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Description of Intermediate Forms in the Evolution of *Bos primigenius f. taurus* on the Basis of Osteometric Characteristics

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Those osteometric characteristics of the aurochs and domestic cattle which clearly distinguish the two forms and at the same time indicate the existence of zones of transgression have been analysed. It was assumed that intermediate dimensions are characteristic of animals which constitute intermediate links in the evolution of the species. It was found that the smallest zone of transgression between the aurochs and cattle was exhibited in the length of the metacarpal III+IV, in the width of the proximal ends of long bones and also the length of the calcaneus. The width of the distal ends of the bones exhibited greater zones of transgression. Intermediate forms at this stage of evolution were characterised by a mosaic of metacarpal III+IV four dimensions typical of the aurochs and cattle. A common characteristic of the mosaic types was a reduction in the width of the shafts, while both ends, and in particular the distal end, of the bones retained relatively great width. The zones of transgression between *Bos taurus primigenius* and *Bos taurus brachyceros* were somewhat greater than those between the aurochs and domestic cattle.

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1. INTRODUCTION

At least two basic stages of change occur in the evolution of domestic cattle, which can be perceived both in qualitative and metric characteristics. The first stage, which involves the transition from the wild form *(Bos primigenius* Bojanus, 1827) to the domesticated *(Bos primigenius f. taurus)*, began at the turn of the Mesolithic and Neolithic, and occurred on a mass scale in the early Neolithic. It continued to the end of the Neolithic, which does not mean that sporadic domestication of aurochs may not have occurred later. Bökönyi (1984) for example points out that there is evidence in Vergil that aurochs were in northern Italy caught and domesticated to supplement herds of domestic cattle which had been ravaged by disease.

The second stage involves the transition of domestic cattle from the original, long-horned form *(Bos taurus primigenius)* to small, short-horned cattle *(Boss taurus brachyceros)* which were more advanced in the changes associated with domestication. This began in the Neolithic, and reached a peak at the turn of the Neolithic and the Bronze Age. It was concluded at the turn of the Bronze and Iron Ages, although the original, long-horned forms survived in certain areas up to the early middle ages.

The fact that the periods of transition were long — covering thousands of years — and that two and later three forms of the species existed simultaneously, allows us to expect that numerous transitional forms which were intermediate links in evolution must have existed between the forms defined as "pure".

Uerpmann (1978) said in describing the period of the beginning of domestication: "In fact, the entire population of a species was never domesticated at once. Only a part of it came under human control, and thereby changed morphologically as a result of this change in habitat. This is not a simple alteration of animal size which indicates domestication, but rather the split of a population into an unaltered, presumably wild part and an altered, presumably domesticated part".

Many scholars have noted the occurrence in archaeozoological material of bones which could not be classified on the basis of size either as aurochs or any of the forms of domestic cattle. This has usually been interpreted as the effect of variability in individual specimens or sexual dimorphism. The existence of intermediate forms in the evolution of domestic cattle has rarely been stressed in assessments of concrete osteological materials. Forms of this kind have however been described, for example in the case of the discovery of skulls indicating a mixture of characteristics of two forms of domestic cattle (Bökönyi, 1974), and of a whole skeleton placed in the ground (Lasota-Moskalewska, 1982—84).

In the present study, an attempt has been made to describe intermediate forms on the basis of an assessment of certain osteometric characteristics. This may lead to improved knowledge of the morphogenetic mechanisms connected with the domestication of cattle.

2. MATERIAL

The material used in this study consists of osteometric data collected in publications dealing with the identification of bones of the aurochs and domestic cattle (Kobryń & Lasota-Moskalewska, 1989). Use has been made of the range of variation in the dimensions of eleven osteometric characteristics, in the case of which it would be possible to establish the limits of size characteristic for intermediate forms (zones of transgression). These were the following characteristics: horncorne basal circumference (HBC); length of the collum scapulae (SCL); breadth of distal end of the humerus (HBD); breadth of proximal end of the radius (RBP); breadth of distal end of the radius (RBD); greatest length of the metacarpal III+IV (McGL); breadth of proximal end of the metacarpal

III+IV (McBP); breadth of distal end of the metacarpal III+IV (McBD); breadth of diaphysis of the metacarpal III+IV (McSD); breadth of distal end of the tibia (TBD); greatest length of the calcaneus (CGL). For intermediate forms between *Bos taurus primigenius* and *Bos taurus brachyceros,* the range of variability in four characteristcs was used (HBD, RBP, RBD, CGL). Apart from data which characterized the population, for detailed analysis use was made of the dimensions of 23 metacarpal III+IV bones of aurochs, and 66 of domestic cattle from the Neolithic period, and also of 14 radius bones of aurochs and 40 of domestic cattle from the same period.

3. METHODS

In order to obtain information on the percentage of the whole dispersion which was occupied by the zone of transgression, the size of each zone was normalized against the total dispersion of a given characteristic, on the following formula:

$$\frac{\text{zone of transgression}}{\text{max (aurochs)} - \text{min (domestic cattle)}} \times 100 \text{ (Index I)}$$

In order to obtain comparable data for all the characteristics, the size of the zone of transgression had to be related to the absolute sizes of a given characteristic. To achieve this, they were normalized at the sum of the maximal and minimal size of the characteristic, on the following formula:

$$\frac{2 \times \text{zone of transgression}}{\text{max (aurochs)} + \text{min (domestic cattle)}} \text{ (Index II)}$$

In order to ascertain which characteristics had a large or small zone of transgression, both after substraction of the extent of distribution and its size, the ratio of both results of normalisation was calculated (Index I × Index II). The same method was applied to the zones of transgression existing between the aurochs and domestic cattle, and to those between the two forms of domesic cattle: *Bos taurus primigenius* and *Bos taurus brachyceros*.

The following bones were selected from the material: metacarpal III+IV of the aurochs and domestic cattle with four basic dimensions (length, breadth of the proximal end, breadth of the distal end, and breadth of diaphysis), and radius bones in which both the dimensions of the breadth of the proximal end and breadth of the distal end had been obtained. These dimensions were encoded (Tables 1 and 2) according to the distribution of sizes of these characteristics obtained in the study by Kobryń and Lasota-Moskalewska (1989) for particular forms of cattle. For *Bos taurus primigenius* and *Bos taurus brachyceros* it was possible to encode only two dimensions of the radius bone (Table 3), because the distribution of dimensions of the metacarpal III+IV bones did not provide a basis for distingushing particular forms of domestic cattle or the zones of transition between them.

Selecting characteristics in pairs, the participation of compatible codes was examined (11, 22, 33), as well as other combinations, grouping the latter into two sets: codes occurring in descending order (32, 31, 21) and those occurring in ascending order (12, 13, 23).

Each of the metacarpal III+IV bones encoded in the way shown above was described according to a four-code model. An aurochs bone should have the model: 1111, and a domestic cattle bone: 3333. The bone of animal that was an intermediate form should theoretically be described by the code: 2222, but because of the absence of zone of transgression in the length of this bone, this model could appear as follows: 1222 or 3222. Since the possibility was admitted that the characteristics of aurochs and domestic cattle could be mixed in intermediate forms, it was accepted that all other mixed combinations of this model also represented intermediate forms.

The share of bones with compatible and mixed codes was examined in the context of the sex of the animals from which the bones originated. Sex was established according to the generally accepted method, by calculating the co-ordinate: x — length of metacarpal III+IV and y—index of the width of its shaft (Calkin, 1960).

4. RESULTS

4. 1. Intermediate Forms between the Aurochs and Domestic Cattle

Of the eleven osteometric characteristics on the basis of which it is possible to distinguish the aurochs from domestic cattle, only the length of the metacarpal III+IV bone did not exhibit a zone of transgression, since the range of variability of this dimension in wild and domesticated forms of the species did not overlap. In the case of the remaining characteristics, the zones of transgression were of varying size (Table 4). The smallest percentage of the whole dispersion (Index I) was occupied by the zone of transgression for the length of the calcaneus, the breadth of proximal end of the metacarpal III+IV bone and the breadth of proximal end of the radius. The remaining characteristics formed a large group with a relatively much larger zone of transgression. Similar results were achieved after normalisation of the size of the zone of transgression (Index II). On the basis of the ratio of the results of both normalisations, in proved possible

Table 1
Value of characteristics (mm) and the corresponding code numbers for metacarpals III+IV. See text for abbreviations. * — absence of zone of transgression.

Code	Form	McGL	McBP	McBD	McSD
1	Aurochs	≥222	>70	>72	>48
2	Intermediate form	—*	70—67	72—65	48—43
3	Domestic cattle	≤220	<67	<65	<43

Table 2
Value of characteristics (mm) and the corresponding code numbers for radius bones. See text for abbreviations.

Code	Form	RBP	RBD
1	Aurochs	>96	>92
2	Intermediate form	96—91	92—81
3	Domestic cattle	<91	<81

to divide the characteristics examined into three groups: (a) the length of metacarpal III+IV, the length of the calcaneus, the breadth of proximal end of metacarpal III+IV, the breadth of proximal end of the radius (ratio from 0 to 1); (b) breadth of distal end of the humerus, breadth of distal end of the radius, breadth of distal end of the metacarpal III+IV, breadth of diaphysis of the metacarpal III+IV, breadth of the distal end of the tibia (ratio from 2 to 3); (c) horncore basal circumference, length of the collum scapulae (ratio greater than 3).

An analysis of consistency (or lack of consistency) in the coded qualification of dimensions of the metacarpal III+IV indicated a fairly wide differentiation in particulars pairs of characteristics (Table 5). In three pairs, in which the length of the bone occurred together with measurements of width, differentiation was attested of percentages of three groups of codes. The highest number of compatible codes came in pairs of length combined with width of shaft and with width of the proximal end. The smallest number of compatible codes was to be found in the pair of lenght combined with width of the distal end. In the group of descending codes, in which lenght was relatively smaller than

Table 3
Value of characteristics (mm) and the corresponding code numbers for radius bones. See text for abbreviations.

Code	Form	RBP	RBD
1	*Bos taurus primigenius*	>80	>72
2	Intermediate form	80—73	72—63
3	*Bos taurus brachyceros*	<73	<63

Table 4
Size of zones of transgression (mm) between dimensions of the bones of the aurochs and domestic cattle. See text for abbreviations.

Characteristic	Zone of transgression	Index I	Index II	Product I×II
HBC	50	15.6	0.20	3.1
SLC	12	20.0	0.21	4.2
HBD	12	17.6	0.14	2.5
RBP	6	9.1	0.07	0.6
RBD	12	17.6	0.15	2.6
McGL	0	0	0	0
McBP	4	7.4	0.06	0.4
McBD	8	16.0	0.13	2.1
McSD	6	15.8	0.16	2.5
TBD	10	15.6	0.13	2.3
CGL	6	6.8	0.04	0.3

width, the greatest share fell to the pair of length combined with width of the distal end, and the smallest share to the pair of length combined with width of the shaft. In the group of ascending codes in which length was relatively greater than measurements of width, the pair that occurred most frequently was length combined with width of the shaft. The two remaining pairs took an identically low share.

In the pair covering width of the proximal end and width of the distal end, a fairly high degree of compatibility of the codes was attested. Descending codes, where width of the proximal end was relatively smaller than width of the distal end, also constituted a considerable percentage. The part played by ascending codes was minimal.

In two pairs in which width of the shaft occurred in second place and width of the proximal and distal ends in first place, both were marked by an absence of occurrence of descending codes. In both pairs there were quite a lot of ascending codes, where the width of both ends was relatively greater than the width of the shaft. These occurred in particularly high numbers in pairs with the width of the distal end. Compatible codes occurred fairly frequently in pairs with width of the shaft in combination with width of the proximal end, and much more rarely in the pair where width of the shaft was combined with width of the distal end (only 53.9%).

Eighty-nine metacarpal III+IV bones, encoded according to four characteristics, were analysed from the viewpoint of the frequency of occurrence of particular combinations of codes — an analysis which should be carried out separately for males and females. A division according to sex of the metacarpal III+IV bones which were examined proved possible only in the aurochs group. Nineteen bones were from males and only 4 from females (Fig. 1). Of the bones of males, 14 bones

Table 5

Proportion of compatible and incompatible codes in the dimensions of the bones of the aurochs and domestic cattle. See text for abbreviations.

Pair of characteristics	Compatible codes (11, 22, 33)		Descending codes (21, 32, 31)		Ascending codes (12, 13, 23)	
	n	%	n	%	n	%
McGL — McBP	71	79.8	14	15.7	4	4.5
McGL — McBD	56	62.9	29	32.6	4	4.5
McGL — McSD	73	82.0	4	4.5	12	13.5
McBP — McBD	65	73.0	22	24.7	2	2.3
McBP — McSD	65	73.0	—	—	24	27.0
McBD — McSD	48	53.9	—	—	41	46.1
RBP — RBD	51	94.4	—	—	3	5.6

were described as an homogeneous type (code 1111) and 5 bones as a mosaic type. All the bones of females were described by mosaic codes (Table 6).

The metacarpal III+IV bones examined of Neolithic domestic cattle proved impossible to divide according to sex because a dense group of points developed in the correlational field (Fig. 1). Therefore the frequency of occurrence of particular types was calculated jointly for males and females. Of the theoretically possible number of combinations 3^4-27, among the cattle bones only 9 types appeared. The greatest number of the bones — in fact half — were described of a compatible code (3333). The remaining eight types, which were mosaics, were marked by a relatively narrow bone shaft in relation to a relatively wide distal end. The width of the proximal end and the length of the bone exhibited greater differentiation.

An analysis of the compatibility of the qualification of the breadth of proximal end and the breadth of distal end of the radius bones showed that the compatibility of the codes was very high for both these characteristics, reaching almost 100% (Table 4).

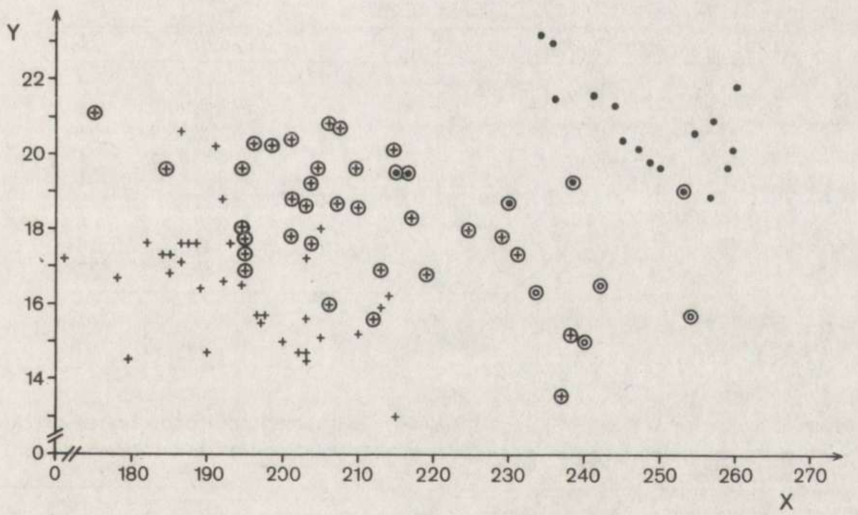

Fig. 1. Distribution of metacarpals III+IV of the aurochs and domestic cattle in the field delimited by co-ordinates: x — greatest length (mm); y — index of width of shaft. Key to symbols: + — domestic cattle, • — aurochs — males, ○ — aurochs — females; an encircled symbol — mosaic type.

4. 2. Intermediate forms between *Bos taurus primigenius* and *Bos taurus brachyceros*

The range of variability of the dimensions of bones typical of *Bos taurus primigenius* and *Bos taurus brachyceros* was established for 4 characteristics, since it was only for these that separate peaks were obtained in distribution frequency curves. These curves overlapped, creating zones of transgression. After the first normalisation (Index I) it proved that all four zones of transgression occupied a similar percentage of the whole dispersion of domestic cattle (Table 7). These percentages were as large (from 18.8 to 20.8%) as the greatest that occurred between aurochs and domestic cattle. The second normalisation (Index II) somewhat differentiated the analysed characteristics, which meant that the result of the product of the two indices made it possible to distinquish two characteristics (the breadth of proximal end of the radius and the length of the calcaneus) which had relatively smaller zones of transgression, and two characteristics which had

Table 6
Differentiation of codes among metacarpal III+IV bones. f=frequency.

Aurochs				Domestic cattle	
Males		Females			
Type of code	f	Type of code	f	Type of code	f
1111	14	1113	1	1113	3
1112	3	1123	1	1213	1
3112	2	1223	2	1323	1
				3133	1
				3212	1
				3213	3
				3223	6
				3323	16
				3333	33

Table 7
Size of zones of transgression (mm) between dimensions of the bones of *Bos taurus primigenius* and *Bos taurus brachyceros*. See text for abbreviations.

Characteristic	Zone of transgression	Index I	Index II	Product I×II
HBD	10	20.0	0.13	2.6
RBP	8	20.0	0.10	2.0
RBD	10	20.8	0.15	3.1
CGL	12	18.8	0.10	1.9

larger zones (the breadth of distal end of the humerus and breadth of distal end of the radius). It must be stressed that this differentiation was not so clear as in the case of the aurochs and domestic cattle, although the division of characteristics into groups was similar.

It was possible to make an analysis of the compatibility (or absence of compatibility) of the codes only for the breadth of proximal end and breadth of distal end of the radius. Of the examined dimensions of 38 radius bones, as many as 32 bones exhibited a very high degree of compatibility of codes. The remaining specimens were marked almost exclusively by descending codes (5 bones) and an ascending code was noted in only one case.

5. DISCUSSION

Of the two stages of development of domestic cattle mentioned in the introduction, the first was considerably more important, since a precise distinguishing of aurochs bones from those of domestic cattle often determines the establishment of the period in which the earliest domestication of cattle occurred in a given area, and consequently the possibility of the local population embarking upon a stock-breeding and agricultural economy. A division of the two types of bones was made possible after objective diagnostic criteria had been established for distinguishing between aurochs and domestic cattle bones (Kobryń & Lasota-Moskalewska, 1989).

An unambiguous identification of bones, or more frequently of fragments of bones, is very difficult for researchers because of the morphological characterisation of bones from specimens that were newly domesticated. Some of the criteria for division cover characteristics that are evaluated subjectively, like for example, the weight of the bone, the thickness of the cortical layer, the shape of the areas of muscle attachment. In the nature of things, the use of these criteria depends on the experience of the researcher and the number of bones that he has at his disposal for purposes of comparison. Osteometric characteristics constitute a much more objective criterion, and it is for this reason that many attempts have been made to establish ranges of variability for certain dimensions that are typical of the aurochs and domestic cattle (Bökönyi, 1962; Stampfli, 1963; Kobryń & Lasota-Moskalewska, 1989). Unfortunately, the majority of metrical characteristics exhibit continuity between the aurochs and domestic cattle. The distribution frequency curves for many characteristics have one peak, which does not enable one to establish the critical values which form the boundary between the size of bones of the wild and domesticated froms. Some characteristics exhibit two peak in distribution, but extremal sizes overlap, creating common fields. These fields are termed zones of transgression (Calkin, 1970) or overlap (Ekman, 1972; Driesch & Boessneck, 1976; Clason, 1983; Bökönyi, 1984).

Researches who describe the overlap of dimensions of the bones of aurochs and domestic cattle most frequently suggest that intermediate dimensions characterize the bones of female aurochs and male domestic cattle. Taking into account the fact that in cattle, particularly domestic cattle, sexual dimorphism manifests itself for example in the absolute values of osteometric characteristics, these suggestions are logically justified. However, on the other hand, the hypothesis of continuous evolution between the wild and domesticated forms, which has never been questioned, makes it possible to presume that there must have existed links in evolution between these two forms animals which were intermediate. Theoretically, these intermediate forms could have been smaller in all bone dimensions than the original form, and larger than the next forms in evolution. In this case, all the osteometric characteristics should have a similar numerical distribution, either singlepeaked or bi-peaked. In proved, however, that of the 25 characteristics of the postcranial skeleton and of the horncore, 14 were characterized by a compact distribution with a single peak, while 11 had two peaks (Kobryń & Lasota-Moskalewska, 1989). This proves that particular characteristics to differing degrees differentiate the bones of aurochs from those of domestic cattle. This observation makes it possible to suggest that in the first stage of the evolution of domestic cattle the skeleton of specimens that constituted intermediate forms should be marked by a mosaic (mixture) of dimensions of the basic forms and dimensions of intermediate forms. This mosaic would result from a differing rate of change in particular dimensions. A great difference in the tempo of reduction of particular dimensions with the passage of time was observed by Lasota-Moskalewska (1980). In a period of about 4000 years, some dimensions of the bones of cattle diminished by 6% and other dimensions by as much as 31%. This would indicate a differing reactivity of metrical characteristics to factors operating in conditions of domestication. These factors — like deliberate extension of the period of lactation, periodical deficiencies in diet, or restriction of locomotion — could have influenced ontogenetic development, but were certainly one of the elements in the selection of animals which bred in domestication. For example, large specimens could have had greater difficulty in surviving periods without food, and their fertility may also have been reduced.

A comparison of the size of zones of transgression indicates that the dimension which most greatly distinguishes the bones of the aurochs from those of domestic cattle is the length of metacarpal III+IV. This would therefore be the characteristic that was most highly reactive. It might seem that in view of its localisation in the skeleton, the length of the metatarsus III+IV would be a similar characteristic. It proved, however, that this latter characteristic exhibits a considerably lower reactivity, since its size distribution was single-peaked. The differences in the reactivity of these two apparently similar characteristics have often been stressed. For example, sexual dimorphism in cattle is greater in the metacarpal III+IV than in the metatarsus III+IV (Fock, 1966; Driesch & Boessneck, 1976; Kratochvil, 1987). This seems to be linked with the more general phenomenon of a different reactivity of the whole fore limb from that of the hind limb to morphogenetic factors. The hind limb, as the motor limb, may react more easily to factors linked with the locomotive function, while the fore limb may be more reactive to the other sets of factors connected with domestication. For example, the effect of inbreeding among bison is greater in the fore limb (Kobryńczuk, 1985). The differing reactivity of the two limbs may also result from the load of the body's weight that they carry. It has been calculated that the fore limb in cattle carries 55% of the body weight when they are stationary (Fock, 1966). For bison, 55% of the body weight in males and 54% in females, falls on this limb (Roskosz, Kobryńczuk & Kobryń, 1980). A greater burden might restrict an extension of lenght of the bone of the fore limb. Moreover, the ossification of the bone of this limb begins earlier in the foetus of cattle, and probably also ends earlier (Prumel, 1987). One of the basic characteristics of domesticated animals is an earlier physiological and also morphological maturity (Bogolubski, 1968). This property might have been one of the original criteria of selection applied by stockbreeders. Animals in domestication complete their growth processes earlier than wild animals, and an earlier attainment of the critical level body mass might have curtailed the extension of length to the metacarpal III+IV bone. It is assumed that these factors were responsible for the greater differences between the aurochs and domestic cattle in the lenght of the metacarpal III+IV bone than in the lenght of the corresponding metatarsus bone.

Further differences in the reactivity of characteristics (expressed in a greater or smaller relative size of the zone of transgression) to the process of domestication consist in the fact that the lenght of the metacarpal III+IV bone differentiates wild and domesticated cattle better than the width characteristcs of this bone. As in the exposition above, this can be linked with a wider phenomenon. Koch (1932) for example observed that when the lenght growth of bones has already been completed, dimensions of width continue to expand, because they are not subjected to the restricting influence of the body mass.

The width of proximal ends of bones seem to be more reactive in domestication than the width of distal ends. This is deduced from the fact that both the width of the proximal end of the metacarpal III+IV bone and the radius had relatively smaller zones of transgression than the width of distal ends of both bones. We are unable to offer an explanation for this observation. Perhaps the result achieved is linked with the phenomenon of allometry (Sych, 1968; McMahon, 1973).

The relatively largest zones of transgression were exhibited by the lenght of collum scapulae and the horncore basal circumference. It is difficult to explain why the scapula is little reactive to the activity of factors connected with domestication. The horncore circumference is a craniometric characteristic, and these seem to be more conservative than the characteristics of the limb skeletons. Bökönyi (1984) writes: "Limb bones are much more plastic and, therefore, react more sharply to environmental and genetic changes than skull elements and horns". We know from studies that compare the changes in the horncore circumference with body height that in the Neolithic one can find short cattle which however had a large horncore circumference (Lasota-Moskalewska, 1989). These probably represent animals that were intermediate forms.

The above arguments show that in the first stage of evolution the skeletons of intermediate forms were characterized by a mosaic of the osteometric characteristics proper to wild and domesticated animals. More detailed information on the character of this mosaic was obtained on the basis of simultaneous analysis of four dimensions of metacarpal III+IV bones. In the group of 89 metacarpals, bones with compatible and mixed codes occurred with similar frequency (47 and 42, respectively). Uniformly aurochs-type bones came from aurochs living in various periods from the Neolithic to the early middle ages. Mosaic types came from materials dated from the early Neolithic through to the Bronze Age. They could therefore represent animals that were intermediate types.

All the bones of domestic cattle came from Neolithic materials. Mosaic types occurred in 50% of the bones in this set. If these types really represented, as the results achieved suggest, intermediate forms between the aurochs and domestic cattle, then it is possible to say that in the Neolithic the proportions of fully-domesticated and newly-domesticated cattle were equal.

Among the mosaic types, only about 25% of all the theoretically possible combinations of characteristics actually occurred. There were too few of these bones to carry out a statistical analysis of the frequency of occurrence of particular types. However, two types were clearly most numerous: here, the shaft was relatively narrow, the length small and the ends were of moderate width, particularly the distal ends.

It is necessary to consider whether this combination could be an effect of age or functional changes. Bökönyi (1984) writes for example that in the bones of the metapodial sections of limbs (particularly in the metacarpals) the burden of body weight sometimes leads in old specimens to a functional hypertrophy of the distal end. It would however seem that there are too many of these bones (*ca.* 25%) for them to come from animals exhibiting these particular characteristics. It is also typical that all the remaining combinations that appear only as individual cases also had narrow shaft in comparison with the width of the two ends. This phenomenon was independent of the length of the bone.

It is possible to suggest the hypothesis that the intermediate forms between the aurochs and domestic cattle had narrowed shafts of the metacarpal III+IV bones. This would be the first symptom of early domestication. Bökönyi (1984) points out that one of the symptoms of the domestication of cattle is a thinner wall of the shafts of long bones. Probably, a reduction in the thickness of the cortical layer in the shaft occurred through a narrowing of the external width of the shaft and not through a widening of the marrow cavity that lay within. In intermediate types with mixed codes, the width of the distal end is almost always large (apart from one case), usually in the categories of aurochs dimensions, or possibly of intermediate forms. The width of the proximal end and length exhibit greater differentiation: *i.e.*, sizes characteristic of domestic cattle also occur. Among the bones from the Neolithic burial ground at Złota Sandomierska all the metacarpal III+IV bones corresponded to the description given above (Lasota-Moskalewska, 1979). These were undoubtedly the bones of domestic animals, and were classified as an early phase of domestication, which was additionally confirmed by their "wild" microstructure (Lasota--Moskalewska, 1979a). It therefore seems that the width of distal end remains large longest, like this dimension in the aurochs. This is consistent with results achieved earlier showing that width of the distal ends of long bones are less reactive than other characteristics.

In summing up the intermediate forms between the aurochs and domestic cattle that have been discussed, it is necessary to take into consideration the occurrence of these forms among males and females.

One major obstacle to analysis of this kind is the impossibility of distinguishing between the sex of metacarpal III+IV bones in domestic cattle. The generally applied method of determining sex was only useful in the case of these bones in the aurochs. Among the bones of males, only 5 mosaic types were found (from 19 bones). The four bones of female aurochs were all of the mosaic type. This result is difficult to interpret. It also seems strange that in chance material the part played by male aurochs should be so large in relation to females. The metacarpal III+IV bones that have been examined, which were found in materials linked with human settlement, almost certainly originated from animals which had been killed in hunting or were domesticated. Theoretically, they could have been found and brought in to the human settlements, but this version is much less likely. The question of why a considerable part of the aurochs killed in hunting were males, and why not one female of the purely aurochs type was killed, must remain unanswered. Perhaps it was a matter of chance, since from the statistical point of view, a group of 23 aurochs bones is small. One might also suggest that male aurochs more frequently approached herds of cattle which were already under human control because of their interest in the cows of the domestic cattle, and therefore became an easier prey for man.

The bones of domestic cattle, forming an indivisible compact group of points indicate a greater concentration of mosaic types over the correlational field demarcated by the high value of the index of width of shaft. In view of its localisation, this area should consist of bones of males. One might therefore think that there were more mosaic types among males of domestic cattle than among females. Perhaps Neolithic man selected for breeding females which were more „cattle-like" in appearance which might have been connected with a higher lactation yield.

In the second stage of domestication mentioned in the introduction, only four characteristics were distinguished on the basis of which it is possible to establish the limits typical of the two forms of domestic cattle: *Bos taurus primigenius* and *Bos taurus brachyceros*. All other characteristics examined in the study by Kobryń & Lasota-Moskalewska (1989) indicated such a high degree of continuity of change that the distribution curves for their frequency were single-peaked. This means that the separating of *Bos taurus brachyceros* took place in a more fluid way than the domestication of wild forms. The osteometric characteristcs of intermediate forms between *Bos taurus primigenius* and *Bos taurus brachyceros* contain intermediate forms in the literal sense of the word. Nonetheless, the existence of the four characteristics mentioned above as distinguishing these two forms of domestic cattle indicates that at this stage, too, intermediate forms were marked by a certain limited mosaic effect in osteometric characteristics. On the basis of comparison of the relative size of zones of transgression, it has been established that the two forms of animal under discussion are more greatly differentiated by the length of the calcaneus and the breadth of proximal end of the radius, and to a lesser extent by breadth of distal end of the radius and breadth of distal end of the humerus. If we accept, as in the earlier agument, that a clearer differentiation of the basic forms reflects a greater reactivity of characteristics morphogenetic factors, one can conclude that at both stages of evolution the same characteristics exhibit a stronger reactivity. It therefore seems that as in the earlier stage, the reactivity of proximal ends of long bones in greater than that of distal ends. Since it is difficult to arrive at a direct explanation of this phenomenon, one might suggest that these characteristics are closely connected with other characteristics which form part of the set of criteria for selection associated with domestication and later breeding and rearing.

This study constitues the first attempt to describe the intermediate forms in the evolution of domestic cattle on the basis of osteometric characteristics. In undoubtedly does not provide solutions to all the problems linked with the classification of bones and much less, fragments of bones — as originating in "basic" or intermediate forms. Nonetheless, the results obtained make it possible to realise that intermediate forms are marked by a mosaic of osteometric characteristics of the basic forms, which arose as a result of the varying reactivity of these characteristics to morphogenetic factors connected with domestication. It seems that particular characteristics exhibit varying degrees of linkage with characteristics that were criteria for selection, and preferred certain specimens in conditions of domestication. This linkage seems to have been similar both in the stage of initial domestication, that is, the transition from wild to domestic form, and in the stage of the separating off of *Bos taurus brachyceros* from *Bos taurus primigenius*. The phenomenon of mosaic applies both to the whole skeleton and to particular characteristics of one bone. In the case of the metacarpal III+IV bone, in the first stage of domestication this most frequently consisted in an early narrowing of the width of the shaft, while a wide distal end was retained.

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PRÓBA CHARAKTERYSTYKI FORM PRZEJŚCIOWYCH W EWOLUCJI *BOS PRIMIGENIUS F. TAURUS* NA PODSTAWIE CECH OSTEOMETRYCZNYCH

Streszczenie

W pracy analizowano cechy osteometryczne tura i bydła domowego, na podstawie których można wyraźnie odróżnić kości formy dzikiej i udomowionej a także kości dwóch form bydła: *Bos taurus primigenius* i *Bos taurus brachyceros*. Wymiary tych cech zachodziły na siebie w wartościach ekstremalnych tworząc pola wspólne, tzw. strefy transgresji. Założono, że wymiary objęte strefami transgresji w większości przypadków charakteryzują zwierzęta będące ogniwem przejściowym w ewolucji bydła domowego. Rozpatrywano dwa zasadnicze etapy ewolucji: (1) przechodzenie od formy dzikiej — tura do bydła domowego — 11 cech; (2) wyodrębnianie się formy *Bos taurus brachyceros* z formy *Bos taurus primigenius* — 4 cechy. Wielkości stref transgresji uzyskane w opracowaniu Kobrynia i Lasoty-Moskalewskiej (1988) poddawano dwukrotnej normalizacji według wzorów I i II. Stwierdzono, że na pierwszym etapie ewolucji najmniejsze względne strefy transgresji wykazywała szerokość końca bliższego kości promieniowej, szerokość końca bliższego kości śródręcza III+IV i długość kości piętowej. Do grupy tej zaliczono także długość kości śródręcza III+IV, która tak silnie różnicowała obie formy gatunku, że nawet nie istniała pomiędzy nimi strefa transgresji. Największe strefy transgresji napotkano w obwodzie możdżenia i długości szyjki łopatki. Reszta cech miała średnie strefy transgresji (Tabela 4). Małe strefy transgresji uzyskane w rozkładzie wielkości niektórych cech interpretowano jako większą reaktywność tych cech na czynniki kształtujące morfotyp bydła żyjącego w udomowieniu. W związku z tym uzyskane wyniki można sformułować w następujące punkty: (1) Wymiary kości kończyny piersiowej są bardziej reaktywne na czynniki związane z udomowieniem niż wymiary kości kończyny miednicznej. (2) Cechy długościowe kości długich są bardziej reaktywne niż cechy szerokościowe. (3) Wymiary końców bliższych kości długich są bardziej reaktywne niż szerokość końców dalszych. (4) Wymiary możdżenia reprezentującego cechy kraniometryczne są mniej reaktywne niż wymiary kości kończyn. W związku z różną reaktywnością cech szkielety zwierząt będących ogniwami przejściowymi pomiędzy turem i bydłem domowym cechuje mozaikowatość (przemieszanie) wymiarów obu form. Mozaikowatość ta dotyczy zarówno różnych kości szkieletu jak i wymiarów jednej kości. Zostało to potwierdzone na podstawie częstości jednoczesnego występowania cech tura, bydła domowego lub pośrednich w różnych parach cech kości śródręcza III+IV oraz kości promieniowej. Wymiary tych kości zostały uprzednio zaszyfrowane zgodnie z wielkościami uzyskanymi na podstawie krzywych frekwencji (Tabela 1, 2). Najmniejszą zgodność stwierdzono w parze szerokości końca dalszego i szerokości trzonu oraz długości i szerokości końca dalszego tej samej kości (Tabela 5). Analizowano także zgodność występo-

wania cech turzych i bydlęcych jednocześnie w czterech wymiarach kości śródręcza III+IV. Kości opisane szyfrem czterocyfrowym zgodnym traktowano jako formy czyste, reprezentujące tura lub bydło domowe, kości opisane szyfrem mieszanym (mozaikowatym) zaś jako formy przejściowe. Formy mozaikowate wystąpiły w badanym materiale w postaci 5 typów u turów i 8 typów u bydła domowego (Tabela 6). Wszystkie typy mozaikowate charakteryzowały się stosunkowo wąskim trzonem i względnie szerokim końcem dalszym kości śródręcza III+IV. Szerokość końca bliższego i długość kości były zróżnicowane. Na następnym etapie ewolucji, pomiędzy *Bos taurus primigenius* i *Bos taurus brachyceros* stwierdzono, że strefy transgresji są nieco większe niż na poprzednim. Szerokość końca bliższego kości promieniowej i długość kości piętowej miały względnie mniejsze strefy transgresji niż szerokość końca dalszego kości promieniowej i szerokość końca dalszego kości ramiennej (Tabela 7). Można przypuszczać, że także na tym etapie ewolucji szerokości końców bliższych są bardziej reaktywne niż szerokości końców dalszych. Na podstawie uzyskanych wyników wyciągnięto wniosek, że cechy bardziej reaktywne prawdopodobnie były silniej sprzężone z cechami będącymi kryterium selekcji preferującej zwierzęta żyjące w warunkach udomowienia. Różnice w sile tego sprzężenia doprowadziły do mozaikowatości cech osteometrycznych u zwierząt będących ogniwami pośrednimi w ewolucji bydła domowego.