Craniodental variability in the domestic dog (*Canis familiaris*) and its Implications for the Variability in Primates

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Abstract

The domestic dog (*Canis familiaris*) constitutes a species that has attained considerable variability in historic times. The crania and dentition of a sample of the domestic dog *Canis familiaris* have been statistically analyzed with methods that have been employed to determine variability in other species. The results point to a degree of variation in the dog crania and dentition that may be a useful tool for creationists in determining the boundaries of the holobaramins (created kinds).

The results obtained from dog crania do not support the division of *Homo erectus* into two, or more, different species, but are compatible with the hypothesis that they are all part of one species.

Variability in the cranium and dentition of this living monobaramin (*Canis familiaris*) suggest that *H. erectus*, archaic *H. sapiens* fossils of diverse origin, and *H. sapiens sapiens* should be lumped into one kind (holobaramin[1]).

The degree of morphological variability in domestic dogs is an important tool for assessing the variability of extinct kinds, and the limits of morphological variability within living beings.

Introduction

The domestic dog has been used by creationists as an example of a creature showing great variation in a short time. This study quantifies the variability of cranial and dental traits of *Canis familiaris*. Although the data obtained are limited, I will utilize them to study the limits of holobaramins[1] of primates, with special attention to the holobaramin that includes human beings—both current and fossil.In this report it is largely cranial traits that have been examined, although some dental measurements have been utilized as well.

The variability has been analyzed by the coefficient of variation, with the range expressed as a percentage of the average, and the index of the minimum and maximum values. Whenever possible, an F-test was used to compare standard deviations.

Using this method the results support a degree of variation in *Canis familiaris* that is equivalent to (or greater than) the variation found in the mix of various near species of genus *Canis*. When the data from several *H.erectus* fossils from both Asiatic and African regions are mixed, their cranial variability is less than that which we find in the domestic dog, and this variability does not generally exceed, the variability (CV) which is considered the usual maximum for a single mammal species. Using the same methodology and standards, a mix of the data of *H.erectus*, archaic *H.sapiens*, and *H.sapiens sapiens* specimens shows that all these species should be lumped into one holobaramin. This work is the continuation and complement of my previously published article (García-Pozuelo-Ramos 1998).

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[1] In this paper I frequently use the words *holobaramin* and *monobaramin*. They are defined according to ReMine (1990): a holobaramin is “A complete set of organisms related by common descent. A group containing all and only those organisms related by common descent.” A monobaramin is “A group containing only organisms related by common descent, but not necessarily all of them.”

Materials and Methods

My data include measurements taken from my own set of dog crania and data from authors cited in the text The dimensions measured were chosen because of their relevance and ease of handling, and are described in Table I and Figure 1. The data for *H. erectus*, archaic *H. sapiens*, and *H. sapiens sapiens* come from several sources. The fossils studied are given in Table II with the number of teeth or skulls analyzed for each case. The craniometric points are as listed in Figure 2.

I used the coefficient of variation, CV[2]. The range is expressed as a percentage of the average—R%; and the index between the maximum and minimum value is $I^{max}/_{min}$. These statistical tools are frequently used in paleontology to determine if different species were included in one fossil sample (e.g. Gingerich, 1974; Cope and Lacy, 1992; Martin and Andrews, 1993; Teaford, Walker, and Mugaisi, 1993; Thomson, 1996). For an additional discussion on these statistical tools, see García-Pozuelo-Ramos (1998).

The criteria used in this study to determine whether the variability in the domestic dog exceeds the variability of the species taxon are based on the work of Martin and Andrews (1993) as well as Thomson (1996), who use mixes of species similar to the one being studied; and Simpson, Roe, and Lewontin (1960) who gave a value of 10 for the CV as the maximum value of variability belonging to a single species. I use a CV limit of 10 as well as the intrinsic variation (the variance or standard deviation of the logarithm of the measurements as in Lewontin, 1966) because it is invariant under a multiplicative change. This compares the variability among different beings like canids and primates in a more effective manner. The intrinsic variation allows a demonstration of similarities even when there is a reduced number of data, as it is usually the case with fossils (Lewontin, 1966). An additional advantage of the intrinsic variation over the CV is that all the usual statistical tests can be performed (Lewontin, 1966).When it has been possible, I have carried out the F-test in order to compare the significance of the differences between different intrinsic variations of humans and dogs. The utilization of F-test to determine the significance of the differences in intrinsic variation of several samples has been demonstrated by Uchida (1996). No matter which method is used, however, one can never say with absolute certainty that a particular sample is composed of just one species (Martin and Andrews, 1993). The data can demon-

Table I. Description of the skull measurements taken from the domestic dog sample. The lettered distances here are shown in Figure 1.

(a’):	Condylobasal length.
(b’):	Maximum skull width across the zygomatic arches.
(c’):	Skull breadth across the mastoid process.
(d’):	Postorbital process width.
(e’):	Interorbital breadth.
(f’):	Minimum width of cranium at postorbital constriction.
(g’):	Cranial vault width to parietal-temporal suture.
(i’):	Face length.
(j’):	Length of auditory bulla from the carotid channel to the farthest back area.
(k’):	Basicranial axis length.
(l’):	Alar caudal foramen to alar rostral foramen arch length.

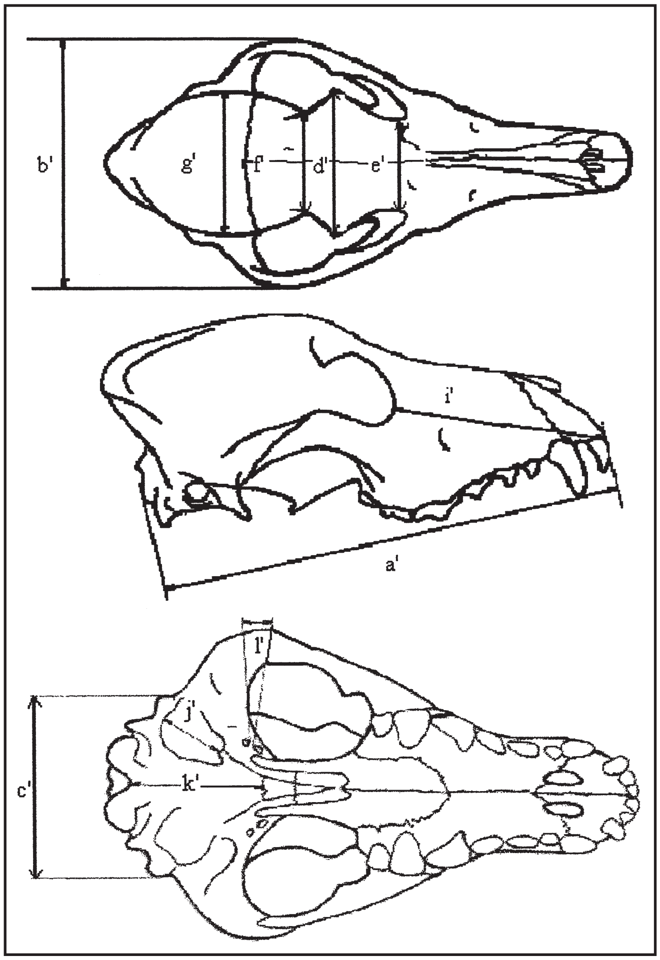

Figure 1. Cranial measurements taken on domestic dog skulls. The lettered measurements shown here are named in Table I.

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[2] CV is the standard deviation expressed in percent to the arithmetic mean of the given population. The Coefficient of Variation is used to compare the variation of a measurement (for example, the length of legs) in different populations or species, independently of the magnitude of their measurement (for example, to compare the length of the legs of elephants with the length of legs of horses).

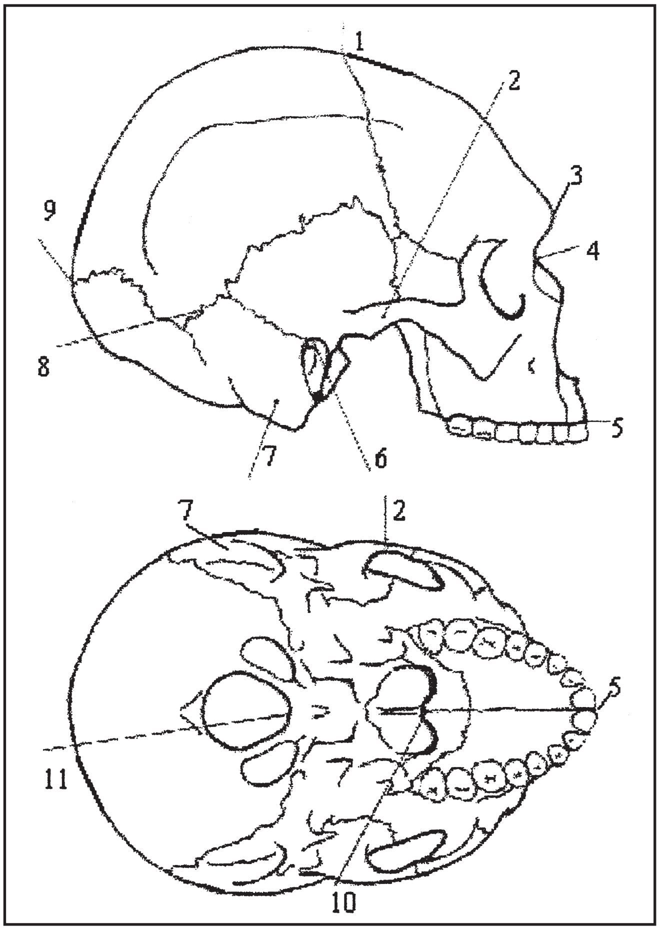

Figure 2. Cranial landmarks on skulls of *Homo sapiens*. (1) Bregma. (2) Zygomatic arch. (3) Glabela. (4) Nasion. (5) Prosthion. (6) Auricular. (7) Mastoidal process. (8) Asterion. (9) Lambda. (10) Staphylion. (11) Basion.

strate the presence of more than one species with some degree of certainty.

Table II. List of teeth and skulls utilized in mix of *H. sapiens sapiens*, archaic *H. sapiens* and *H. erectus*. The numbers in parentheses following each type of specimen refer to origin of data.

Teeth

Homo sapiens sapiens: KS 81001 B,C,D,E,H (1); KP 79501 (1); Krm 13400, 14696, 16424 (2); 262587, 304095, 320916, 339064 (3).

Archaic *Homo sapiens*: Xujiayao (1); Changyang (1); PA 74, 874, 875 (1); Ehringsdorf (3); Le Moustier (3); Spy 1, 2 (3); La Quina H5 (3); Krapina (3); L.H.18 (4); Dmanisi (5); Thomas Quarry 1 (5); Mauer (5).

Homo erectus: Chenjiawo (1); PA 637, 836, 838, 839 (1); *H. erectus pekinensis* (1); KNM-ER 820, 922, 3733 (6); KNM-WT 15000 (6); Sangiran 4, 5, 17 (6); Tighenif 1, 2, 3 (6); Trinil 4 (6).

Skulls

Homo sapiens sapiens: Liujiang (1); Zhoukoudian 101, 102, 103 (1); Cohuna (7); Kow Swamp 1, 5, 14 (7) Cossack (8); 792 (9); 279540 (10); 23, 1303, 1417, 1420, 219263 (11); 228017 (12); 7539-10, 242869, 283619, 378403 (13); 3780, 3786, 3811, 3829, 3839, 4040, 4042, 4071, 4080 (14).

Archaic *Homo sapiens*: Dali (1); Jinniushan (1); Rhodesia (3); Neander (3); Spy 1, 2 (3); Gibraltar (3); Monte Circeo (3); Petralona (3); Cr 4, 5, 6 (15); Ndutu (16); Steinheim (16); La Ferrassie 1 (17); La Chapelle aux Saints (17); La Quina (17); Le Moustier (17); Danakil (18).

Homo erectus: Gongwangling (1); Hexian (1); *H. erectus pekinensis* II, III, V, X, XI, XII (1); KNM-ER 3733, 3883 (6); OH 9(6); Sangiran 2, 4, 10, 12, 17 (6); Trinil 2 (6).

References

(1) Wu, and Poirier (1995). (2) Rightmire, and Deacon (1991). (3) Hrdlicka (1930). (4) Day et al. (1980). (5) Gabunia, and Vekua (1995). (6) Wood (1991). (7) Thorne, and Wolpoff (1981). (8) Freedman, and Lofgren (1979). (9) Burkitt, and Hunte (1922). (10) Hrdlicka (1924). (11) Hrdlicka (1928). (12) Hrdlicka (1927). (13) Hrdlicka (1944). (14) Shapiro (1929). (15) Arsuaga et al. (1997). (16) Clarke (1990). (17) Heim (1974). (18) Abate (1998).

Results and Discussion

Comparison of the coefficient of variation between measurements from skulls of different canids shows that the CV values for the domestic dog (*Canis familiaris*) generously exceed the CV values of different species and mixes of canis, called Mix1 and and Mix2 (Table III and Figure 3). The width of the neurocranium (g'), however, is an exception in that this width is similar in the dog and the other canid species analyzed. The g' value for domestic dog is less than 10 and is less than the g' value for Mix1 and Mix2 (Table III and Figure 3).

Morey (1992) has studied a sample of 65 dogs from several different archeological sites. I have compared the sample of dogs studied by Morey (1992) with my sample of 43 domestic dogs in three measurements —a' (length of cranium), g' (cranium width), and i' (length of face). The three measurements show a greater CV value in my sample, especially in the length of the cranium (a'), and the length of the face (i') (Table III and Figure 4). These data suggest that within historical times the morphological diversification of the domestic dog has increased.

In the order Primates, the mix of seven species of guenons (genus *Cercopithecus*) manifests a variability CV below 10 except in basion-prosthion length (16 of Ta-

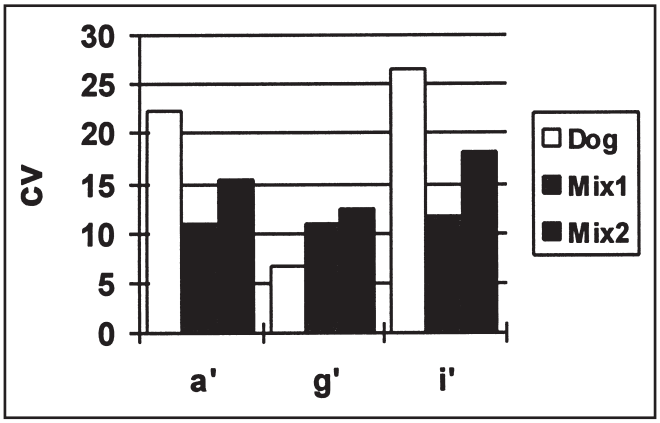

Figure 3. Comparison of the coefficient of variation between cranial dimensions of domestic dog and Mix1 (*C.lupus* and *C.latrans*), and Mix2 *C.lupus*, *C.latrans*, and *C.aureus*). The lettered items are listed in Table I and illustrated in Figure 1.

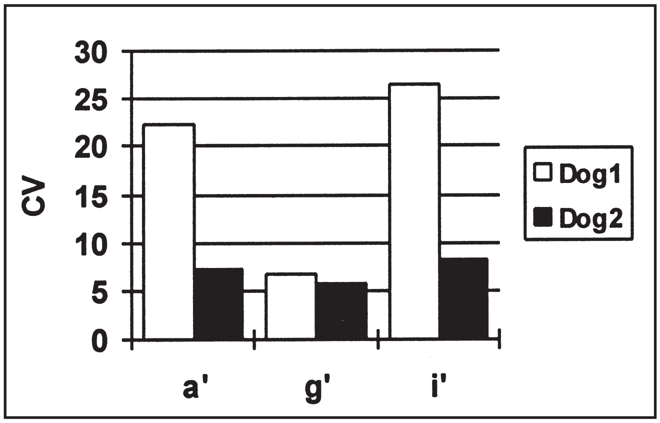

Figure 4. Comparison of the coefficient of variation between cranial dimensions of domestic dog, Dog1: author's collection, and Dog2: archaeological collection after Morey (1992). The lettered items are listed in Table I and illustrated in Figure 1.

ble IV) and staphylion-basion length (26 of Table IV). The three measurements that have been possible to compare between the *Cercopithecus* mix and *Canis familiaris* (postorbital constriction—6 of Table IV and f' of Table VI ; interior biorbital breadth—19 of Table IV and e' of Table VI; and bizygomatic breadth—20 of Table IV and b' of Table III) show the greater variability in the domestic dog. Hence, *Cercopithecus* represents one morphologically coherent group, just as has been suggested by some authors (Hartwig-Scherer, 1993; García-Pozuelo-Ramos, 1997; Robinson and Cavanaugh, 1998).

In the case of the mix of data of three pongids—*Gorilla gorilla* (the gorilla), *Pan troglodytes* (the chimpanzee), and *Pongo pygmaeus* (the orangutan)—the postorbital constriction is less variable than in the dog. The

Table III. Comparison of the coefficient of variation between measurements from skull of different canids and mixes.

Canids	a'	b'	c'	e'	g'	i'
Dog1	22.2(43)	15.8(40)	18.8(41)	20.5(41)	6.8(42)	26.5(43)
Dog2 (1)*	7.3	-	-	-	5.6	8.2
Canis lupus(1)*	5.2	-	-	-	3.8	5.5
Canis latrans(1)*	4.4	-	-	-	3.9	5.5
Canis aureus(1)*	7.0	-	-	-	4.9	8.2
Mix1(1)*	10.9	-	-	-	10.8	11.6
Mix2(1)*	15.3	-	-	-	12.4	18.0
Vulpes vulpes(2)*	4.6	5.2	6.0	8.0	-	-
Lycaon pictus(3)*	-	-	-	-	6.1	3.4

The numbers in parentheses behind the CV values for Dog1 correspond to the number of specimens used in this study. The numbers in parentheses with an asterisk (standing after each category) correspond to the references for the original data in which (1)* is Morey, 1992; (2)* is Huson, and Page, 1979; and (3)* is Girman et al., 1993. Mix1 included *C. lupus* (the gray wolf), and *C. latrans* (the coyote). Mix2 contained *C. lupus*, *C. latrans*, and *C. aureus* (the golden jackal). Dog1 is the author's collection of dog skulls, and Dog2 is the archaeological collection of dog skulls in Morey (1992). Key letters in Table IX.

Table IV. Coefficient of variation, index between the maximum and minimum value and range, expressed as a percentage of average in measurements from skull in mix of *Cercopithecus* genus (guenons).

Mix of Cercopithecus	3	6	7	8	10	16	19	20	26	40
CV	8.5	4.1	7.1	8.5	6.3	12.1	6.8	9.7	13.4	7.3
Imax/min	1.7	1.2	1.4	1.6	1.4	1.6	1.4	1.5	1.7	1.4
R%	60.7	20.0	29.4	46.7	32.0	47.5	30.8	41.5	54.9	34.4

3: Basion-nasion length. 6: Postorbital constriction. 7: Biauricular breadth. 8: Anterior basicranial breadth. 10: Basion-bregma chord. 16: Basion-prosthion length. 19: Interior biorbital breadth. 20: Bizygomatic breadth. 26: Staphylion-basion length. 40: Maxilar breadth. This mix included C. aethiops, C.ascanius, C.cephus, C. l'hoesti, C. mitis, C. mona, and C. neglectus. Key numbers, and data after Verheyen (1962).

Table V. Coefficient of variation in measurements from skull of pongids.

Pongids	1	2	3	5	13	20
G. gorilla (the gorilla) (61)	6.7	6.6	6.5	6.2	8.9	11.0
P. troglodytes (the chimpanzee) (60)	3.5	3.4	5.0	5.0	7.4	5.7
P. pygmaeus (the orangutan) (53)	5.6	7.5	6.3	6.6	10.2	13.9
Mix of the three (174)	10.1	6.9	10.2	7.0	9.2	15.4

1: Maximum length. 2: Maximum breadth. 3: Basion-bregma length. 5: Post-orbital constriction. 13: Palatal breadth. 20: Bizygomatic breadth. Key numbers and data after O'Higgins, Moore, Johnson, and McAndrew (1990). The numbers in parentheses after each category at the left are the number of specimens analyzed.

variability of maximum breadth and bizygomatic breadth (2 and 20 in Table V) in a mix of pongids is similar to the variability of cranial vault width and bizygomatic breadth (g' and b' in Table III) in domestic dog (Dog1 in Table III). We cannot compare the palatal breadth of the mix of pongids with my sample of dogs, but their CV is less than 10. Only one of the six measurements (the basion-bregma length) in great apes has a CV value slightly greater than 10 (Tables III, V, VI, and Figure 2). These results support the idea suggested by some authors that all the pongids belong to the same holobaramin (García-Pozuelo-Ramos, 1997).

The mix of *H. erectus* I have studied exposes a CV in cranial traits below 10, except in the biasterionic breadth (Table VII and Figure 2). Hence, the cranial variability in *H. erectus* specimens is smaller than what is considered the limit of the species. The CV of dental measurements leads to the same conclusion (García-Pozuelo-Ramos, 1998). Kramer (1993) has also found that the variability of certain cranial measurements of *H. erectus* does not justify the division of this taxon into several species, as was proposed by other researchers (e.g. Jacob, 1976; Alexeev, 1986; Wood, 1992).

When we compare the CV for cranial variability in modern man with values for a mix of *H. erectus*, archaic *H. sapiens*, and *H. sapiens sapiens* (modern man), the mix is more variable (Tables VIII and IX). In the case of the basion-bregma length (Figure 2), the CV values in the mix of *Homo* is greater than in the mix of pongids (Tables V and IX).

Dental variability (CV, $I^{max}/_{min}$, and R%) in mix of *Homo* is lower than such variability in the domestic dog (Table IX, García-Pozuelo-Ramos, 1998). The F-test analysis demonstrates that differences between the intrinsic variability of dental measurements in the mix of *Homo* and domestic dog are significant (see Table X).

The cranial measurements that can be compared between the dog and the mix of *Homo* are few in this study. The variability (CV, $I^{max}/_{min}$, and R%) of the cranial greatest length is greater in the domestic dog than in the mix of *Homo* (Tables III and IX). The F-test analysis shows that the difference between intrinsic variability in *Homo* and *Canis familiaris* is significant for cranial greatest length (Table X). Four of the seven cranial measurements analyzed in the mix of *Homo* have a CV value of less than 10. Three of these cases are greater than CV value 10, and one of these is biasterionic breadth (Figure 2). There is no measurement of biasterionic breadth for the domestic dog in this study. However, I have compared it with cranial vault width (g' of Table I). In the dog the CV value is less than that of the mix of *Homo*. That difference is significant according to the F-test (Table X). According to these data the cranio-dental variability of the mix of *Homo* would be, at most, similar to such variability in *Canis familiaris*, when these data are taken together.

Dental variability is greater in *Canis familiaris* than in the mix of *Homo* (Table IX, and García-Pozuelo-Ramos, 1998) but it is more difficult to compare the variability between these two. In the mix of *Homo* four out of seven measurements are not greater than CV of value 10. In the case of the dog, fourteen measurements of the cranium generously exceed CV of 10. Only one, g' (cranial vault width to parietal-temporal suture, Table I and Figure 1), has a CV value less than 10 which was also less than that seen in canids mix1 and mix2 and it was close to the CV of other species of canids (Table III).

Table VI. Coefficient of variation, index between the maximum and minimum value and range, expressed as a percentage of average in measurements from skull of dog.

Dog1	d'	f'	h'	j'	k'	l'	m'	n'	o'
CV	20.1(41)	10.6(42)	21.1(39)	17.3(43)	19.7(41)	25.9(43)	22.6(40)	29.0(39)	25.6(40)
$I^{max}/_{min}$	2.2	1.7	2.4	1.8	2.0	3.1	2.1	3.3	2.4
R%	78.0	57.3	82.8	56.5	65.3	109.4	73.5	109.3	83.2

The numbers in parentheses correspond to the number of specimens measurements for each lettered data item. This table is complementary to Table III. The lettered measurements are described in Table I and illustrated in Figure 1.

Table VII. Coefficient of variation in measurements from skull of *H. erectus*.

	8	9	12	14	25	31
CV	7.5(13)	4.0(13)	4.3(13)	10.2(14)	8.7(14)	8.0(11)

8: Minimum frontal breadth. 9: Maximum parietal breadth. 12: Supramastoid breadth. 14: Biasterionic breadth. 25: Bregma-lambda length. 31: Lambda-asterion length. The numbers in parentheses correspond to the number of specimens used in this study. Key numbers and data after Wood (1991).

Table VIII. Coefficient of variation in cranial dimensions of *Homo sapiens sapiens*.

	AUB	BNL	XCB	ZYB	WCB	ASB	BPL	DKB	BBH
CV	4.4	4.3	3.8	4.8	5.4	4.5	5.3	9.7	4.2

AUB: Biauricular breadth. BNL: Basion-nasion length. XCB: Maximum cranial breadth. ZYB: Bizygomatic breadth. WCB: Minimum cranial breadth. ASB: Biasterionic breadth. BPL: Basion - prosthion length. DKB: Interorbital breadth. BBH: Basion-bregma length. Key letters, and data after Howells (1989).

Table IX. Coefficient of variation, index between the maximum and minimum value and range, expressed as a percentage of the average in measurements from skull in mix of *Homo* genus.

	1	2	3	4	5	6	7
CV	8.8(19)	7.8(19)	8.4(28)	8.1(29)	10.1(30)	10.7(30)	6.7(58)
$I^{max}/_{min}$	1.3	1.3	1.4	1.4	1.6	1.6	1.4
R%	29.8	23.6	34.1	31.0	45.1	47.9	30.1
	8	9	10	11	12	13	
CV	11.5(23)	6.0(18)	13.7(15)	9.4(47)	9.2(12)	11.8(14)	
$I^{max}/_{min}$	1.5	1.3	1.6	1.5	1.3	1.5	
R%	40.4	26.3	48.3	39.0	27.5	40.1	

1: M^1length. 2: M^1width. 3: M_1length. 4: M_1width. 5: M_2length. 6: M_2width. 7: Cranial greatest length (glabela ad maximum). 8: Basion-bregma length. 9: Basion-nasion length. 10: Bregma-lambda chord. 11: Minimum frontal breadth. 12: Biauricular breadth. 13: Biasterionic breadth. The mix is composed of *Homo erectus*, archaic *H. sapiens*, and *Homo sapiens sapiens*. The list of skulls studied is found in Table VI. The numbers in parentheses correspond to the specimens used in this study.

The variability of the basicranial axis length, k' (Table VI and Figure 1) measured from the midventral side of the foramen magnum to the basisphenoid-presphenoid suture has special significance because of the stability of the base of the cranium (Enlow, 1992). The variability of this feature (CV) is much higher than 10. It appears that not only dogs, but all canids belong to one holobaramin (Crompton, 1993). Hence, I believe that the mix of *Homo* may constitute a single holobaramin.

Under stressful conditions of domestication, the fox (*Vulpes vulpes*) increases its variability. A great part of this enhanced variability is in the same direction as that of the dog (Belyaev and Borodin, 1982). In approximately 20 years time, the wild fox altered its behavior becoming a domestic animal. It changed a few aspects of its morphology, there were hormonal changes, and it even underwent changes of the karyotype (Belyaev, 1979). Parsons (1986) has suggested that the explosions of variability concentrate in periods of environmental stress. Cases of environmental stress could have been frequent in nature on a worldwide scale after the Fall and again as a result of the Flood. But what is it that unleashes a process of variation under conditions of stress? Crossing-over, (i.e., genetic recombination) is more frequent and mutations are more common. Mobile genetic elements increase their mobility, passing from one place to another in the genome which produces alterations of genetic function (Belyaev and Borodin, 1982; Parsons, 1986). Molecular details of these processes have been seen in recent investigations. Heat-shock proteins are produced under high temperatures stress conditions. One of these proteins (Hsp90) under normal conditions involving no stress, masked certain genetic determinants in *Drosophila*. These genetic determinants were noted under stress conditions as Hsp90 changed its function and take on stress-protective functions (Rutherford and Lindquist, 1998). These genetic determinants produced morphological variants which were heritable. To demonstrate that stress played an important role in the diversification of baramins after the Fall and after the Flood would be more difficult. Currently, however, there is a theoretical possibility of checking this. Under environmental stress, a fluctuating asymmetry is produced, that is, an alteration of the organismal morphological symmetry produced by a developmental instability (Parsons, 1992). Study of fluctuating asymmetry can reveal whether or not stress was a cause for the increase in variability in living beings after the Fall and after the Flood. The great number of fossil specimens required to make this research possible, however, would present a problem.

Conclusion

Study of the cranial metric variability in a sample of *Canis familiaris* (domestic dog) makes four things clear. (1) Metric variability in the skull of *Canis familiaris* corresponds to the variability expected in a combination of more than one species of wild dogs. (2) Cranial metric variability of archaeological specimens of *Canis familiaris* is smaller than that found in living *Canis familiaris*. This demonstrates an increase of the variability of this species in historical times. (3) Cranial metric variability of *H. erectus* skulls of diverse origin confirms the interpretation that they all belong to a single species. (4) Cranial and dental metric variability in a sample of domestic dogs is close to one represented by a population composed of a mixture of data representing *H. erectus*, fossil *H. sapiens*, and *H. sapiens sapiens*. This information suggests that *H. erectus*, fossil *H. sapiens*, and *H. sapiens sapiens* should be lumped into one holobaramin.

Table X. F-tests for dogs and for the genus *Homo*.

	M1L	M1W	M1L	M2L	SL	SW
M1L	3.88/1.42 +					
M1W		4.85/1.19 +				
M1L			4.15/1.36 +			
M2L				6.51/1.94 +		
SL					10.42/0.85 +	
SW						0.88/2.56 +

SL: skull length. SW: skull width. The number to the left of the slash corresponds to intrinsic variation x 10^3, for dogs. The number to the right corresponds to the intrinsic variation x 10^3 for the Homo mix described in the caption of Table IX. The plus sign (+) indicates a statistically significant difference between the standard deviations of the two samples (P<0.05).

Although more research on other hominids is necessary, these data support the creation idea that human beings were produced by the Creator as a separate holobaramin, distinct from and unrelated to other primate or pongid holobaramins.

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