anthropological and Ethnological Sciences, 13th Congress, México, D.F., Mexico. Theme: Cultural and Biological Dimensions of Global Change. Write: Linda Manzanilla, Instituto de Investigaciones Antropológicas, Universidad Nacional Autónoma de México, Ciudad Universitaria, Coyoacán, D.F. 04510, Mexico.
- August 8-14. Four Million Years of Hominid Evolution in Africa: International Congress in Honour of Dr. Mary D. Leakey's Outstanding Contribution in Palaeoanthropology, Arusha, Tanzania. Write: C. C. Magori, P.O. Box 65453, Dar es Salaam, Tanzania.
- August 17-23. 7th International Conference on Hunting and Gathering Societies, Moscow, Russia. Write: Linda Ellanna, Department of Anthropology, University of Alaska, Fairbanks, Alaska 99775, U.S.A.