A C T A T H E R I O L O G I C A

VOL. XIV, 7: 69—117. BIAŁOWIEŻA 5.IV.1969

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The Postnatal Development of F_1 Hybrids of the European Bison and Domestic Cattle

Bisoniana XXXIX

[With 5 Tables and 15 Fig.]

A description is given of the development of 6 hybrids of the European bison and Black and White lowland cattle (*bw*) (3 ♂♂ and 3 ♀♀) during the period from birth up to age of 24 months, on the basis of 16 measurements and 8 indices. A description is also given of the exterior of 8 F_1 hybrids over 4 years old, obtained from crossing of the bison males with partners of the Polish Red (*pr*) or *bw* (4 ♂♂ and 4 ♀♀). The hybrids exhibit the vigour, manifested by intensive prenatal development, which in turn leads to attaining large body measurements at birth, greatly exceeding the weight of domestic calves. The mother's species was found to affect body weight and structure of hybrids at birth and as adult. Heterosis during postnatal development is manifested in the intensive development of hybrids, particularly during the first six months of life. F_1 males at the age of 6 months exceed the body weight of *bw* by 44%, at 12 months by 14% and at 18 months by 8.5%. Females at the age of 6 months are 23% heavier than *bw* heifers, but later the differences are slight. Hybrids of both sexes at the age of 4 years exceed the body weight of domestic cattle. In the structure of hybrids the characters in which the European bison strain dominates are the hump, shortening of the trunk, longleggedness, development of depth, more intensive than for other measurements, and in females incomplete domination of the type horns. Other structural characters are intermediate or closer to those of domestic cattle. Comparison of the results the Białowieża experiments with others showed that not all breeds of cattle transmit the characters of their structure to hybrids equally strongly. In our case the characters of domestic cattle were more strongly transmitted by the *bw* breed than the *pr* breed.

I. INTRODUCTION

The earliest mention of hybrids of the European bison and domestic cattle are to be found in the studies by Buffon and Pusch (cited after Ackerman, 1898) published as long ago as the 19th century. More exact data are available on hybrids of the European bison and the schwytz breed of cattle, which were obtained during the period from 1847—1857 by the Pole Walicki (Müller, 1852; Karcov, 1903). By crossbreeding the European bison and domestic cows he obtained 3 hybrids of F_1 and 12 of the II generation (Zablocki, 1956). European bison were also crossed with cows of the Grey Ukrainian breed in the reserve at Askania Nova in Russia as from 1897 (Iwanow & Philiptschenko, 1916; Ivanov, 1950; Zablocki, 1939). During the period from 1905—1928 28 hybrids in all were born there, 11 of which were from the first generation (cf. pedigree list of European bison and cattle hybrids do given in earlier paper — Krasińska, 1967). From 1897—1938 there was European bison blood in 254 animals from Askania Nova, and a large part of these animals were taken to various zoological gardens (Mohr, 1952; Zablocki, 1939; 1956). Attempts were made at a later data at Askania Nova at crossbreeding European bison × American bison with cows of the Grey Ukrainian and metissimentaler breeds. Studies on this problem of a more planned character were initiated in 1932, and by 1935, 31 hybrids with different percentage of domestic cattle blood had been obtained (Mokeev & Żuravok, 1935; Żuravok, 1935).

Studies on the hybridization of the European bison with domestic cattle were undertaken in Poland in 1953 in the Płock ZOO (Taworski & Woliński, 1960). The hybrid »Famela« was also obtained in 1962 by crossing European bison with a cow of the Polish Red breed in the Experimental Animal Breeding Station Polish Academy of Sciences at Popielno (Zaniewski, 1967). Systematic investigations, planned on a wider scale, on the hybridisation of the European bison with domestic cattle, were begun at Białowieża at the initiative of Professor A. Dehnel. It was there in 1960 that for the first time in the world a calf was obtained from a female European bison and domestic bull (Dehnel, 1961). Walicki's experiments carried out in this direction ended in effect with the female bison covered by a domestic bull dying of pneumonia (Karcov, 1903). By the end of 1968, 35 hybrids were obtained at Białowieża, 10 of which were F_1, 22 — 3/4 cattle and 3 — 6/8 cattle (Dehnel, 1961; Demiaszkiewicz, 1961; Krasińska, 1963, 1967; Krasińska & Pucek, 1967).

The majority of studies on hybrids of European bison and domestic cattle give only a description of the exterior of adult hybrids their behaviour or only numerical data from experiments. There are only a few studies dealing with the structure of hybrids on the basis of body measurements and weight. Among these is the study by Iwanow & Philiptschenko (1916) discussing hybrids of European bison and Grey Ukrainian cattle aged 2—8 years. The study by Żuravok (1935) is concerned with the development of hybrids of the European × American bisons and domestic cattle. The only Polish data, although fragmentary, on the structure and weight of the body of European bison hybrids are those in the study by Taworski & Woliński (1960).

The aim of the present study is to trace the development of hybrids of F_1 generation of European bison × Black and White lowland cattle (*bw*) from birth up to the age of 24 months, and comparing it with the development of domestic calves and European bison hybrids obtained in other experiments. Endeavour has also been made to define the degree of heredity of the parent characters in hybrids of European bison and domestic cattle at the age of over 4 years, based on my own observations and earlier data in literature.

II. MATERIAL AND METHOD

1. Material and Breeding Conditions of the Hybrids

The object of our observations was formed by 6 hybrids obtained by crossing European bison with domestic cattle of the *bw* breed, born in the experimental reserve of the Mammals Research Institute, Polish Academy of Sciences, at Białowieża, during the period 1962—1964. The development of 3 females (»Fanny«, »Fatima«, »Figa«) and 3 males (»Farad«, »Facet«, »Fakir«) was traced during the period from birth to 24 months of life (Table 1). In addition a description was given of the exterior of 8 Białowieża hybrids obtained during the period 1960—1962, from crossing European bison with domestic cattle of the *bw* breed (males — »Facet«, »Farad« and female »Fanny«) and with domestic cattle of the *pr* breed (2 males — »Filip«, »Filon«, and 3 females — »Fama«, »Famela«, »Filutka«). The exterior was examined in fully-grown animals, over the age of 4 years, and compared both with the initial forme (cattle of the two above-mentioned breeds, European bison) and also with other hybrids of European bison and domestic cattle. Use was made for this purpose of earlier publications, and the numerical data they contain were appropriately converted to make them comparable with the results of my own observations.

The results of my own investigations are based on observations and measurements of 11 hybrids (Table 1).

The Białowieża hybrids live in four 10 ha enclosures covered by an old forest stand of the *Querco-Carpinetum medioeuropeum* Tx., 1936

type. Two of these enclosures include meadows 2 ha in area. A feeding place is set apart in each enclosure, 25 m² in area, enclosed by a fence and containing a trough for feeding concentrates, a concrete trough for water and racks for hay under a roof.

The animals live in herds composed of cows and young animals, or adult bulls and young animals, and are able freely to choose the wooded areas or the small glades covered by a herb layer, or the cultivated meadows.

The hybrids were fed, according to their age, sex and weight, on mixture *B* [1]), oatmeal, hay and fodder beet in accordance with the standard feeding for domestic cattle. The calves remained with their mothers until they were 4 months old. The domestic cows, mothers of the

Table 1.

List of hybrids F_1 of European bison and domestic cattle studied.

No	Name, sex	Birth day	Father	Mother
1	Filon, ♂	6 VIII 1960	Ananas *pr*	Ponętna *w*
2	Filip, ♂	25 VIII 1960	Ananas *pr*	Podkomorzanka *w*
3	Fama, ♀	14 X 1960	Pokorny *w*	Alma *pr*
4	Filutka, ♀	7 IX 1961	Ananas *pr*	Podkomorzanka *w*
5	Facet, ♂	28 IV 1962	Pokorny *w*	No 98 *bw*
6	Farad, ♂	29 IV 1962	Pokorny *w*	No 107 *bw*
7	Fanny, ♀	30 IX 1962	Pokorny *w*	No 114 *bw*
8	Fakir, ♂	12 VIII 1963	Pokorny *w*	No 114 *bw*
9	Figa, ♀	23 VIII 1963	Richtje *bw*	Ponętna *w*
10	Fatima, ♀	29 VIII 1964	Pokorny *w*	No 114 *bw*
11	Famela, ♀	30 II 1962	Puk *w*	Wolna *pr*

pr — Polish red cattle, *bw* — Black white lowland cattle, *w* — wisent.

hybrids, yielded 8—10 litres of milk daily, according to control milkings, and were thus not the best milk-yielders. When the calves were one month old they were gradually given supplementary food in the form of hay, oatmeal and beets. They were given mixture *B* in the second year of life. During the summer hybrids graze but have not sufficient grass for their needs. The natural food is supplemented by young shoots, leaves and the bark of trees. The animals are fed individually, but as they were not tied up for feeding it was impossible to prevent the stronger animals eating food intended for the weaker ones.

2. Body Measurements and Indices

Contradictory opinions are held as to the role of indices describing the postnatal development of animals. According to many authors body

[1]) Mixture *B*: bran, ground corn, post-extract meal, fodder urea and the addition of Ca, P, Na, Si, Mn, Fe, Cu, Mg, Co.

weight gives a more reliable basis for defining the animal's development than measurements (Konopiński, 1928; Hammond *et al.*, 1958; Pająk, 1958). Other authors, however, consider that linear measurements of the body are very important, and give them priority over weight as a means of tracing development (Šahnazarov, 1958). Body weight and measurements were taken as the measure of development in the present study. Calculation was made of the structure indices best describing the external proportions of the animals.

The calves were weighed and measured on the first day following birth, then at monthly intervals, each time at the same hours of day before feeding. Weighing was done with decimal scales at the beginning and later on a large weighing machine. Measurements were made in accordance with directions for cattle (Lush, 1930; Konopiński & Kotliński, 1949; Borisjenko, 1954; Ruszczyc, 1955; Weber, 1957; Liskun, 1961; Olbrycht & Nowicki, 1961; Weinzenried, 1961) using a Lidtin rod, compasses and tape measure.

As from 1965 the hybrids were weighted and measured after they had been caught and confined in a cage specially constructed for the purpose (Krasińska, 1967).

Fifteen basic measurements were made. Their names have been accepted in accordance with those used by breeders when measuring cattle, in order to facilitate comparisons. The names and way in which the various measurements were made are given below:

1. Withers height — vertical distance from ground to top of the withers (measured with a rod) (Fig. 1, a—b).
2. Sacral region height — measured by rod along a perpendicular line passing through the middle of the back (Fig. 1, c—d).
3. Body length — distance from shoulder joint to *tuber ischii* (measured with a rod) (Fig. 1, e—f).
4. Thorax breadth — horizontal distance between the most exterior points of the shoulder joints (measured with compasses or rod) (Fig. 1, g—h).
5. Thorax depth — distance from dorsal line (immediately behind the rear angle of the shoulderblade) to a point at the level of the medial line of the sternum (measured with rod) (Fig. 1, i—j).
6. Heart girth — measured with a tape measure immediately behind the scapule (Fig. 1, k).
7. Fore cannon girth — measured with a tape measure at the narrowest place of the metacarpus (Fig. 1, l).
8. Pelvis lenght — measured with compasses from anterior point of *tuber coxae* to tangent with *tuber ischii* (measured with compasses) (Fig. 1, f—m).
9. Hip bone breadth — horizontal distance between external points of the hips (measured with compasses) (Fig. 1, n—o).
10. Pelvis breadth — horizontal distance between greater trochanters of the femur (measured with compasses).

11. Lenght of head — distance from upper nuchal crest to lower margin of the muzzle (measured with compasses) (Fig. 1, p—r).
12. Lenght of the forehead — distance from upper nuchal crest to a line connecting the medial angles of the eye (measured with compasses) (Fig. 1, p—s).
13. Breadth of head — measured with compasses in the region of the lateral angles of the eye (Fig. 1, t—u).
14. Breadth between horns — distance between bases of horns at upper points (Fig. 1, w—z).
15. Length of horns — measured with a tape measure along the external curve of the horn from basis to end (Fig. 1, A—B).

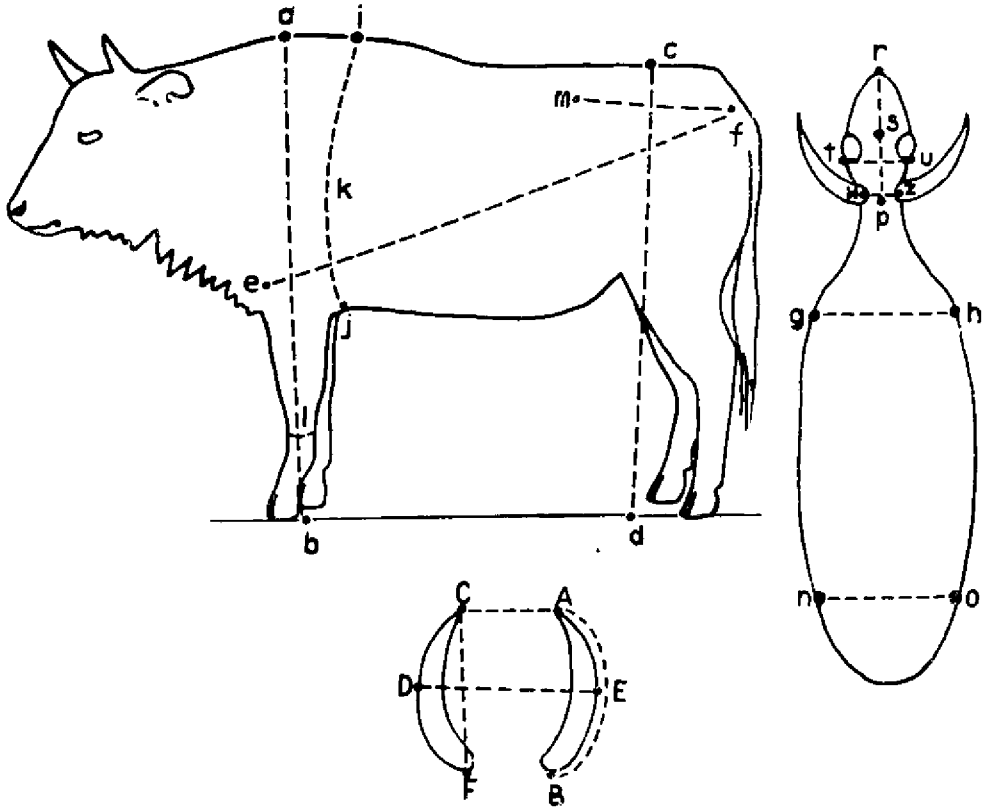


Fig. 1. Figure showing the main measurement points. Explanation of lettering and description of measurements are given in the text.

In order to describe the profile of horns in adult individuals (acc. to L i s k u n's method — I w a n o w & P h i l i p t s c h e n k o, 1916) the following additional measurements were made:

16. Distance between ends of horns (Fig. 1, A—C).
17. Maximal distance between curves of horns (Fig. 1, D—E).
18. Straight lenght od horns (Fig. 1, C—F).
19. Circumference of horns.

Calculations was made on the basis of the measurements obtained of the following 8 indices:

1. Sacral region height × 100/withers height,
2. Heart girth × 100/withers height,
3. (Withers height — thorax depth) × 100/withers height,
4. Fore cannon girth × 100/withers height,
5. Heart girth × 100/body lenght,
6. Withers height × 100/body lenght,
7. Thorax breadth × 100/thorax depth,
8. Thorax depth × 100/withers height.

Measurements of the horns were made in respect of the following adult individuals — F_1 hybrids, 30 cows of the Polish Red breed from Końskowola and 6 cows of the *bw* breed, mothers of the hybrids [2]).

III. RATE OF GROWTH OF BODY MEASUREMENTS AN INDICES

1. Body Weight of F_1 Hybrids at Birth

Distinct sex dimorphism can be observed in the body weight at birth of F_1 hybrids (European bison × *bw* breed) since males are from 13—18 kg heavier than females (Tables 2, 3). Female European bison, which in comparison with domestic cows give birth to fairly small calves (about 25 kg — Krasiński, 1968), also bore smaller hybrids than domestic cows. In the case of female calves these differences were 10 and 14 kg and male calves, about 21—30 kg (Table 3). This shows that within one sex differences in body weight at birth depend on the species of the mother.

2. Body Weight of F_1 Hybrids During Postnatal Development

It is clear from analysis of the absolute values of the body weight of female hybrids (Fig. 2) that this was doubled in the three animals examined after 29, 36 and 40 days, and trebled after respectively 78, 80 and 75 days. At the age of 12 monthe females attained a body weight from 7.5 to 9 times greater than that at birth. The growth rate of both daughters of domestic cows (»Fanny« and »Fatima«) were similar over the whole period of two years. The daughter of a female bison, »Figa«, which was smaller at birth, did not attain the body weight reached by the two-year old hybrids produced by *bw* cows until it was $2^1/_2$ years old.

[2]) Detailed values of measurements and body weights and indices of the structure of the hybrids are to be found in manuscript of Doctor of Veterinary thesis in the Library of the Mammals Research Institute, Polish Academy of Sciences, at Białowieża and the Library of the Veterinary Faculty of Warsaw Agricultural University.

The body weights of males are similar up to the age of 4 months (Table 3, Fig. 2). Later they deviate in the case of »Fakir«, which may however be due to the poorer nutrition conditions, since this hybrid after weaning did not crop grass as did the other two males. Body weight at birth was doubled after 39, 42 and 46 days in the case of the young bulls, and trebled after respectively 83, 86 and 97 days, that is,

Table 2.

Comparison of body weights at birth of hybrids F_1 (wisent × cattle) and of parental breeds of domestic cattle.

No	Kind of crosses or name	n	Body weigth at the birth (in kg)		Author
			Min.-Max.	Avg.	
1	*wb* × *gu* F_1	2		42.3	Ivanov, 1950
	gu			27.7	
2	*wb* × *gu ms*				
	Males F_1	3	40.8—57	50.27	Žuravok, 1935
	Females F_1	4	37.5—50	43.0	
	gu	10		28.0	
	Female *bw*	1		24.0	
3	*w* × *bw* males F_1				
	Lopus	1		58.1	Taworski & Woliński, 1960
	unnamed	1		46.0	
	białow.	3	51.0—60	56.3	Krasińska, 1963
	bw			42.8	Skolasiński, 1964
4	*w* × *bw* females F_1	2	37.5—42.0	39.75	Krasińska, 1963
	bw			36.1	Skolasiński *et al.*, 1966
5	*w* × *pr* females F_1				
	Famela		48		Zaniewski, 1967
	Fama		39		Demiaszkiewicz, 1961
	pr		27—36		Pająk, 1958
6	*c* × *w*				
	Males F_1	2	± 30		Dehnel, 1961
	Females F_1	2	28		Krasińska, 1963, 1967

Abbreviations: *wb* — wisent × bison, *gu* — grey Ukrainian cattle, *ms* — metis-simentaler cattle, *w* — wisent, *bw* — black white lowland cattle, *białow.* — hybrids F, Białowieża, *pr* — Polish red cattle.

slightly later than is the case with the females. One year old hybrids exceeded their birth weight to a lesser degree (only 7—7.5 times greater) than the females at the same age.

The growth rate of hybrids during the period of postnatal development was analysed on the basis of percentage increases in body weights, taking body weight at birth as 100% and also on the basis of mean

daily increases per month and relative increases illustrating intensivity of variations in body weight between successive months of life.

In females the rate of increase in body weight is very high up to the age of 6 months (after which it slows down for the 7th — 13th months), then again rises at the age of 13—17 months (Table 3, Fig. 2). Over the age of 18 months the daughters of domestic cows exhibited a very considerable decrease in growth rate which was not observed in the daughter of the female bison »Figa«.

Table 3.

Comparison of body weights of hybrids F_1 and domestic cattle.
1. Fanny — F_1, 2. Figa — F_1, 3. Fatima — F_1, 4. ♀♀ *bw* — Skolasiński *et al.*, 1966. 5. ♀♀ — *bw* × *gu* — Žuravok, 1935, 6. ♀ wisent × bison, 7. Farad — F_1, 8. Facet — F_1, 9. Fakir — F_1, 10. ♂♂ *bw* — Skolasiński, 1964.

Age, months	Body weight in kg									
	1	2	3	4	5	6	7	8	9	10
At birth	42	26	37.5	36.1	42.3	28	58	60	51	42.03
3	137.6	97	135	102.1	126	71	180	172	160	113.5
6	234	164	223	179.6	220.2	121.2	300	300	250	194.06
9	278	202	268	240.1	260.5	157	374	374	302	276.05
12	313	256	300	304.2	321	183	434	432	350	356.12
15	375	—	373	365.6	397.5	241.5	510	520	405	417.5
18	420	325	415	418	416.5	265.5	570	580	455	493
21	430	360	420	—	—	—	612	690	490	—
24	440	398	430	—	424	276	720	760	570	600[1])
	Percentage increase of body weight									
At birth	100	100	100	100	100	100	100	100	100	100
3	327.6	346.4	360	282.8	297.8	253.4	310.3	286.7	313.7	269.7
6	557.2	585.7	594.7	497.5	520.6	432.8	517.2	508.0	490.2	461.2
9	661.9	721.4	714.4	665.1	615.8	560.7	644.8	623.3	592.2	656
12	745.2	914.3	800	824.7	743.0	653.4	748.3	720	686.3	846.3
15	892.9		994.7	1012.7	939.7	862.5	879.3	866.7	794.1	992.2
18	1000.0	1160.7	1106.7	1157.9	983.5	948.2	982.8	966.7	892.2	1171.6
21	1023.8	1288.5	1120	—	—	—	1055.2	1150.0	960.1	—
24	1047.6	1410.7	1120	—	1002.3	985.7	1241.4	1266.7	1117.8	—

[1]) Konopiński & Kotliński, 1949;
bw — black white lowland cattle, *gu* — grey ukrainian cattle, *wb* — wisent × bison.

The period of intensive juvenile growth in males lasts up to the 8th month of life (Fig. 3), after which it decreases, particularly in the case of »Fakir«. As from the 14th month of life it again becomes slightly higher.

Average daily increases are in general irregular (Fig. 4). Among females they are greater in the daughters of domestic cows than in »Figa«, the daughter of a female bison. During the period from the 6th month of life these increases are maintained on a high level (young

bulls 1—2 kg, heifers 0.55—1.28 kg) after which they decreased sharply in females, and more moderately in males (Fig. 4). At the age of 14—16 months growth in daily increases can be observed from 0.33—1.0 kg in females and 0.67—1.73 kg in males. At the age of about two years daily increases in males are again maintained on a high level (about 0.8 kg), whereas in females increases are very small (about 0.13 kg). Relative increases exhibit a constant tendency to decrease, periods of the most intensive decreases being observed in heifers between the 6th and 7th month, and in males between the 5th and 6th month of life.

Table 4.

Comparison of body weights and body measurements of females hybrids F_1 and females of parental forms.

Measurement	Cows *bw*[1] 5 yrs	Ponętna *w* 8 yrs	Famela F_1 4 yrs	Fanny F_1 4 yrs	Filutka F_1 4 yrs	Fama F_1 5 yrs	Cows *pr*[2] 5 yrs	Galka F_1[3] 8 yrs
Withers height	122.1	157	154	149	155	149	121.08	153
Sacral region height	131.8	151	153	148	153	147	123.58	147
Body length	153.7	152	162	150	152	161	154.79	143.5
Thorax breadth	39.4	34	54	53	50	48	37.4	—
Thorax depth	67.3	83	85	75	82	74	62.57	82
Hearth girth	183.4	225	223	207	218	204	166.2	213
Fore cannon girth	18.6	20	23	22	22	23	17.99	19.5
Pelvis length	49.2	52	60	54	47	54	46.61	—
Hip bone breadth	52.3	44	55	49	48	52	46.09	54
Pelvis breadth	46.2	38	49	42	44	44	41.7	46
Length of head	50.0[4]	49	56	47	57	50	51.5[5]	49
Length of the forehead	25.0[4]	25	26	22	22	22	23.7[5]	26
Width at eyes	20.25[4]	24	22	20	22	22	22.5[5]	25
Breadth between horns	14.5[4]	22	20	16	18	18	17[5]	26
Length of horns	25.0[4]	42	33	30	30	32	23[5]	48.5
Body weight kg	482.6	530.0	750	550	500	505	424.4	—

[1]) Skolasiński, 1959; [2]) Szczekin-Krotow *et al.*, 1958; [3]) Iwanow & Philiptschenko, 1916; [4]) mothers of hybrids (*bw*); [5]) Cows *pr* Końskowola; *bw* — black and white lowland cattle; F_1 — hybrids F_1; *pr* — Polish red cattle; *w* — European bison.

Comparing the increase in body weight of hybrids, males and females, it was found that the differences which existed in the absolute weights at birth are maintained up to the age of 24 months (Fig. 2). The growth rate of body weight in heifers is higher than in young bulls up to 18 months of life in the case of »Figa« even up to the 24th month (Fig. 3). Decrease on the growth rate of body weight takes place earlier in females than in males. A second drop in growth rate (percentage increases, daily increases) occurs in males at the age of 12—13 months, but in the daughters of the domestic cows later, at the age of 18—24

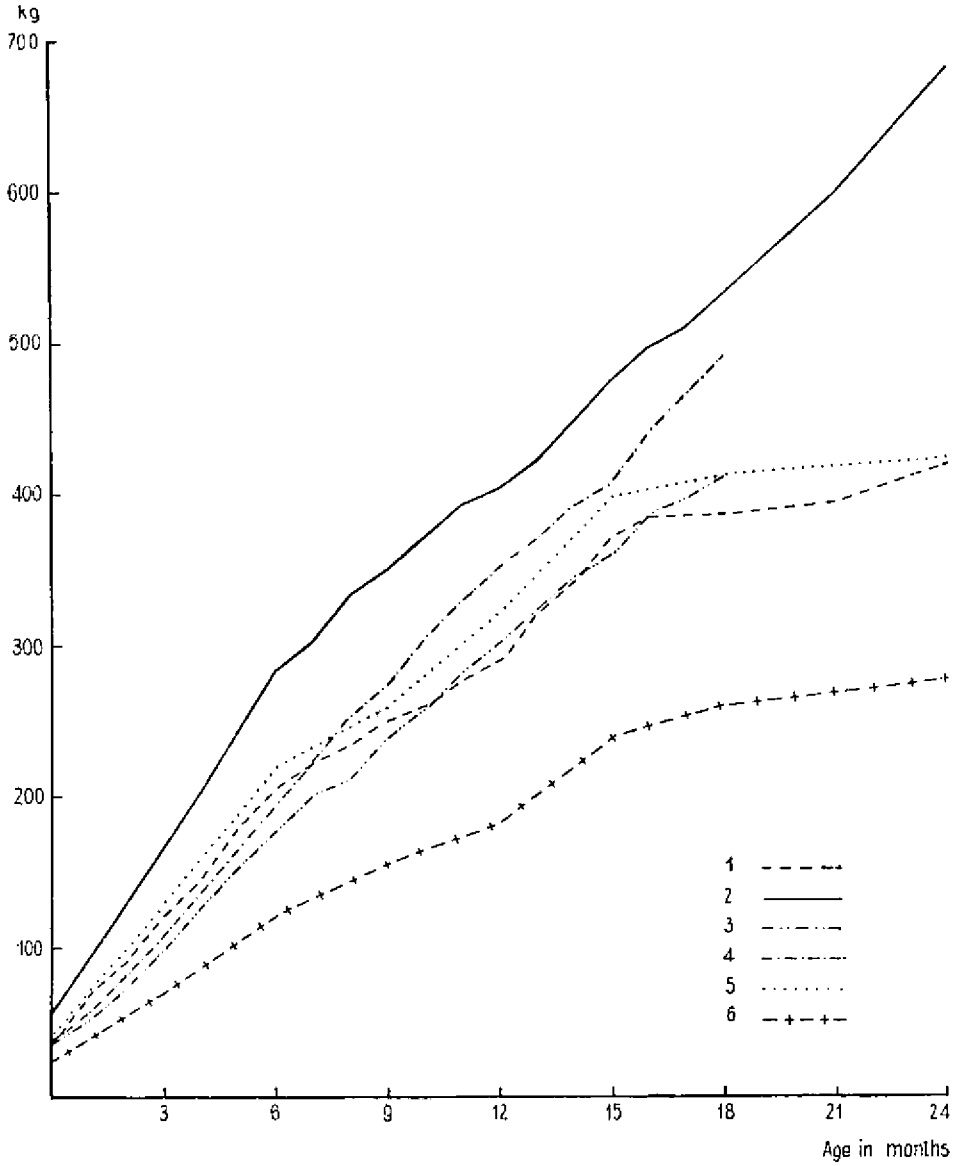


Fig. 2. Age variability of the body weights of hybrids F_1 and initial forms. 1. Białowieża females F_1, 2. Białowieża males F_1, 3. Females Black and White Lowland breed (*bw*) (after Skolasiński *et al.*, 1966), 4. Males Black and White Lowland breed (after Skolasiński, 1964), 5. Females F_1 — (European bison × American bison) × Grey Ukrainian cattle (after Żuravok, 1935), 6. Female — European bison × American bison (after Żuravok, 1935).

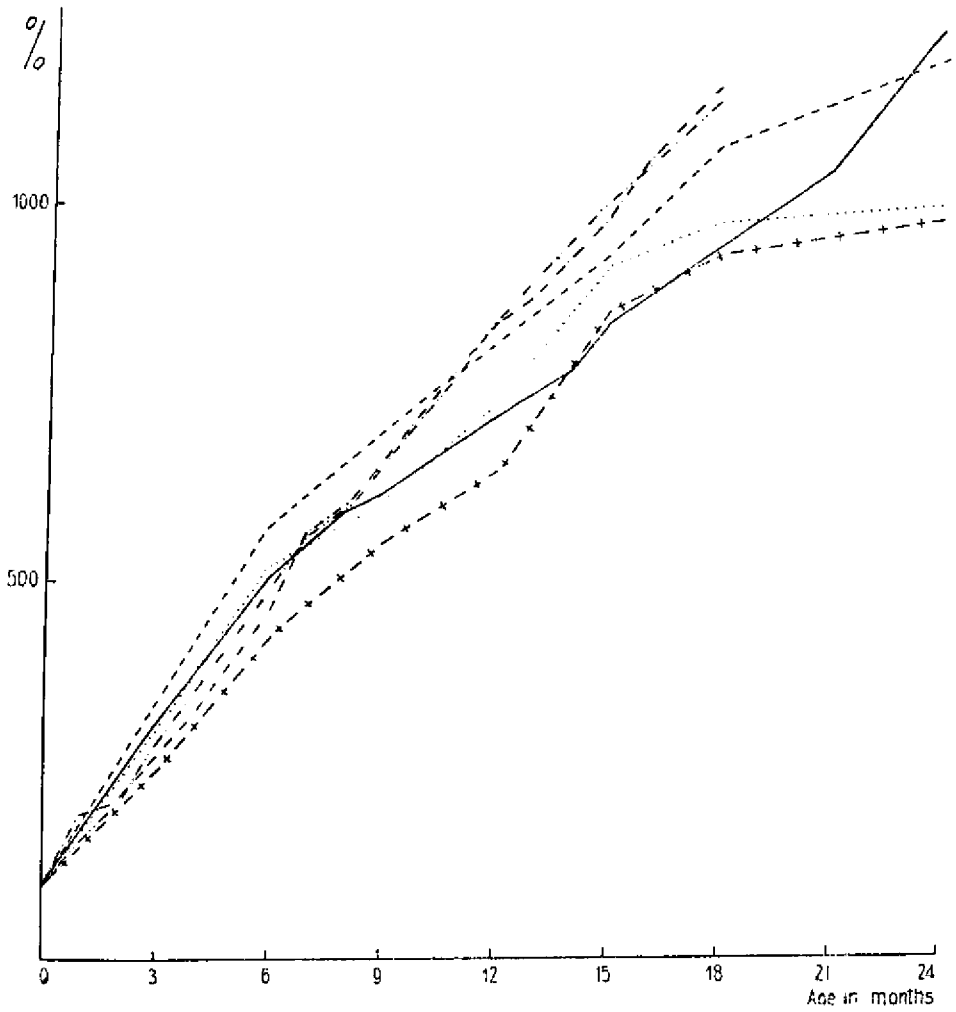


Fig. 3. Increase of the body weights of hybrids F_1 and initial forms (in per cent). Explanations — see fig. 2.

months. It would appear that this may perhaps be connected with the later sexual maturation of hybrid females. The mean daily increases in the weight of males were higher than in females throughout the whole study period (Fig. 4). At an age of up to 6 months in males these increases were on an average 1.27 kg, in females 0.91 kg, then up to the age of 12 months 0.95 kg in males and 0.71 kg in females, while up to the age of 18 months they were 0.86 kg in males but 0.65 in females.

The relative increases in body weight in females were higher than those in males up to the 6th month of life, but these relations are reversed at a later period.

3. Body Measurements of F_1 Hybrids

The proportions of the trunk structure in F_1 females at birth are similar in all the individuals examined. The daughters of domestic cows are of identical build, whereas »Figa« — the daughter of a female bison, was lower and shorter.

Body proportions of males F_1 also are similar at birth, but all body dimensions were smaller in »Fakir«. Both male and female calves are tall and short-bodied at birth. At the age of 12 months the proportions of the trunk structure are reversed. The trunk is strongly elongated in

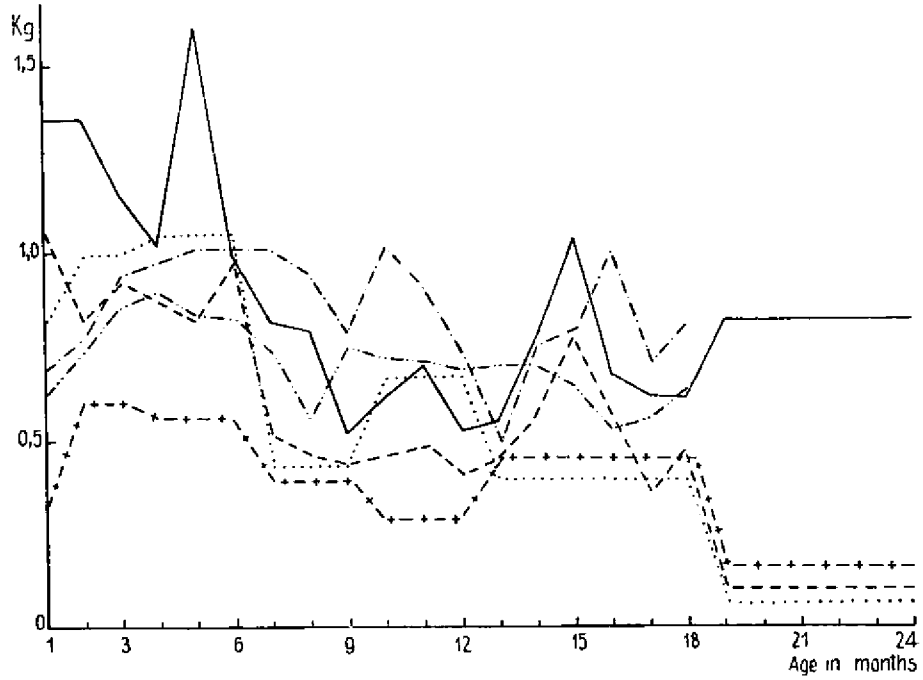


Fig. 4. Age variability of average daily gains of hybrids F_1 and initial forms. Explanations — see fig. 2.

relation to the height, this being more marked in young bulls. At the age of 18 and 24 months the quicker increase in length of the trunk in comparison with height is intensified in hybrids of both sexes. Young bulls attained the square body shape at the age of 3—5 months, and heifers at the age of 7—10 months.

Development of the thorax and pelvis is similar in hybrids of both sexes, the females differing as to smaller dimensions. The thorax rapidly deepens with age, particularly in males. The hip bone breadth smaller than pelvis breadth in hybrids of both sexes at birth, exhibits more

rapid development, so that of the age of 18 months both measurements are equal. At the age of 24 months, however, the pelvis is wider at the ilium than at the trochanters, *i. e.* the reverse of the relations found at birth.

When the development of head measurements is analysed it can be seen that the changes are proportional in hybrids of both sexes. Whereas at birth the structure of the head of females and males exhibited no differences, by the age of 18 months the head of males is wider in relation to lenght, has a longer forehead, and thicker and longer horns.

Among the F_1 males the smallest dimensions and proportions of structure, closer to these of females at the age of 24 months, were exhibited by »Fakir«, this being undoubtedly due to its having been castrated at the age of 18 months.

In comparisons of percentage increase of the various body dimension from birth up to the age of 24 months (Fig. 5) the measurement at birth was taken as 100%. It was found in females that the two measurements of trunk height increase most slowly, the fore cannon girth, body lenght (measurement no. 3), and pelvis length exhibit an intermediate growth rate. The increase in heart girth is most intensive up to the age of 6 months, after which this measurements, and also thorax depth and breadth, show only slightly higher growth rates than the development of hip bone breadth.

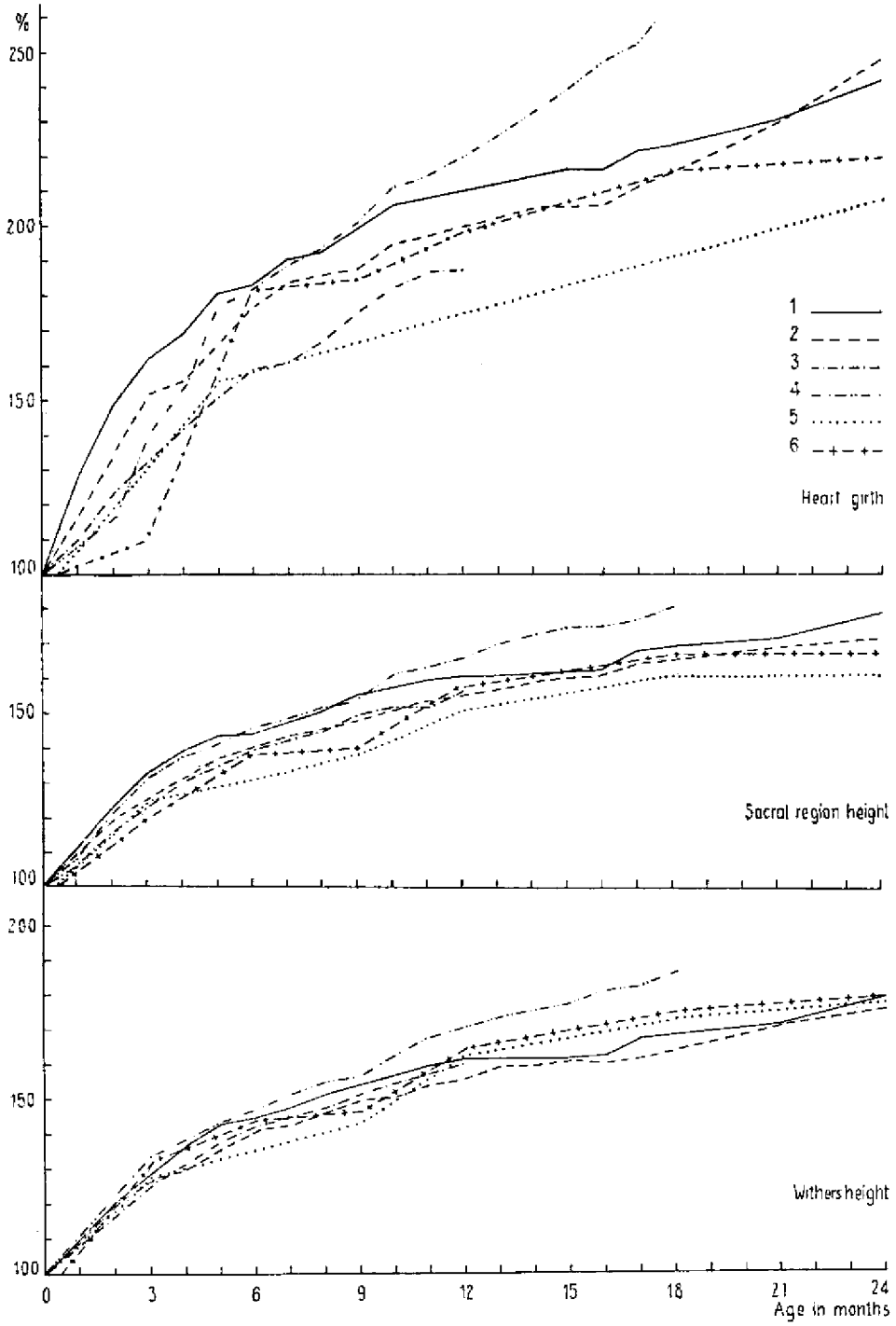
In F_1 males, as in females, the measurements of trunk height increase most slowly with age, and hearth girth — most quickly. The growth rate of heart girth after 12 months of life is slower than that of hip bone breadth.

In hybrids of both sexes the growth rate of withers height and sacral region height is uniform up to the age of 24 months. Females exceed males in the more rapid growth rate of heart girth, pelvis breadth, hip bone breadth and thorax breadth. Similar growth rate is exhibited by thorax depth, body lenght and pelvis lenght, but growth rate of fore cannon girth is slower.

As at birth, at the age of 24 month distinct sex dimorphism is observed in body dimensions of F_1 hybrids. The far larger males are distinguished by their more massive build, more strongly developed anterior part of the body, heavier head with thicker and longer horns.

4. Indices of the Body Structure of F_1 Hybrids

Many authors are of the opinion that comparison of several of the body measurements dependent on each other provides a better descrip-


%
250
200
150
100
1
2
3
4
5
6
Heart girth
150
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Sacral region height
200
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Withers height
0
3
6
9
12
15
18
21
24
Age in months

Fig. 5.

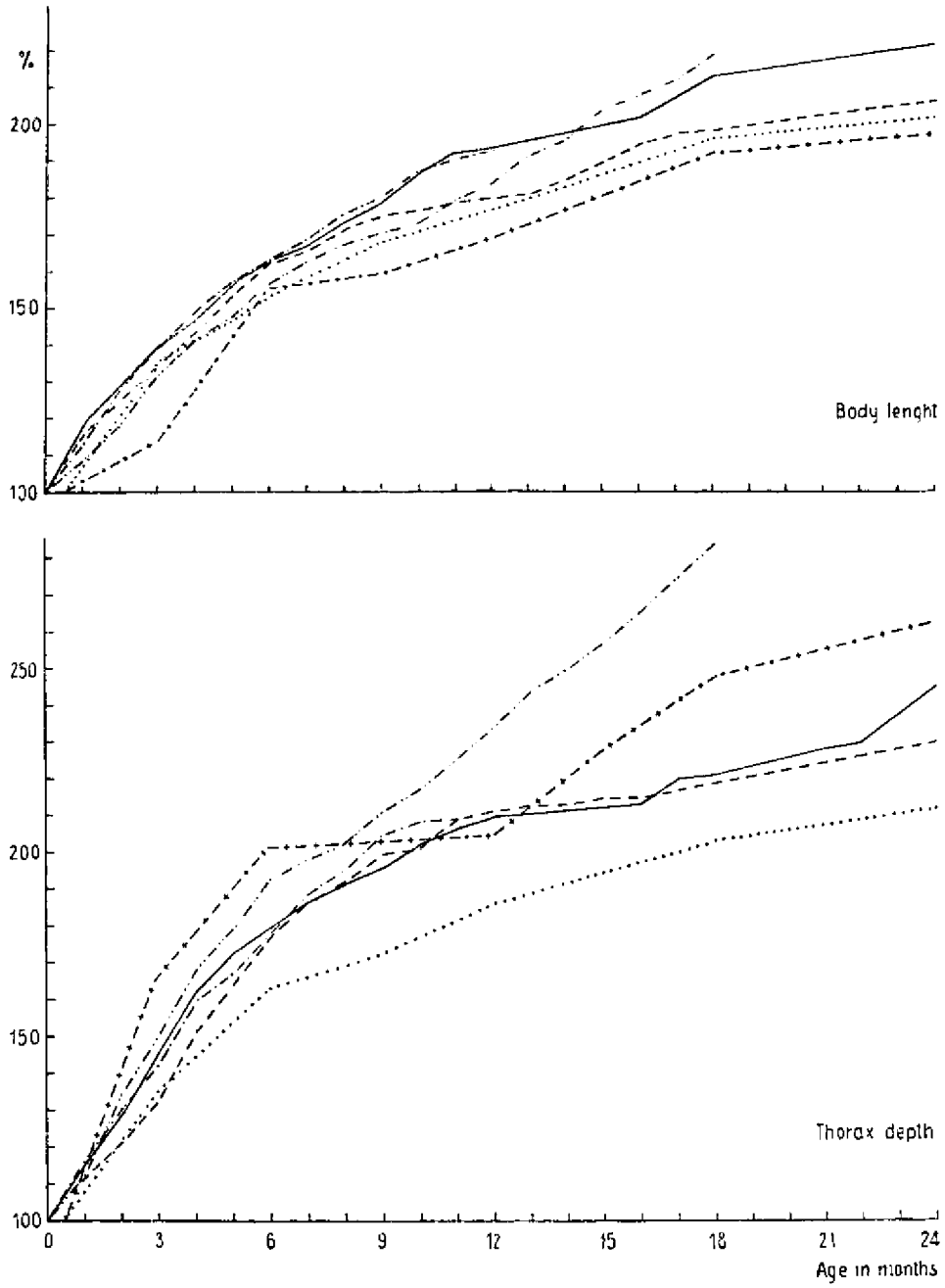
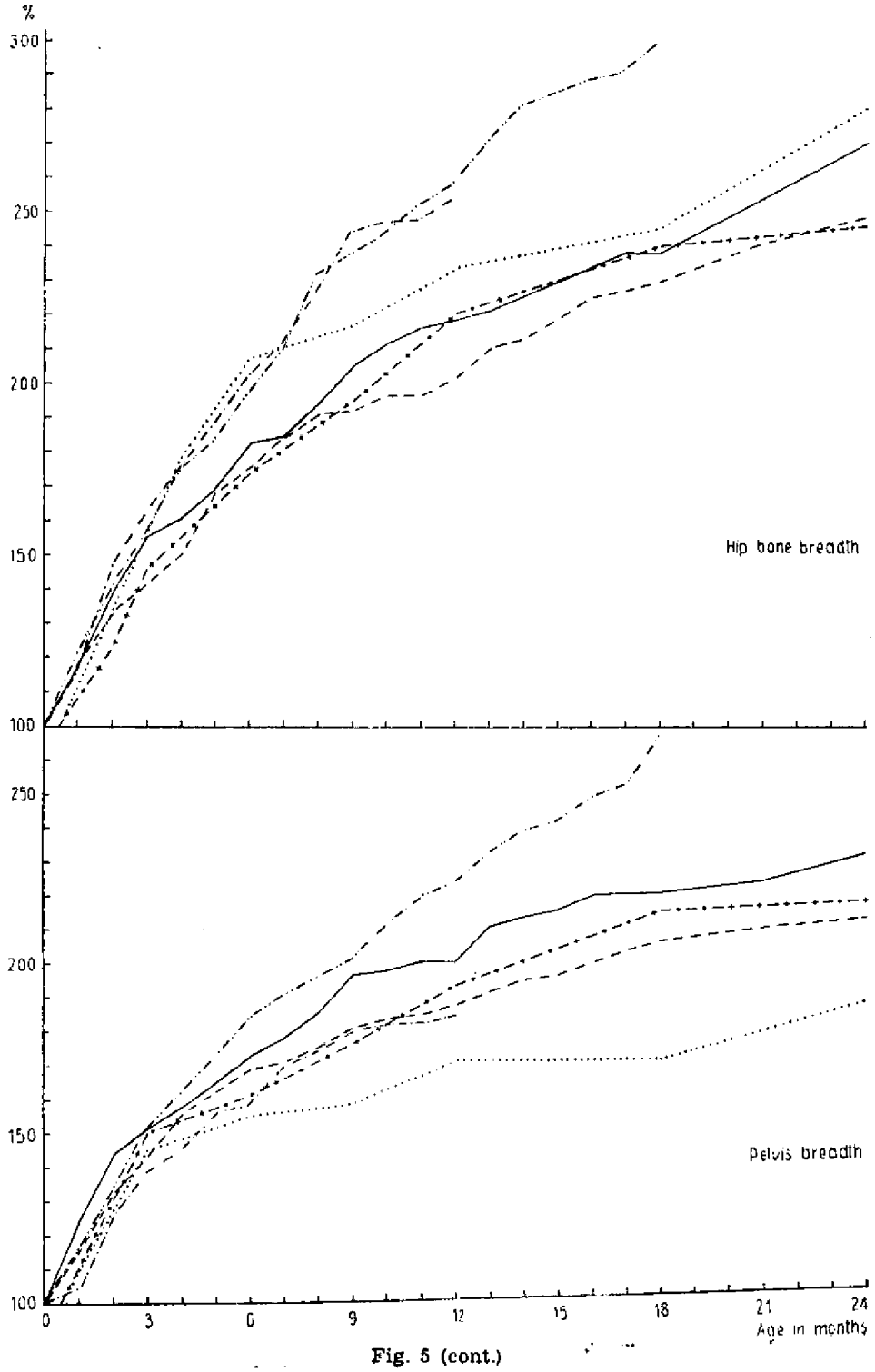


Fig. 5. Rate of the increase of body measurements of hybrids F_1 and initial forms (in per cent).
Explanations — see fig. 2.


%
300
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Hip bone breadth
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Age in months

Fig. 5 (cont.)

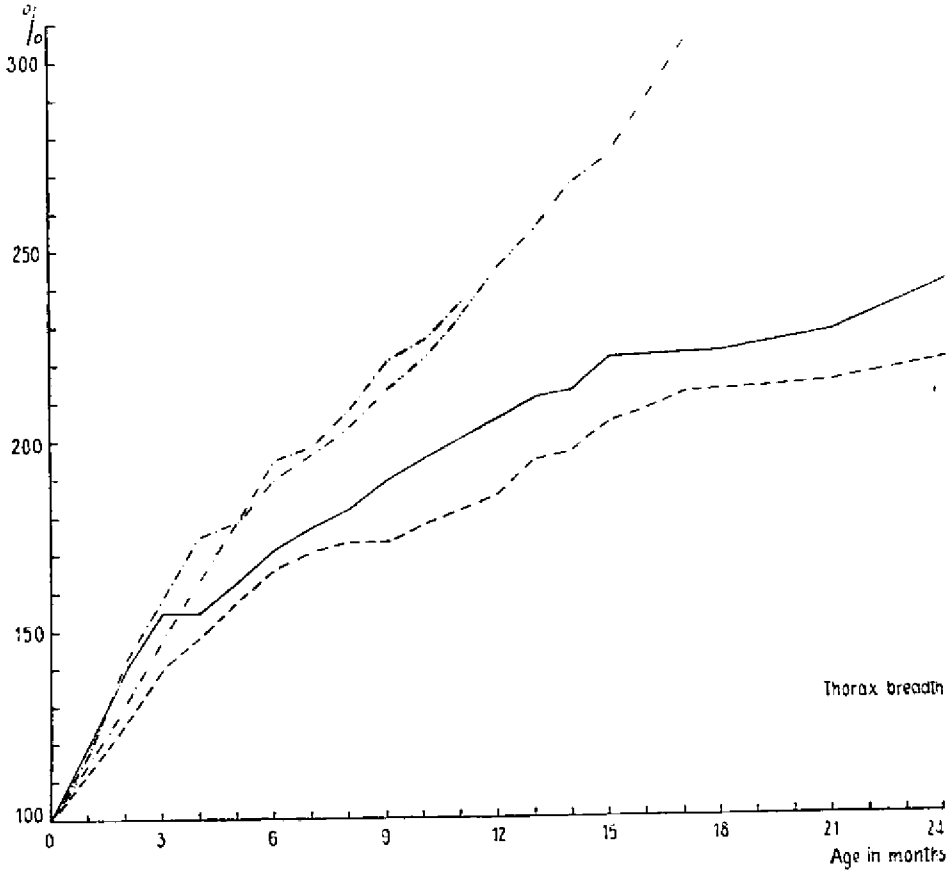

Fig. 5 (cont.)

tion of the animal's build than single measurements (Duerst 1931; Borisjenko, 1954; Ruszczyc, 1955; Pająk, 1958). Indices of structure have also been taken into consideration in analysing the postnatal development of F_1 hybrids.

Female F_1, daughters of domestic cows, exhibit considerable similarity in build, while »Figa«, the daughter of a female European bison, was smaller and shorter at birth (Fig. 12). These differences disappear at the age of 24 months.

Male F_1, on account of their uniform origin, exhibit a more balanced type of build (Fig. 12).

Indices: (Withers height — thorax depth) × 100/withers height and Withers height × 100/body lenght, in hybrids of both sexes markedly decrease by to the age of 9 months, as from which they are stabilized, exhibiting only very slight variations. Females attained the square body shape later than males. At birth the males were longer in relation to

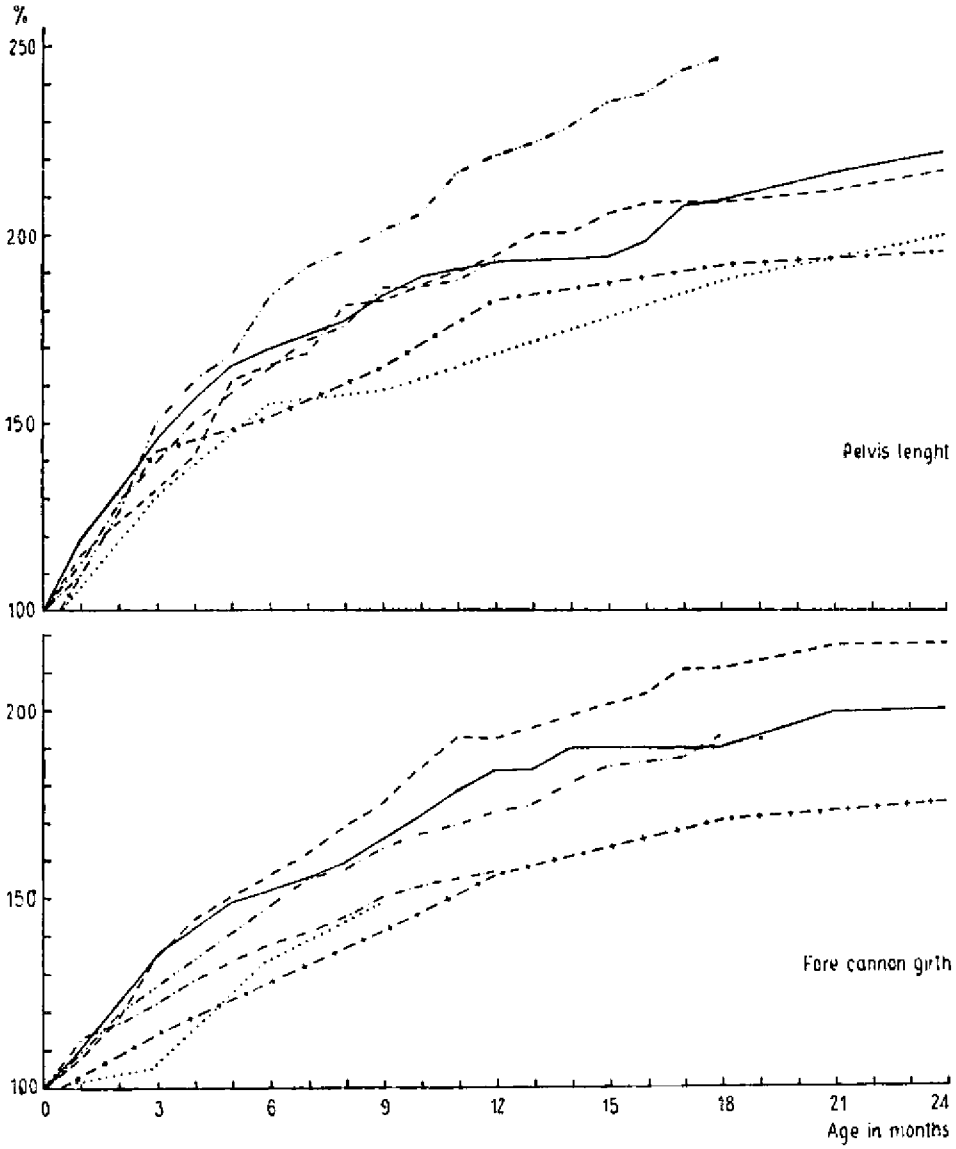

Fig. 5 (cont.)

height than females, but at the age of 24 months the proportios of body structure were similar in hybrids of both sexes. Females are more longlegged than males up to the age of 24 months.

Indices: Heart girth × 100/withers height and Thorax depth × 100/withers height exhibit increase in hybrids of both sexes up to the age of 6—7 months, from which time onwards they remain on an unchanging level. As from the age of 4 months the index of thorax

depth in males exhibits a higher value than in females, which is due to the more intensive development of thorax depth as compared with the withers height.

Index: Sacral region height × 100/withers height exhibits slight changes only in hybrids of both sexes which points to the even development of the two measurements of withers height. At the age of 24 months the line of the back in males is almost horizontal, while the females »Fanny« and »Figa« are still built up in the pelvis.

Index: Fore cannon girth × 100/wither height exhibits a slow increase in hybrids of both sexes up to the age of 16—17 months. This is connected with the more rapid development of the thickness of the bones than their elongation. This index is similar in both males and females at birth, but at the age of 24 months it is higher in males, which points to their skeleton being more massive.

Indices: Thorax breadth × 100/thorax depth and Heart girth × 100/body length exhibit considerable individual and age variations. Thus at birth and at the age of 24 months the value of the index of thorax breadth in females and males are similar, which is evidence of the similarity of the proportions of the thorax structure.

To recapitulate it may be said that the proportions of the animals' build do not exhibit great differences between hybrids of the two sexes. In the case of bulls, however, those parts of the body which are connected with the typical male outline (depth and height of trunk, more massive head etc.) are better developed.

IV. EXTERIOR OF F_1 HYBRIDS OVER THE AGE OF 4 YEARS

1. Body Weight

Distinct sex dimorphism is evident in the body weight of F_1 hybrids (Table 4, 5). The males are on an average 290 kg heavier than the females. Male F_1 obtained from the female bison covered by a domestic bull of the *pr* breed are lighter than those produced by domestic cows of the *bw* breed covered by a male bison. Among the females of the two groups the differences in weight depending on the breed of the mother are not so distant.

2. Body Measurements and Indices

Female F_1 represent a balanced type in respect of the general body structure. Daughters of female bison do not exhibit distinct differences in comparison with the daughters of domestic cows, but are smaller (Table 4). »Famela« was distinguished from all the cows by reason of

its greater body measurements. The similarity of the indices also confirms the slight degree of variation in the proportions of the build of F_1 cows. The head in females is characterised by a short forehead. »Famela« was the least longlegged. All the cows are built up at the withers.

Analysis of the build of male F_1 on the basis of body measurements and indices justifies the statement that bulls obtained from crossing the female bison with a *pr* bull are smaller, are characterised by a sloping line of the back and less strongly developed pelvis than the progeny of *bw* domestic cows and bison, which may be attributed to the influence of the mother's species (Table 5). »Facet« and »Farad« are

Table 5.
Comparison of body weights and body measurements of males hybrids F_1 and males of parental forms.

Measurement	Pokorny, *w* 8 yrs	♂♂ *pr* [2]) 5 yrs	Richtje *bw* 5 yrs	Filon F_1 5.5 yrs	Filip F_1 5.5 yrs	Facet F_1 4 yrs	Farad F_1 4 yrs	Herkules F_1 [1]) 3 yrs
Withers height	170	126.5	155	155	150	171	166	151
Sacral region height	162		135	153	148	168	163	145.5
Body length	176		171	176	163	186	174	163
Thorax breadth	52	51	58	63	57	66	63	37.5
Thorax depth	98	73.5	81	87	77	97	92	79
Hearth girth	262	198.0	223	235	228	258	252	193
Fore cannon girth	29	20.25	25	24	25	27	26	19
Pelvis length	60	52.0	55	53	55	65	65	57
Hip bone breadth	52	55	54	51	52	60	56	45.5
Pelvis breadth	42	48.75	52	48	48	50	53	43.3
Length of head	53		52	58	59	60	58	48
Length of the forehead	27		25	25	26	29	28	26
Width at eyes	38		25	25	26	30	27	26.5
Breadth between horns	32		18	25	26	30	25	24
Length of horns	39		27	39	40	40	42	48.5
Body weight kg	730	600	790	800	730	1030	930	—

[1]) Iwanow & Philiptschenko, 1916, [2]) Szczekin-Krotow *et al.*, 1958, *pr* — Polish red cattle, *bw* — black white lowland cattle.

characterized by greatest body measurements. Markedly strong build at the shoulder occurs in all bulls. Breadth of the thorax is similar in all the bulls. The head is massive, with thick and long horns.

Distinct sex dimorphism is observed in body weight and size of F_1 hybrids. The thorax is shallower in relation to its height in females in comparison with males. Only the build of »Famela« is similar in its proportions to those of males. In relation to depth the breadth of the thorax is smaller in females (except »Fanny«). Males are longer in relation to height than females, and have a thicker bone structure. »Filut-

ka«, »Fanny« and »Filip« were the most longlegged. Hearth girth in relation to thorax depth is greater in males, and similarly they are more strongly built at the withers than females. In males the head is of more massive structure, wider and with a longer forehead.

3. Horn Profile

Horns begin to grow during the first month of life in hybrids of both sexes, but growth is more intensive with age in males than in females. Over the age of 4 years the horns of males are far thicker and longer than those of females (Table 4, 5).

Horn profile in male hybrids differs from that of females. In bulls the horns follow a lateral direction on leaving the skull, then bend upwards, and in females the extreme ends of the horns bend towards the centre (Fig. 15).

V. COMPARISON OF THE DEVELOPMENT AND EXTERIOR OF F_1 HYBRIDS OF THE EUROPEAN BISON WITH DIFFERENT BREEDS OF DOMESTIC CATTLE

1. Postnatal Development During the Period from Birth to the Age of 24 Months

There are few studies discussing the development of hybrids from European bison domestic cattle and their exterior when adult (Müller, 1852; Karcov, 1903; Iwanow & Philiptschenko, 1916, Mokeev & Zuravok, 1935; Zuravok, 1935; Zablocki, 1939, 1956; Taworski & Woliński, 1960). Although these studies, like the present one, are based on a relatively small amount of material, yet on account of its unique character their results have been compared with the development of domestic cattle, a species thoroughly elaborated in respect of postnatal development and, in addition, on the basis of abundant material.

A large number of studies were available for comparison of the build of Białowieża hybrids with the build of calves of the *bw* breed, but I used data from recent years, obtained from material bred on the outdoor rearing system (Skolasiński, 1964; Skolasiński *et al.*, 1966). These studies do not unfortunately describe the development of calves of both sexes up to the age of 24 months (heifers only up to 12 months).

Up to the present there has been a lack of exhaustive data on the development of the European bison during postnatal life, particularly data based on live material. A certain amount of information can be gleaned from anatomical works (Empel, 1962; Roskosz, 1962;

Swieżyński, 1962; Empel & Roskosz, 1963). There are also data on the development of one female European bison × American bison hybrid during the period from birth up to 24 months, from Askania Nova, which data, on account of their unique character, have been included in the comparison (Żuravok, 1935).

1.1. Body Weight

The animal's weight at birth is a measure of intensivity of prenatal development. There are many factors conditioning and influencing this period of development, and in consequence body weight at birth. Among these the genetic factors, connected with the species or breed of the animal, the calf's sex, heterosis, occurring when cross-breeding, extreme food deficiencies and high temperature are most important. The influence of the father can also be traced here, but to a lesser degree than that of the mother, which in addition creates a long-lasting uterine habitat affecting the development of the embryo to a considerable degree in rabbits and mice and in birds (Hammond, 1949, 1958; Ellis *et al.*, 1955; Staliński, 1959; Meyer, 1964).

In the present investigations, and when analysing results of other experiments, it was also found that the mother exerts an influence on the body weight of hybrids at birth (Table 2, 3). Domestic cows covered by an European bison or European bison × American bison give birth to large hybrids, and female bison — to small hybrids. The body weight at birth of hybrids of both sexes borne by female bison was similar to that of bison calves.

Distinct sex dimorphism was observed in birth weights of both domestic calves and hybrids of European bison × domestic cattle. The birth weight of male F_1 from Białowieża exceeds of *bw* male calves by 8—17 kg, their weight coming outside the range body weights of the males of this breed (30—48 kg). Similarly the birth weight of male F_1 from Płock and Askania Nova greatly exceeded that of domestic calves (Fig. 15). Heifers originating from the *pr* breed at Białowieża and Popielno were 3—12 kg heavier at birth than *pr* heifers, and their weights exceeded the range of variations in weight of this breed (27—36 kg). The weight of female hybrids from *bw* cattle only slightly exceeded the birth weights of *bw* heifers, and corresponded to the extreme values in the range of variations in their weight. The birth weight of hybrids from Askania exceeded that of domestic heifers by 9.5—22 kg.

To sum up it may be said that in F_1 hybrids [European bison × cattle, (European bison × American bison) × cattle] heterosis appears during the prenatal period of growth. This is manifested in intensifica-

tion of development, when the mother of the hybrid is a domestic cow, and is particularly marked in male calves.

The phenomenon of heterosis, manifesting itself most strongly in distant hybridisation, is a generally known fact (Kushner, 1938, 1941; Kołataj, 1967), and was also recorded among American bison × cattle hybrids (Deakin *et al.*, 1935, 1941; Logan, 1950; Peters, 1963).

The postnatal development of the animal is connected with its body weight at birth. Calves with a particularly low birth weight have a low degree of viability (Hammond *et al.*, 1958; Meyer, 1964; Flade, 1965). This weight is directly connected with later development up to the age of 8—12 weeks (Abelein & Ritter, 1959; Bernard, 1962 — cited after Meyer, 1964). In animals bred for meat this connection is also maintained at a later period of development.

In male hybrids [3]) there is particularly intensive rate of increase in body weight up to the age of 8 months, which is not observed in domestic bulls, in which body weight increases regularly during the first year of life (Fig. 3). In male hybrids reduction in rate of increase in weight lasts from 9 to 13 months, but in *bw* bulls this occurs at the age of 7—8 months. This phenomenon is connected with sexual maturation (Skolasiński, 1958) and the later reduction in increase at the age of 15 months Konopiński (1928) connected with physiological processes taking place in the organism, such as ossification of cartilages, eruption of teeth. Slowing down of the rate of increase in hybrids at a later age than domestic bulls is also presumably caused by »sexual maturation« [4]) which takes place later in hybrids than in domestic males. The rate of increase in body weight in F_1 bulls is higher than in *bw* males up to the age of 9 months. The curve of increase in absolute body weight of male hybrids up to the age of 18 months exhibits a considerable predominance over the weight of *bw* bulls (Fig. 2). At the age of 6 months male hybrids exceed the weight of *bw* males by 44%, at 12 months by 14% and at 18 months by 8.5%. Mean daily increases (Fig. 4) in male hybrids do not exhibit such regularity as in *bw* bulls. They are greatest during the first six months of life and decrease during the period when the rate of increase in body weight slows down. During the first year of life, however, their mean value is higher than in *bw* bulls.

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[3]) In this part of the study the word hybrids used without an adjective means the Białowieża hybrids.

[4]) This process does not of course lead to attainment of sexual maturity, but is merely the manifestation on the occurrence of normal sexual drive (Krasińska, 1967).

F_1 heifers up to the age of 10 months have a far higher rate of increase in body weight than *bw* heifers (Fig. 3), weight increasing most intensively in the hybrid »Figa« up to the age of 18 months. Hybrids out of (European bison × American bison) × Grey Ukrainian cattle exhibited a lower rate of increase in weight than the Białowieża hybrids, and the lowest rate in hybrids (European bison × American bison) × metissimentaler breed (Table 3, Fig. 3). The rate of increase in body weight of the female hybrid European bison × American bison, from the age of 15 days up to 24 months is lower than in Białowieża hybrids and is similar to our F_1 males only during the period from 12—17 months. Female hybrids exhibit more intensive increase in body weight than males, but in *bw* heifers the rate of increase was higher than in young bulls only up to the age of 8 months (Skolasiński *et al.*, 1966). According to other authors the influence of sex is marked only up to the age of 3 months (Dobkowski, 1961). The first reduction in intensive rate of increase in body weight in Białowieża and Askania females takes place at the age of 6 months, and the second in two daughters of domestic cows and Askania hybrids at the age of 18—24 months, which may be connected with their late sexual maturation. For cattle the period of the first 3 months is the period of most intensive growth (Pająk, 1958), and in the case of *bw* heifers, 6 months (Kaczmarek & Nowicki, 1961).

Absolute body weights of F_1 hybrids, the daughters of domestic cows, are higher than in *bw* heifers up to 18 months, in the case of the daughter of the female bison are similar to *bw* up to the age of 11 months, and lower at the age of 18 months ((Table 3, Fig. 2). Absolute values of the body weight of Askania hybrids are similar to those of the Białowieża animals throughout the whole period of development. The lowest body weights are exhibited by the female European bison × American bison throughout the whole period (Table 3, Fig. 2). Mean daily increases in female hybrids are higher than in *bw* heifers only during the first six months of life. Doubling of the weight of females and trebling occurred earlier in Białowieża hybrids than was recorded for *bw* heifers from the Poznań area (Konopiński & Kotliński, 1949), which is also proof of the intensivity of their development. At the age of 6 monts F_1 males were 23% heavier in weight than *bw* heifers, but at the age of 12 and 18 months these differences no longer occurred.

The F_1 hybrid »Żukawa« European bison × (*bw* × watussi cattle) from Płock Zoo weighed 109 kg at the age of 1.5 months (Taworski & Woliński, 1960) and thus more than the 2-month old Białowieża heifers, and its weight increased by 200 kg during the year, which is

evidence of the intensive increase in its weight. This heifer also developed most intensively up to the age of 6 months (Taworski & Woliński, 1960).

The percentages of daily increases are lower in female hybrids than males, as was also observed in cattle (Pająk, 1958; Skolasiński, 1959; Skolasiński *et al.*, 1966). Relative increases in the body weight of hybrids of both sexes, in domestic calves and Askania calves decrease similarly with age.

It is characteristic that despite the low birth weight in comparison with other hybrids the daughter of the female bison — »Figa« — exhibits the maximum rate of increase in body weight from birth to 24 months of life, greatly exceeding that of *bw* heifers. This indicates that in this animal, as in the progeny of domestic cows, heterosis occurs during postnatal development. A similar phenomenon was also observed in the F_1 hybrids born by the American bison females (Peters, 1963).

1.2. Body Measurements and Indices

In postnatal development the axial skeleton begins to grow more quickly than the bones of the limbs (Pająk, 1958; Nowak, 1966). The upper limit of the animal's size is determined genetically, but the mother was observed to exert a great influence on the size of progeny in different species of mammals, and this influence is also maintained during postnatal development (Flade, 1965). When examining the transmission to progeny of the dimensions of different parts of the body in cattle a certain percentage of hereditary differences in structure between different individuals was found (withers height, fore cannon girth, heart girth, hip bone breadth), which led to the suggestion that by proper selection it would be possible to bring about a change in body measurements in subsequent generations (Tyler *et al.*, 1948).

The development of different body dimensions does not take a uniform course. Development in height in cattle ends earlier than development of breadth and depth (Weinzenried, 1961). The proportions of pelvis and head alter similarly with age (Konopiński & Kotliński, 1949). Parts of the body strongly developed in calves change slowly with age (*e. g.* height, but the opposite applies to parts more weakly developed (Hammond *et al.*, 1958). The mother was found to exert a great influence on the proportions of body build at birth of its progeny in different species of mammals (horses, cattle, dogs, rabbits) — Ellis *et al.*, 1958; Hammond *et al.*, 1958; Meyer, 1964; Staliński, 1959.

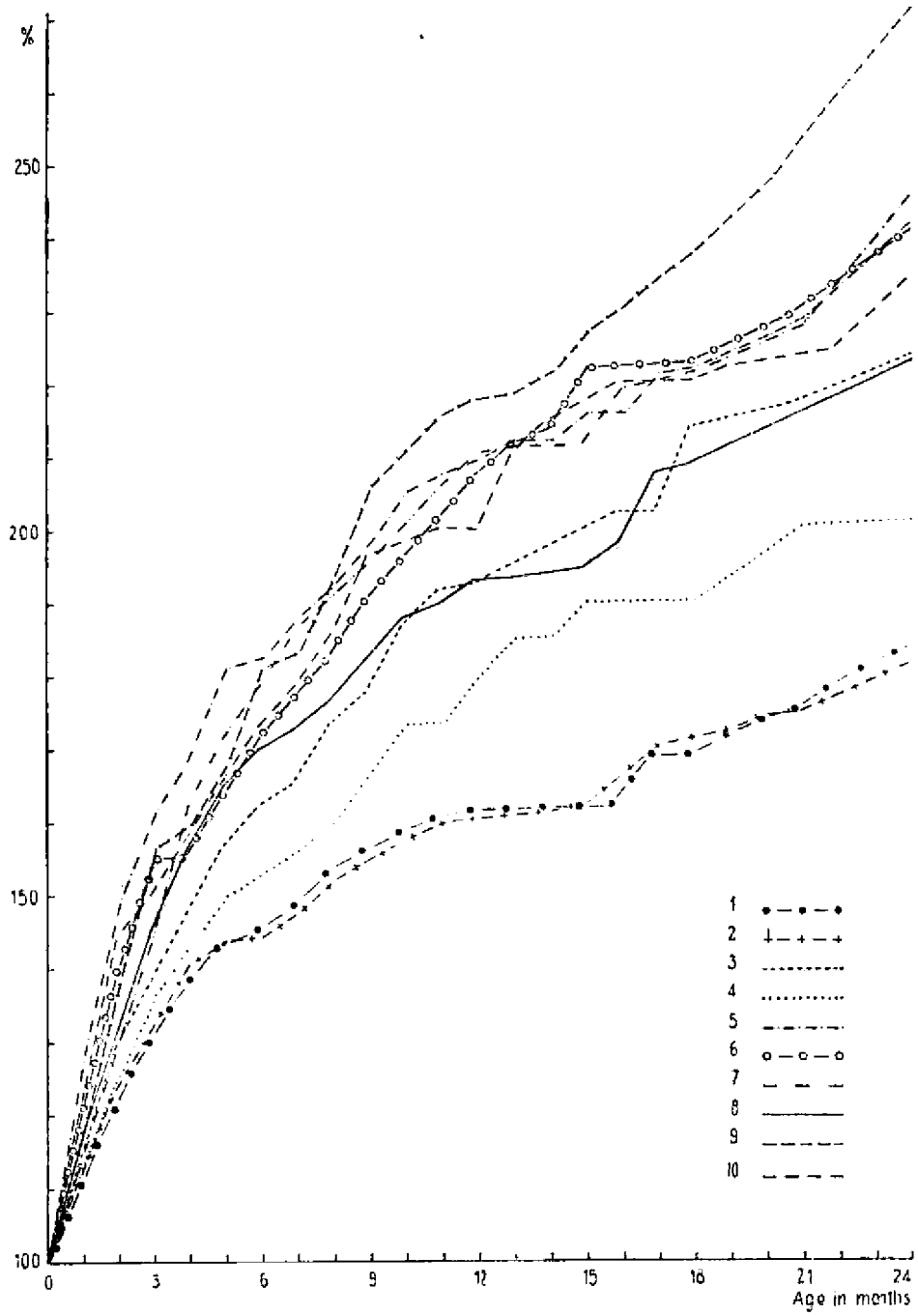
In the present study the mother was found to influence the build of

F_1 hybrids. Hybrids produced by a female bison differ in respect of build from the progeny of domestic cows.

Sex dimorphism is distinctly present from the time of birth in all the Białowieża hybrids, Askanian animals and domestic calves examined. As in the case of domestic calves, at birth the hybrids are short and high, have small heads, but the *bw* calves have a better built pelvis region relation to their size, a shallower thorax and are more massively built up at the sacral region, are longer in relation to height and the difference between hip bone breadth and pelvis breadth is greater in them than in hybrids. »Żukawa« at the age of 2.5 months was similar in build to the Białowieża hybrids. The 15-day old Askanian hybrids were more strongly built up in the sacral region than the Białowieża heifers at birth, were longer and had a deeper thorax. The build of the trunk of the female European bison × American bison was similar at the age of 15 days to that of the *bw* femals. The one year-old females from Askania were higher and longer than the Białowieża females, and the build of the trunk was similar to that in *bw* in respect of the other body dimensions the thorax was shallower and the pelvis narrower than in the Białowieża animals. *Bw* yearlings of both sexes were lower, more strongly built in the sacral region, with a shallower thorax than in the Białowieża hybrids. The height of the female European bison × American bison at the age of 12 months was similar to that of the *bw* heifer, but shorter, deeper and with a less strongly built pelvis. The proportions of the trunk change at the age of 12 months in all the hybrids, as they do in domesic calves. The trunk becomes markedly elongated in comparison with height, only the female European bison × American bison retaining the same proportions as at birth. At the age of 18 months *bw* bulls are lower and longer than male F_1, have a broader and shallower thorax and better developed pelvis. The Askanian hybrids at the age of 18 months are still higher and longer than the Białowieża hybrids and have a narrower rump. At this age the female European bison × American bison has a deeper thorax and narrower rump in relation to its size. At the age of 24 months the Askanian hybrids differ from the Białowieża animals only in respect of their greater length.

When the percentage increases in body dimensions are compared it can be seen that the Białowieża hybrids of both sexes exceed the *bw* calves in rate of development of fore cannon girth and heart girth up to the age of 7—8 months (Fig. 5). Changes with age in the body length and its height are similar in respect of intensivity in all F_1 hybrids, *bw* calves and the female European bison × American bison (Fig. 5).

Rate of increase in thorax breadth and hip bone breadth is higher in Białowieża hybrids than in domestic calves. The Askanian hybrids also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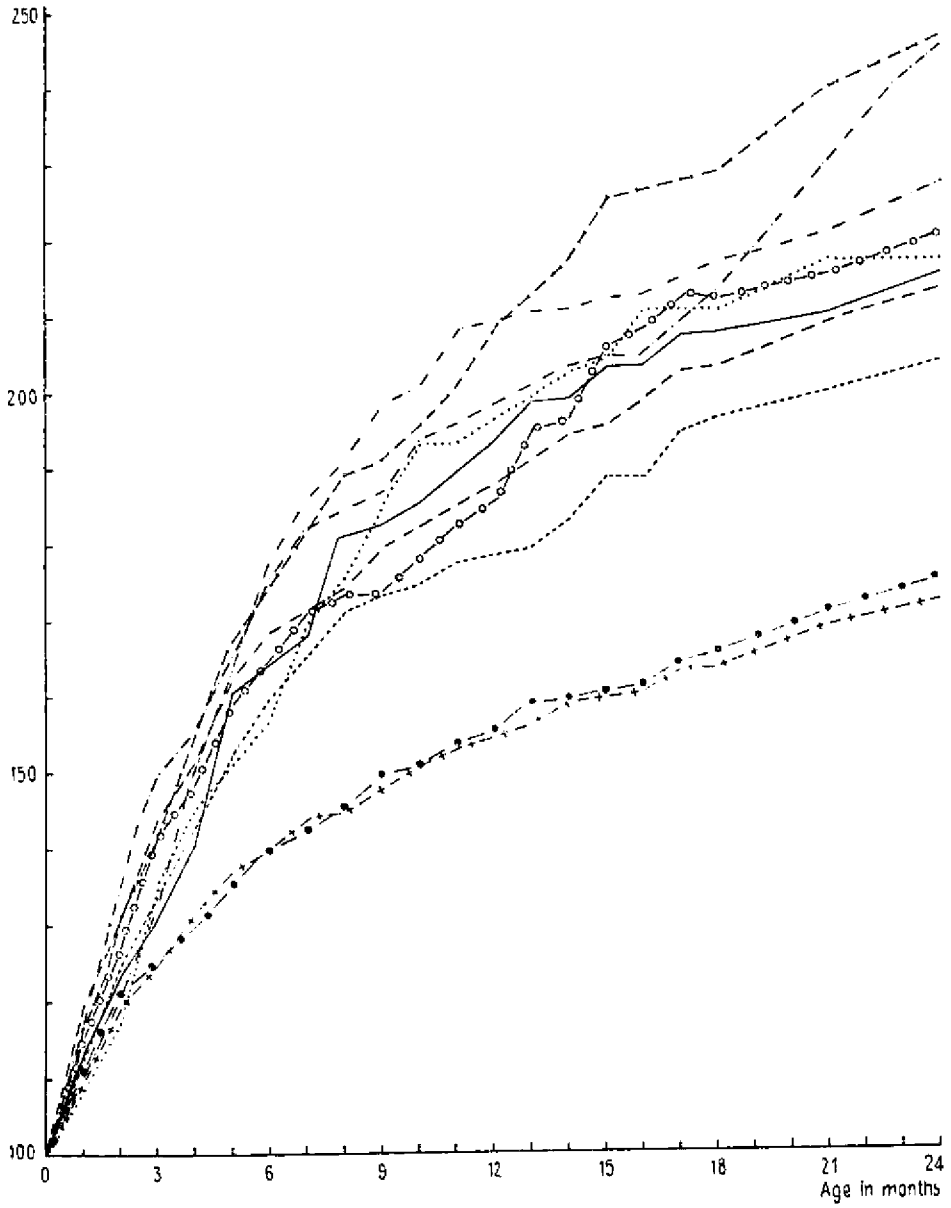


Fig. 7. Rate of the increase of body measurements of males hybrids F_1 (in per cent). Explanations — see fig. 6.

Fig. 6. Rate of the increase of body measurements of females hybrids F_1 (in per cent).
1. Withers height, 2. Sacral region height, 3. Body length, 4. Fore cannon girth, 5. Heart girth, 6. Thorax breadth, 7. Thorax depth, 8. Pelvis lenght, 9. Hip bone breadth, 10. Pelvis breadth. ←—

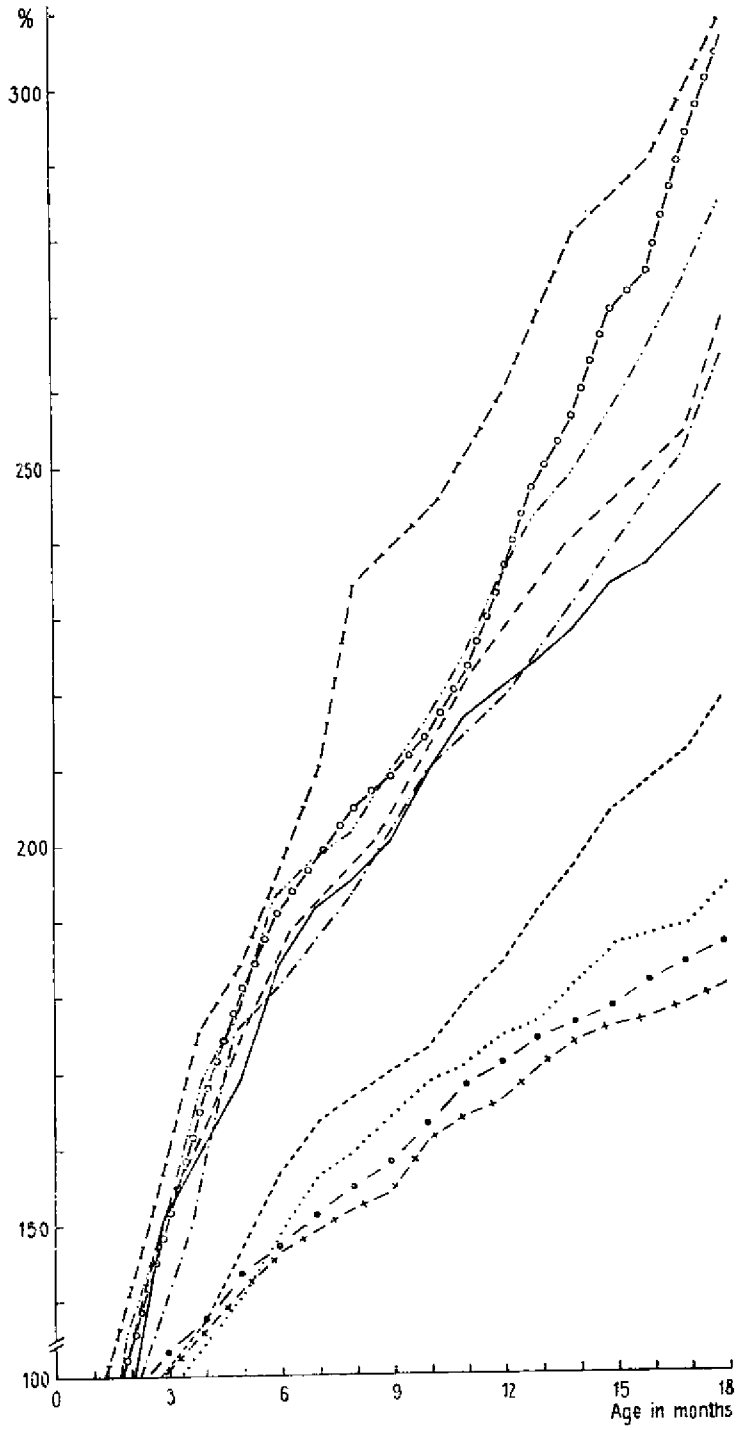


Fig. 8. Rate of the increase of body measurements of males *bw* breed (acc. to data of Skolasiński, 1964).
Explanations — see fig. 6.

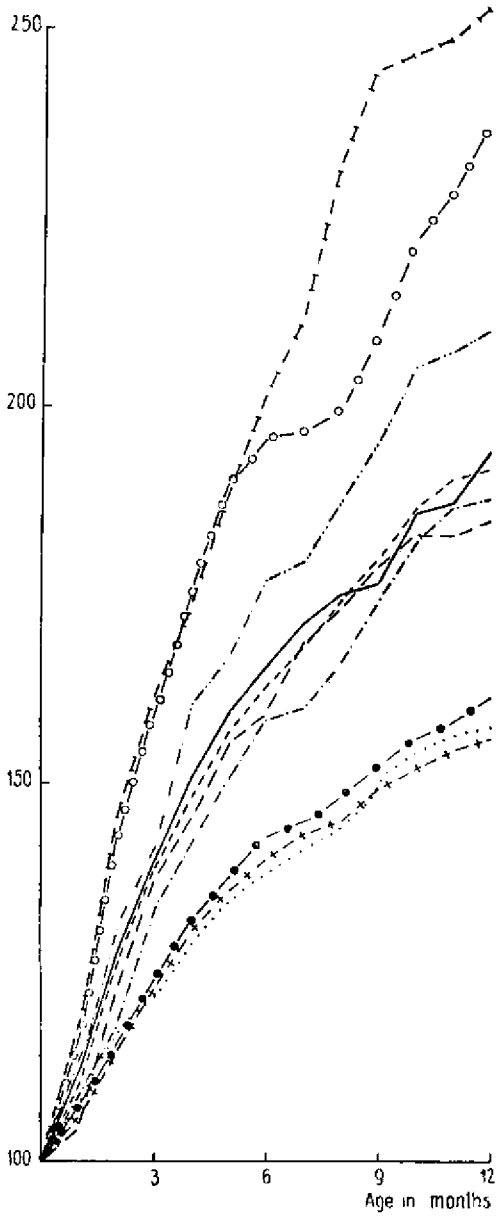


Fig. 9. Rate of the increase of body measurements of females *bw* breed (acc. to data of S k o l a s i ń s k i *et al.*, 1966).
Explanations — see fig. 6.

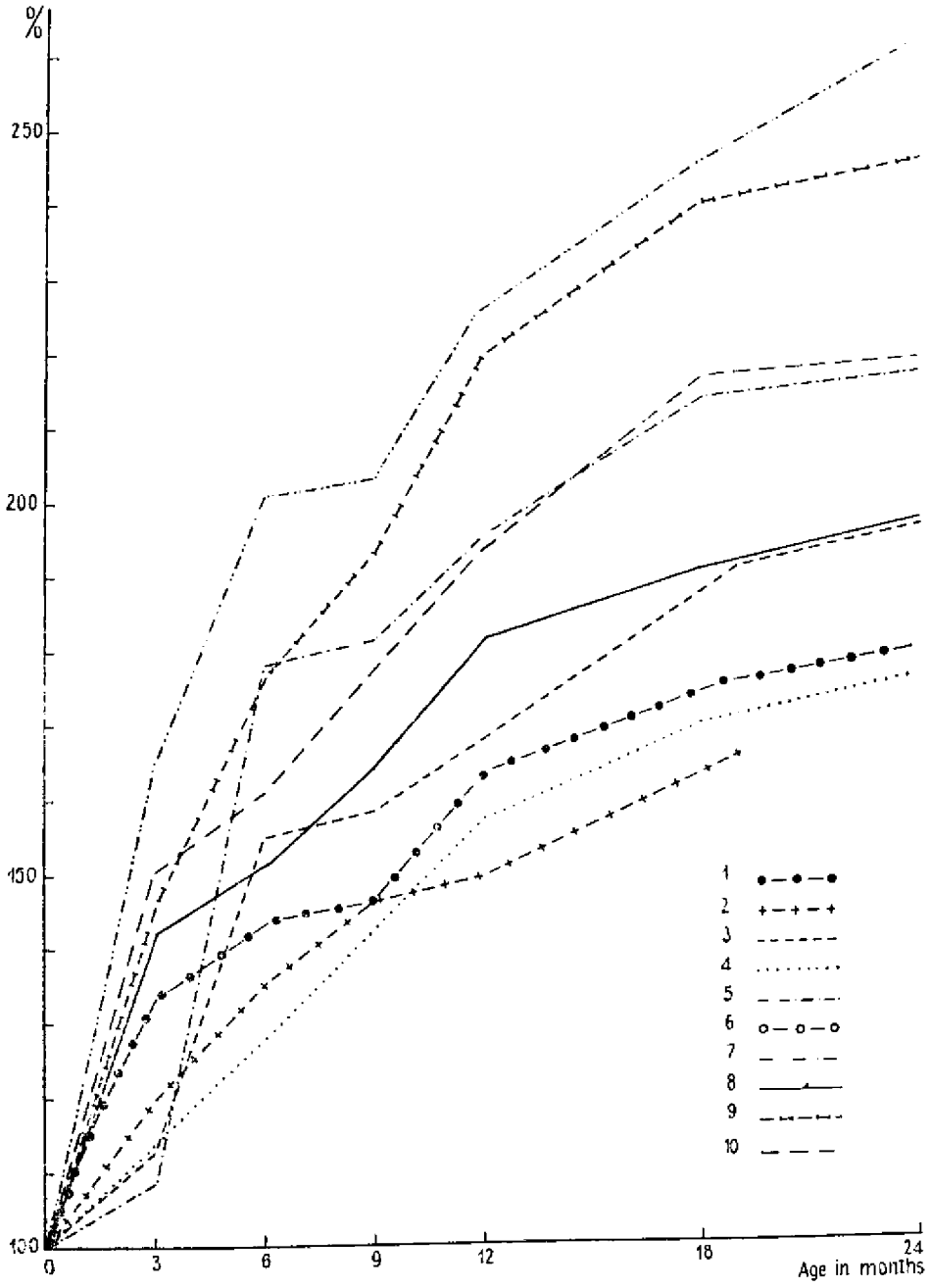


Fig. 10. Rate of the increase of body measurements of female European bison × American bison (after Żuravok, 1935).
Explanations — see fig. 6.

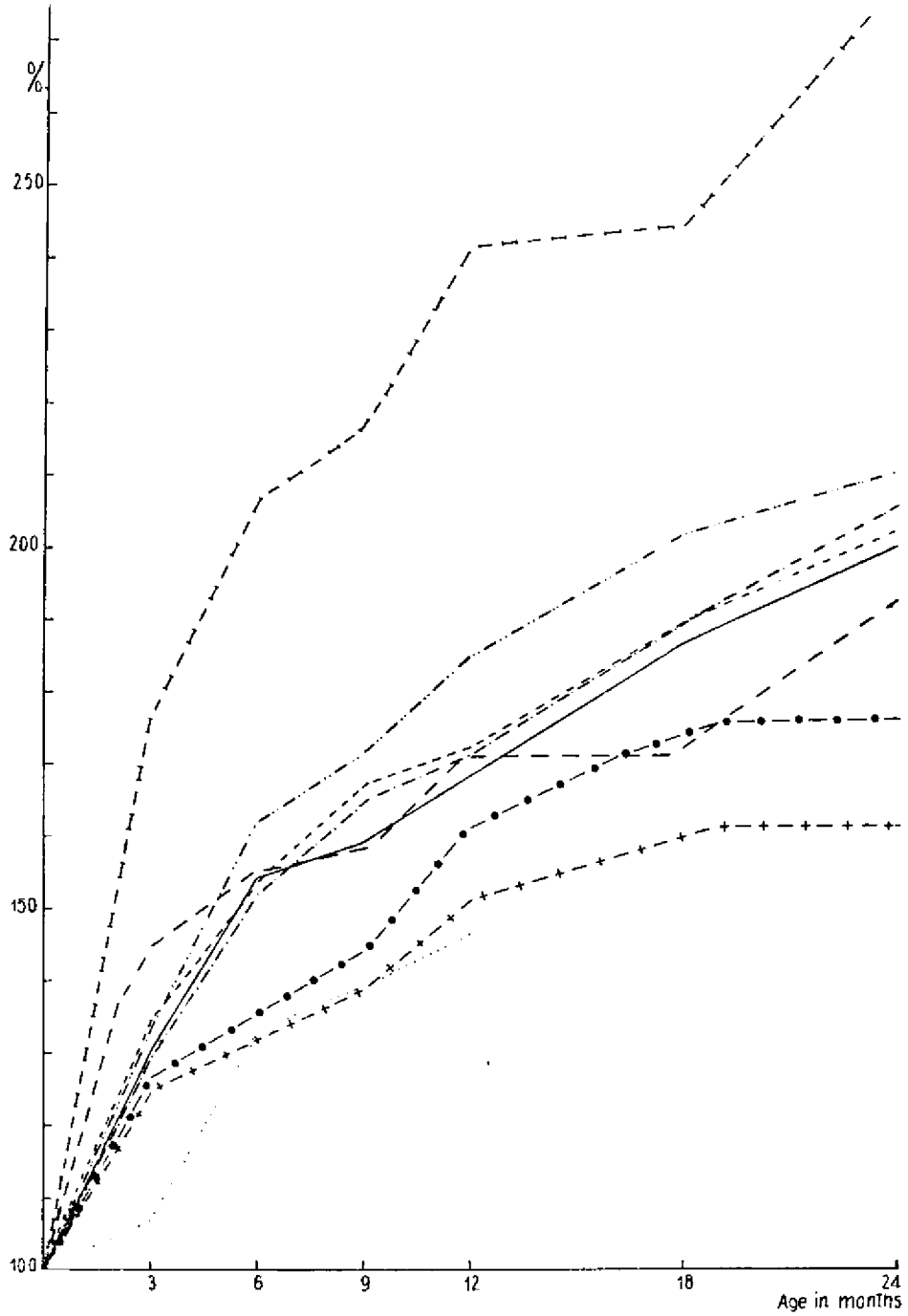


Fig. 11. Rate of the increase of body measurements of females (European bison × American bison) × Grey Ukrainian cattle (after Zuravok, 1935). Explanations — see fig. 6.

have a higher rate of increase in hip bone breadth than the Białowieża hybrids (Fig. 5). The increase in fore cannon girth, pelvis length and breadth is slowest in comparison with that in Białowieża hybrids and *bw* calves (Fig. 5). The female European bison × American bison is characterized, in comparison with the other animals, by the most intensive increase in thorax depth up to the 8th month of life.

When the rate of increase with age of all body measurements is compared (Fig. 6—11) it will be found both in the domestic calves of both sexes and in the female European bison × American bison, Askanian and Białowieża hybrids, dimensions of the trunk exhibit the slowest rate of increase. This sometimes also applies to the fore cannon girth. Whereas in Askanian hybrids and domestic *bw* calves it is hip bone breadth which increases most intensively from birth, and after this, the thorax breadth in *bw* (and in males also is depth) and in the female European bison × American bison increases most intensively throughout the 24 months of life. No differences occur in Białowieża hybrids, on the other hand, in the rate of increase of the above dimensions, but in hybrids of both sexes heart girth increases most intensively up to the age of 6 months, its depth in males up to the age of 12 months, and it is not until later that the rate of increase in hip bone breadth becomes greater. This fact can be referred to the effect of the typical European bison structure on hybrids.

The square shape of the body is attained in hybrids of both sexes at an age similar to that in *bw* calves.

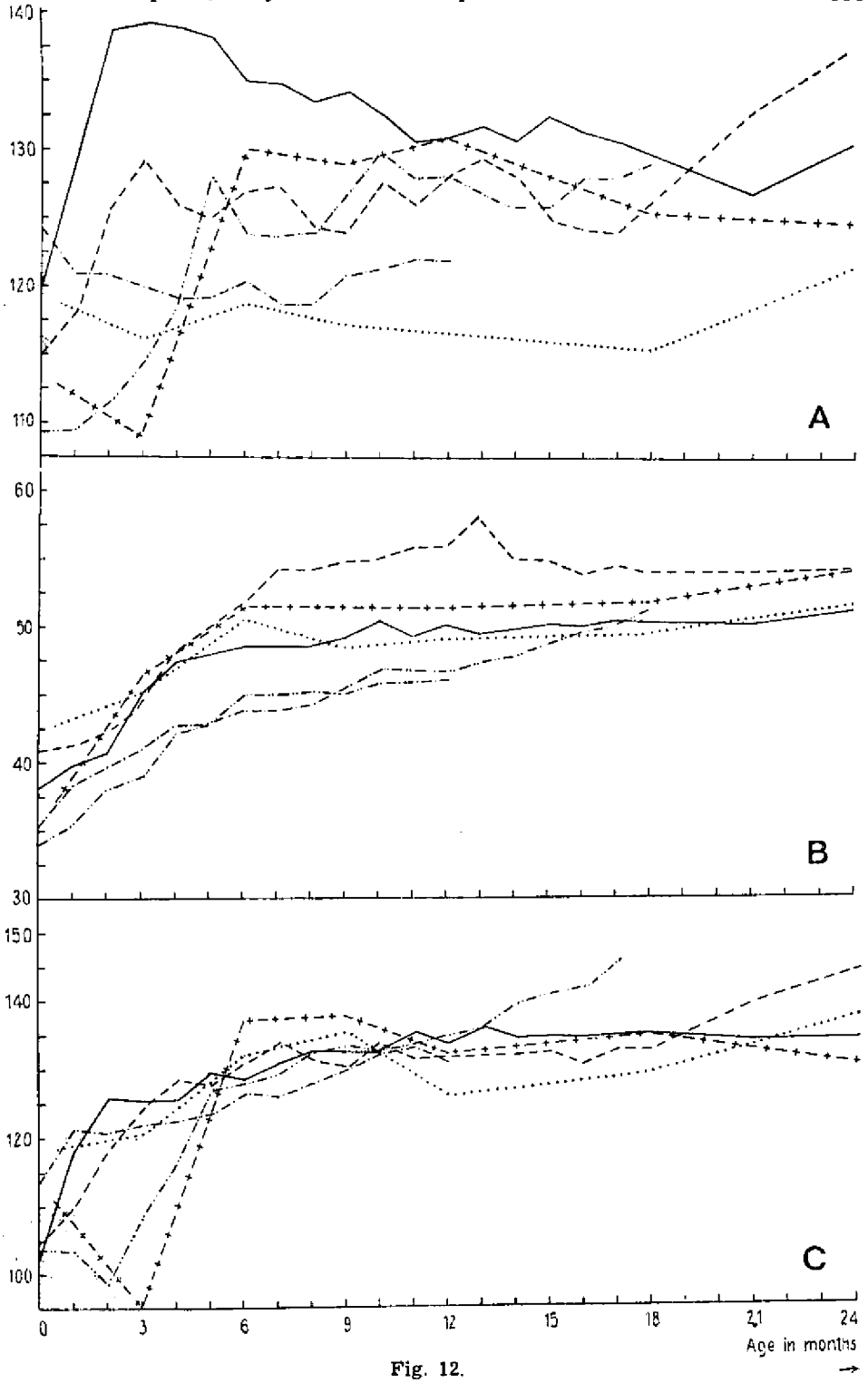
The proportions of the rump change with age in a similar way in both F_1 hybrids and domestic cattle. At the age of 2 years the pelvis breadth is equal to or less than the hip bone breadth, and thus the reverse of the relations found at birth.

It is characteristic here that among F_1 females, the daughter of the female bison — »Figa«, smallest at birth, exhibited the most intensive rate of increase in the majority of the body dimensions.

The development of Białowieża hybrids (body weight and dimensions) is greater or similarly intensive from birth to 24 months of life in domestic cattle as opposed to the female European bison × American bison, which grew far more slowly, probably like European bison calves.

Analysis of the growth of hybrids in comparison with the initial forms on the basis of the changes in structure indices (Fig. 12) shows that changes with age in the absolute values of indices and percentage increasses are identical in character, only the index: fore cannon girth × 100/withers height differing (Fig. 13).

Indices: (Withers height — thorax depth) × 100/withers height, and withers height × 100/body lenght decrease with age in all the animals


140
130
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A
60
50
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Age in months

Fig. 12.

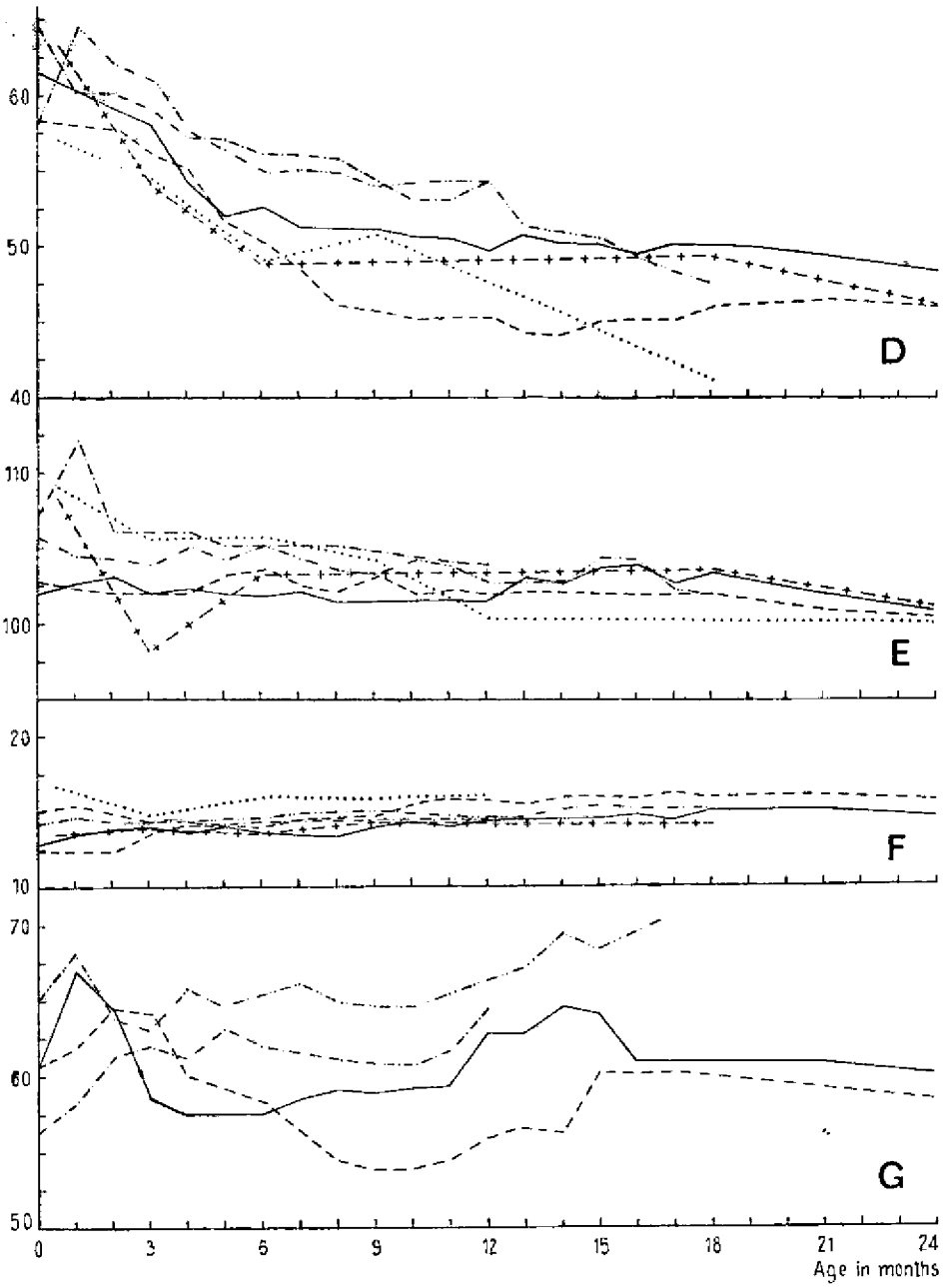

Fig. 12 Age variability of body indices of hybrids F_1 and parental forms. A. Heart girth × 100/body lenght, B. Thorax depth × 100/withers height, C. Heart girth × 100/withers height, D. (Withers height — thorax depth) × 100/withers height, E. Sacral region height × 100/withers height, F. Fore cannon girth × 100/withers height, G. Thorax breadth × 100/thorax depth, H. Withers height × 100/body lenght.
Explanations — see fig. 2.

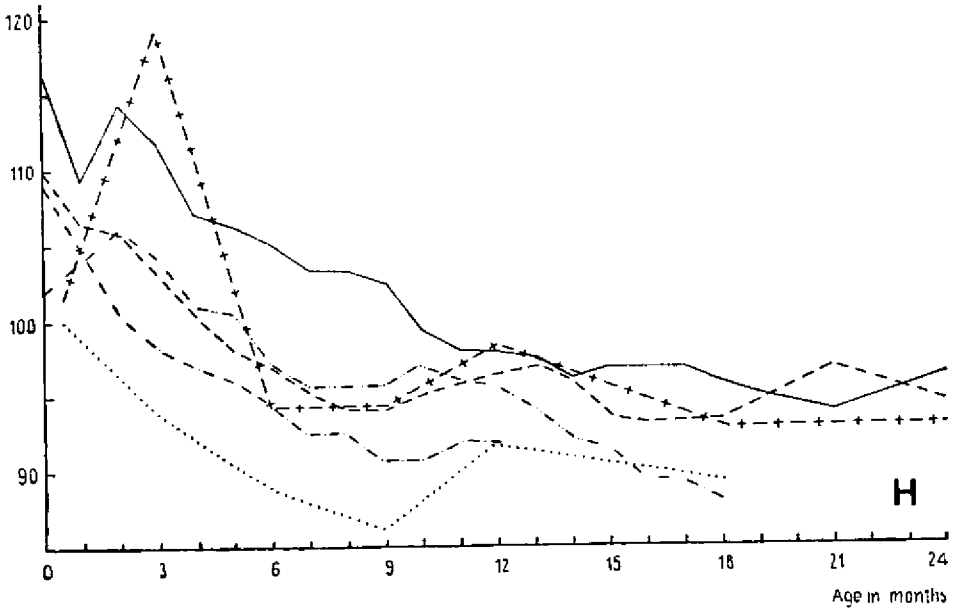

Fig. 12 (cont.)

compared (Fig. 12). During the development period the hybrids are less longlegged than domestic calves, but this difference diminishes with age. The values of the index: (Withers height — thorax depth) × 100/ /withers height are similar in the Białowieża and Askanian hybrids and the female European bison × American bison. The latter's trunk is similar in proportions to those in the Białowieża females, while the Askanian hybrids are longer than the *bw* and Białowieża animals.

Indices: Heart girth × 100/withers height and thorax depth × 100/ /withers height (Fig. 12) increase during the first months of life in all the animals, than become stable. Domestic calves from birth to the age of 24 months are characterized by a shallower trunk in relation to height than the hybrids. The Askanian hybrids and the female European bison × American bison exhibited similarity in the build of the anterior part of the body to the Białowieża hybrids.

Indices: Thorax breadth × 100/thorax depth and Heart girth × 100/ /body length (Fig. 12) exhibit great individual and age variation in the animals of all the groups. The Białowieża hybrids and female European bison × American bison are characterized by a more strongly built anterior part of the body than in domestic cattle. Thorax breadth in relation to height is greater in domestic *bw* calves than in hybrids.

Index: Sacral region height × 100/withers height (Fig. 12) changes with age only very slightly. At birth the domestic calves are more heavily built in the pelvis than hybrids. At the age of 24 months the

dorsal line is almost horizontal in hybrids, but has not yet become so in domestic cattle.

Index: Fore cannon girth × 100/withers height (Fig. 13) increase in F_1 hybrids up to the age of 16—17 months, but changes only very slightly. At birth the domestic calves are more heavily built in the pelvis than hybrids. At the age of 24 months the dorsal line is almost horizontal in hybrids, but has not yet become so in domestic cattle.

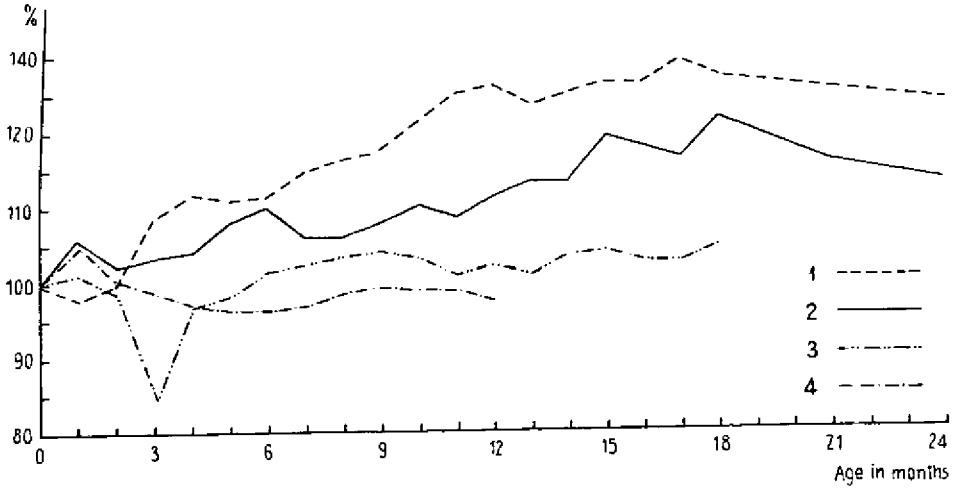

Fig. 13. Increase of the index (Fore cannon girth × 100/withers height) of hybrids F_1 and *bw* cattle (in per cent).
Explanations — see fig. 2.

Index: Fore cannon girth × 100/withers height (Fig. 13) increase in F_1 hybrids up to the age of 16—17 months, but changes only very slightly in cattle. During the first months of life the Askanian hybrids have the thickest bone structure. The bones of the Białowieża hybrids, thinner at birth than in *bw*, increase more intensively in thickness, so that at the age of 18 months the skeleton is more massive than in *bw* calves. It must, however, be remembered that this index correctly represents the thickness of fore cannon above the hock only during the first months of life, since this measurement includes 50% skin, tendon and fascia (A r z u m a n i a n, 1957).

2. Exterior of Adult F_1 Hybrids

Data in literature on the build of adult cattle of the *bw* and *pr* breeds are based entirely on description of domestic cows, on account of the greater stability of the structure characters in females (K o n o p i ń s k i, 1923, 1936; K o ł a k o w s k i, 1933; K o n o p i ń s k i & K o t l i ń s k i,

1949; Szczekin - Krotow *et al.*, 1955; Pająk, 1958; Skolasiński, 1959; Nowak, 1966). The build of adult European bison × domestic cattle hybrids (»Galka«, »Herkules«) has been discussed by Iwanow & Philiptschenko (1916), and that of (European bison × American bison) × domestic cattle by Żuravok (1935). Bearing in mind that Białowieża hybrids over the age of 4 years have not yet completed their physical development (cattle grow up to the age of 5—6 years — Herman, 1959, and European bison 6—7 years — Roskosz, 1962) where possible their build has been compared with the parental breed at a similar age. Where this was impossible they have been compared with the structure characters of the parents. The Białowieża hybrids were allocated to the group of adult animals as the proportions of their build do not undergo any further significant changes in these animals.

2.1. Body Weight

No definite reports have been encountered in literature on the weight of adult European bison hybrids, apart from general statements as to their great weight, exceeding that of domestic cattle (Ivanov, 1950; Zablocki, 1956). Our data show that as in domestic cattle, sex dimorphism is marked in the body weight of F_1 hybrids. The influence of the mother's species is particularly distinct in the body weight of male hybrids. The progeny of bison × *bw* cows are over 200 kg heavier than bulls (even younger ones) obtained from crossing a *pr* bull and bison female. This influence is not so strongly marked among female hybrids. When the body weight of cattle of the parental breeds is compared (Szczekin - Krotow *et al.*, 1955; Skolasiński, 1959) with that of hybrids it will be seen that the hybrids of both sexes are always heavier (Fig. 14).

2.2. Body Measurements, Indices of Body Structure

The influence of the mother's species is evident in the structure of adult F_1 hybrids, this being particularly strongly marked in male F_1. This influence may be connected with the genes of chromosome X.

When analysing measurements and indices of body structure differences will be found in build between domestic cows, hybrids and female European bison (Table 4). Thorax breadth is slightly greater in F_1 females than in domestic cows, but far greater than in the female bison. The index: Thorax breadth × 100/thorax depth in hybrids corresponds to values of this index in cattle of the meat-milk type. The pelvis in hybrids is less strongly built than in domestic cows, but is wider than

in the female bison and hybrids from Askania. Domestic cows have the shallowest thorax, Białowieża hybrids a medium thorax and the female bison and »Galka« from Askania the deepest one. Analogically, the values of the index: Thorax depth × 100/withers height show that female F_1 hybrids, like bison, have a deeper thorax in relation to their height.

The female bison and »Galka« are characterized by the largest hump, which is far smaller in Białowieża hybrids.

The head of F_1 cows is similar in the proportions of its structure to those of domestic cows, but in the female bison and »Galka« the head is wider and the forehead longer.

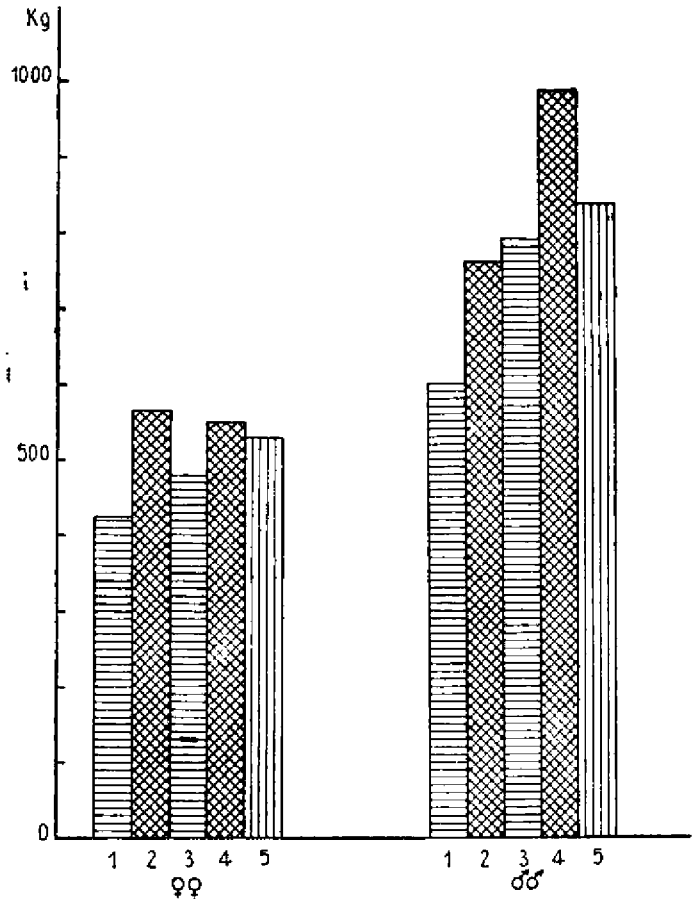

Fig. 14. Comparison of the body weights of adult hybrids F_1, and parental forms. Females: 1. Females *pr*, 2. Females F_1 European bison × *pr*, 3. Females *bw*, 4. Females F_1 European bison × *bw*, 5. Female wisent. Males: 1. Males *pr*, 2. Males F_1 *pr* × European bison, 3. Male *bw*, 4. Males F_1 European bison × *bw*, 5. European bison.

bw — Black and White Lowland cattle, *pr* — Polish Red cattle.

Białowieża cows are shorter in relation to height than domestic cattle, but longer than the female bison and »Galka«. Their trunk length is thus intermediate between the parent forms.

Fore cannon girth and index: Fore cannon girth × 100/withers height point to the similarity in skeleton structure between Białowieża hybrids and domestic cows, but it is smaller in the female bison and »Galka«.

All F_1 hybrids are far higher than domestic cows, as was noted in the case of W a l i c k i's hybrids (K a r c o v, 1903). The index: (Withers height — thorax depth) × 100/withers height in domestic cows, »Galka« and the female bison is greater than in F_1 cows, in which it corresponds to the values of the index in the meat type of cattle. Similarly the index: Hearth girth × 100/body length in the hybrids corresponds to the meat type of cattle.

To sum up it may be said that female Białowieża hybrids exhibit many characters of build characteristic of the meat type of cattle. Their build exhibits characters intermediate between the parent forms, but is closer to the domestic animal. »Galka« from Askania and W a l i c k i's hybrids, on the other hand, had more characters of structure of the European bison than the Białowieża hybrids.

In analysing the build of F_1 males (Table 5) it can be said that individuals produced from a female bison by a male *pr* have smaller body measurements, a more sloping dorsal line and less strongly developed rump than hybrids produced from a *bw* cow covered by an bison (despite the fact that they were older).

Male F_1 hybrids from Białowieża and »Herkules« from Askania exceed the body measurements of domestic bulls, but are shorter in relation to height (Table 5). The Białowieża hybrids have a smaller hump than the bison or »Herkules«. It must, however, be rememberd, that the development of spinous processes in the bison lasts up to 8 years (R o s k o s z, 1962) and the hump in the Białowieża hybrids may yet become larger. The rump was least strongly built in »Herkules« and the bison, and while it is broader in our hybrids, it is not developed to the degree found in domestic bulls. Thorax breadth in Białowieża hybrids and domestic bulls is similar, and far narrower in the bison and »Herkules«. The index: Thorax breadth × 100/thorax depth confirms the similarity in the build of hybrids and domestic bulls. Thorax depth is greatest in bison, and smaller in domestic bulls than in hybrids. In relation to height the domestic bulls and bison are deeper than the hybrids. F_1 hybrids are slightly longer legged than bison, and significantly longer legged than domestic bulls. Fore cannon girth and index: Fore cannon girth × 100/withers height are similar in all the groups of animals, which points to the similarity in skeleton structure.

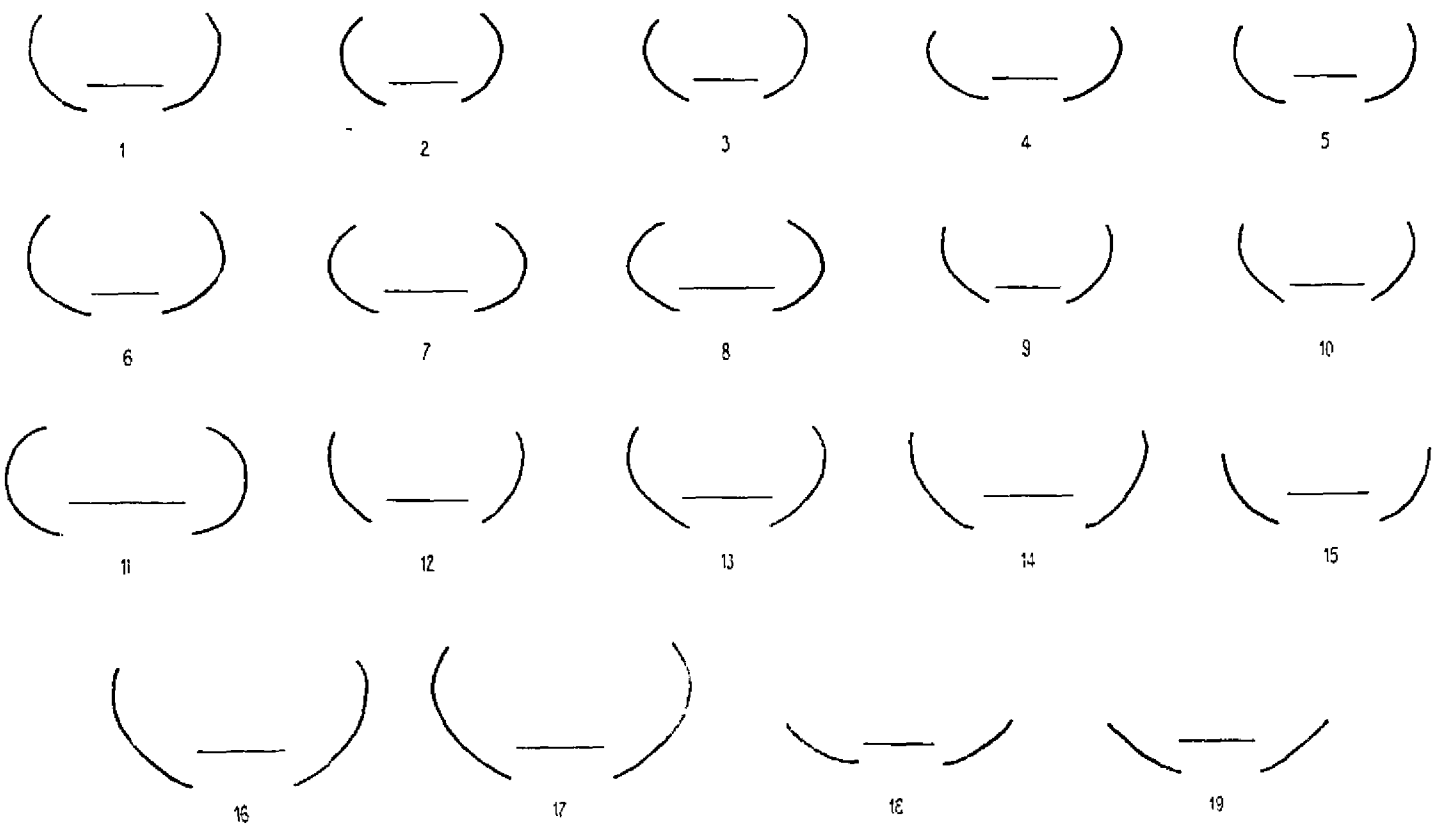

Fig. 15. The variability of horns profile of hybrids F_1 and parental forms.
Females: 1. »Famela« F_1, 2. »Fama« F_1, 3. »Filutka« F_1, 4. »Fanny« F_1, 5. »Figa« F_1, 6. »Dunja« F_1 (after Iwanow & Philiptschenko, 1916), 7, 8. Females of European bison, 9. Females *bw*, 10. Females *pr*. Males: 11. European bison, 12. »Filon« F_1, 13. »Filip« F_1, 14. »Facet« F_1, 15. »Fakir« F_1, 16. »Farad« F_1, 17. »Herkules« F_1 (after Iwanow & Philiptschenko, 1916), 18. Male *bw*, 19. Male *pr*. *pr* — Polish Red breed.

The head in Białowieża hybrids and »Herkules« exhibits a structure intermediate between the parent forms. The bison has a short, broad with a long forehead. W a l i c k i's hybrid had the bison head and horns (K a r c o v, 1903).

Comparison of the head structure in hybrids of both sexes with the skull of an European bison shows, as is clear from examination of the skulls of hybrids from European bison and European bison × American bison with domestic cattle from Askania (A n d r e e v a, 1935; B o g o l j u b s k i j, 1935), that hybrids have head structure intermediate between the parent forms. Their heads are longer and narrower than the head in European bison. Exact results cannot be obtained until anatomical material has been examined.

Male hybrids from Białowieża exhibit, like females, an intermediate build between the parent forms, but are more similar to the domestic cattle. The anterior part of the body (breadth and depth) is more strongly developed in them than in the European bison or domestic bull.

In hybrids of both sexes, during both the development period and in adult animals, such characters of the bison build dominate as the high hump (in adults), shortening of the trunk and long legs, and more intensive development of depth measurements.

Analysis of the structure of European bison hybrids with different breeds of domestic cattle permits of concluding that not all breeds of cattle transmit the characters of the species *Bos taurus* L. to a uniformly great degree. In our experiment cows of the *bw* breed transmit the characters of structure typical of domestic cattle to a greater degree than the *pr* breed. In the Askanian experiment, on the other hand, Shorthorn cows transmit characters of domestic cattle to a greater degree than the Grey Ukrainian breed (Z a b l o c k i, 1956).

The absence of the hump in the animals of both sexes examined at the age of 3 years permits of concluding that development of the spinous processes of the thoracic vertebre is more intensive in hybrids at a more advanced age (3—4 years).

2.3. Horn Profile

The horns in hybrids of both sexes began to grow earlier than in domestic cattle, *i. e.* at the age of 1 month, whereas in domestic calves (K o n o p i ń s k i & K o t l i ń s k i, 1949) this does not take place until the age of 4—5 months. Similarly the horns grow more intensively with age in hybrids than in domestic cattle.

In F_1 males over 4 years old the horns are thicker and longer than in domestic bulls, and are similar in length to those of the bison (Table 5). They leave the skull at a different angle than that in bulls of the *pr* and *bw* breeds. The horn profile in them is similar to the horn profile of Askanian hybrids (Fig. 14), the horns of which have been described as typical of domestic cattle (Iwanow & Philiptschenko, 1916). In Walicki's hybrids, on the other hand, the horns were typically European bison horns (Karcov, 1903).

The horns in F_1 cows over 4 years old are also thicker and longer than the horns in cows of the *bw* and *pr* breeds (Table 4), and shorter than the horns of female European bison and Askanian females. The horn profile in them is similar to that in certain *pr* cows, but closer to the horns in female bison (Fig. 14), similarly in fact to the case with Walicki's hybrids, and contrary to that in Askanian hybrids (Karcov, 1903; Iwanow & Philiptschenko, 1916). There is thus incomplete domination of the bison type of horns in female Białowieża hybrids.

3. Practical Conclusions

The phenomenon of heterosis occuring in hybrids of European bison and domestic cattle and manifested in intensive development, both prenatal and postnatal, forms a basis for drawing conclusions as to the possible practical use of hybrids. The marked heterosis of hybrids can be explained by their high degree of heterozygosis. European bison (outstandingly homozygous as the result of long-term inbreeding) were coupled with breeds of domestic cattle with strongly established breed characters, and thus also with a high degree of heterozygosis. Increase in body weight in hybrids of both sexes during the first six months of life is particularly intensive (six — month old males exceed the weight of domestic calves by 44% and females by 23%). On the other hand muscles of domestic cattle grow most intensively during the first 6 months of life (in *bw* cattle up to 91 days of life) (Pająk, 1958; Skolasiński *et al.*, 1966). These may be a practical hint for utilizing the European bison hybrids for the production of young »beef«.

Analysis of the structure of adolescent (2-year old) and adult F_1 hybrids demonstrating the predominance in body weight over domestic cattle (with similar bone thickness) and the values of the indices of build and also the strongly developed anterior part of the body in hybrids, justifies expecting a large amount of meat from them. It is know from anatomical studies that the strongly developed anterior part of the body in the European bison consists to a great extent of the strongly formed muscles (Świeżyński, 1962). It will only be possible

to present exact data on the quantity and also the quality of meat in hybrids after analysis of slaughtered animals.

A factor which cannot be overlooked is the hybrids' great resistance to disease, the ease with which mechanical injuries heal and resistance to cold, which permits of free breeding of hybrids. This may greatly reduce costs of maintenance of hybrids in comparison with domestic cattle.

It must however be remembered that the results of the Białowieża experiment, although interesting from the practical point of view, are burdened with some error due to the small amount of material used. This should form an inducement to repeat the experiment on an animal breeding scale.

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Received, November 12, 1968.

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ROZWÓJ POSTNATALNY HYBRYDÓW F_1 ŻUBRA Z BYDŁEM DOMOWYM

Streszczenie

W pracy przedstawiono rozwój postnatalny 6 sztuk hybrydów (Tabela 1) żubra z bydłem domowym rasy nizinnej czarno białej (*ncb*) — (3 ♂♂ i 3 ♀♀) w okresie od urodzenia do 24 miesięcy. Otrzymane wyniki porównano z danymi o rozwoju hybrydów żubra z innymi rasami bydła i cieląt rasy *ncb*.

Następnie scharakteryzowano eksterier 8 hybrydów F_1 (Tabela 1) w wieku powyżej 4 lat, otrzymanych w Białowieży w latach 1960—62, ze skrzyżowania ♂ lub ♀ żubra z bydłem rasy czerwonej polskiej (*czp*) i *ncb* (4 ♂♂ i 4 ♀♀) i porównano z cechami budowy hybrydów żubra i innych ras bydła oraz z formami rodzicielskimi.

Wykonywano 15 podstawowych pomiarów ciała i na ich podstawie obliczono 8 indeksów.

Stwierdzono istnienie wpływu matczynego na ciężar ciała hybrydów F_1 przy urodzeniu. Krowy domowe kryte żubrem lub żubrobizonem rodziły duże mieszańce, żubrzyce zaś — małe. Krzyżówki obu płci urodzone przez żubrzyce miały ciężar ciała zbliżony do żubrząt.

U hybrydów pokolenia I ujawnił się wigor mieszańców manifestujący się intensywnym rozwojem prenatalnym, co prowadziło do uzyskiwania dużych ciężarów ciała przy urodzeniu, zwłaszcza gdy matką hybryda była krowa domowa, przewyższających znacznie ciężar przy urodzeniu cieląt domowych (Tab. 2). Również w czasie rozwoju postnatalnego u hybrydów (♂ lub ♀ żubr × dom.) występuje heterozja ujawniająca się w postaci szczególnie intensywnego rozwoju w pierwszym półroczu życia (Ryc. 2, 3), w okresie kiedy u bydła najintensywniej przyrastają mięśnie. W wieku ½ roku hybrydy samce przewyższają ciężarem samce *ncb* o 44%, a samice o 23%. Średnie przyrosty dobowe w 1 półroczu życia są u samców F_1 wyższe od *ncb* o 0,43 kg, u samic o 0,19 kg.

W budowie hybrydów samców stwierdzono różnice uzależnione od gatunku matki, potomstwo żubrzycy różni się budową od hybrydów uzyskanych po krowach domowych.

Rozwój hybrydów w okresie od urodzenia do 24 miesięcy życia jest zbliżony do bydła i jest znacznie intensywniejszy od rozwoju żubrobizonki, dojrzewającej wolnej, prawdopodobnie tak, jak żubrzęta. Hybrydy białowieskie ustępują cielętom *ncb* pod względem tempa rozwoju szerokości klatki piersiowej i szerokości zadu w biodrach.

Porównując tempo rozwoju wszystkich wymiarów ciała (Ryc. 6—11) stwierdzono, że u hybrydów F_1 podobnie jak u *ncb* wymiary wysokości tułowia wykazują najwolniejsze tempo wzrostu. U hybrydów białowieskich podobnie jak u żubrobizonki najwyższe tempo wzrostu wykazuje w pierwszym półroczu życia obwód i głębokość klatki piersiowej, podczas gdy u cieląt domowych — szerokość zadu w biodrach.

W budowie hybrydów F_1 w wieku powyżej 4 lat cechami dziedziczonymi po żubrze są między innymi garb, skrócenie tułowia w stosunku do jego wysokości, wysokonożność, rozbudowa przodu ciała, u samic niepełna dominacja typu rogów. Inne cechy budowy są pośrednie, ale bliższe dla bydła domowego.

Porównanie doświadczenia białowieskiego z innymi wykazało, że nie wszystkie rasy bydła jednakowo silnie przekazują cechy budowy gatunku *Bos taurus* L. krzyżówkom. W naszym przypadku silniej przekazywała cechy bydła rasa *ncb*.

Ciekawe dla praktyki wyniki doświadczenia białowieskiego, jednak obciążone błędem małej liczebności materiału, powinny stać się bodźcem do powtórzenia tego doświadczenia w skali hodowlanej.