

GENETIC RELATIONS BETWEEN BODY MEASUREMENTS AT THREE AGES IN HOLSTEINS ¹

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SUMMARY

Body measurements at 6 mo., 1 yr., and 2 yr. of age were used to study patterns of growth relationships. Phenotypic correlations between measurements on the same animal, phenotypic correlations between one measurement on the dam and another on the daughter, genetic correlations, and heritabilities were calculated and considered. The influence of genetic factors relative to that of environmental factors increased with age. The effect of general factors was most evident at 6 mo., whereas the effect of group and specific factors became more evident as age increased.

Workers in population genetics have used two methods to investigate genetic relationships. These are the method of path coefficients, devised and applied by Wright (5-8), and the method of genetic correlations proposed by Hazel (1) and Hazel *et al.* (2).

Both methods were used by Touchberry (3) in a study of milk production and body measurements of 3-year-old Holstein cows in the Iowa State College herd. Genetic correlations were calculated, using the method of Hazel (1). Touchberry then applied Wright's method to genetic and phenotypic correlations. His results indicate the influence of general factors (common to all measurements), two group factors (having a common effect on two or more measurements, but not on all), and specific factors (affecting only one measurement).

MATERIALS, METHODS, AND RESULTS

This study is of six measures of body size at 6 mo., 1 yr., and 2 yr. of age. The method of measuring is described by Touchberry and Lush (4). Each value used is the average of two (three in the early years, before it was discovered that the actual error of measuring was small) independent measurements by different workers. All six measures at all three ages on 334 cows and their dams from the Iowa State College Holstein herd were used. The data were collected from 1930 through 1953.

The symbols used are: H—Wither height; D—chest depth; L—body length; C—chest girth; G—paunch girth, W—weight. The symbols without primes refer to the offspring; those with primes refer to the dams.

All correlations were computed within groups of daughters by the same sire, to eliminate the effects of time trends.

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Phenotypic correlations between measurements of the same individual at 6 mo., 1 yr., and 2 yr. of age are shown (Table 1). Phenotypic correlations between one character in the dam and one in the daughter are presented (Table 2). The latter are used to estimate genetic correlations and heritabilities.

The genetic correlations are presented (Table 3). These were calculated by the method presented by Hazel (1). The equation is:

$$r_{GG} = \sqrt{\frac{r_{ij} r_{ij'}}{r_{ii'} r_{jj'}}$$

Where r_{GG} is the genetic correlation between characters i and j .

r is the phenotypic correlation between character i in the daughter and character j in the dam.

TABLE 1
Phenotypic correlations between body measurements on the same individual at 6 mo., 1 yr., and 2 yr. of age

		D	L	C	G	W
H	6M	.83	.82	.83	.68	.82
	1Y	.81	.80	.79	.60	.74
	2Y	.75	.76	.61	.39	.52
D	6M		.78	.91	.74	.85
	1Y		.80	.88	.69	.77
	2Y		.74	.80	.53	.62
L	6M			.79	.68	.87
	1Y			.71	.61	.78
	2Y			.56	.42	.65
C	6M				.81	.91
	1Y				.76	.89
	2Y				.60	.83
G	6M					.87
	1Y					.85
	2Y					.82

TABLE 2
Phenotypic correlation between one character in the dam and one in the daughter among 334 pairs at 6 mo., 1 yr., and 2 yr. of age

		H'	D'	L'	C'	G'	W'
H	6M	.17	.04	.06	.01	-.02	.02
	1Y	.23	.16	.13	.14	.03	.10
	2Y	.44	.32	.25	.23	.05	.22
D	6M	.15	.13	.06	.10	.04	.08
	1Y	.16	.18	.05	.15	.08	.10
	2Y	.35	.40	.20	.31	.18	.29
L	6M	.12	.04	.09	.00	.04	.05
	1Y	.08	.05	.10	.05	.02	.07
	2Y	.27	.24	.32	.21	.14	.26
C	6M	.15	.13	.07	.10	.07	.09
	1Y	.15	.17	.06	.14	.14	.14
	2Y	.32	.32	.16	.28	.20	.27
G	6M	.14	.13	.09	.06	.13	.11
	1Y	.06	.05	.09	.02	.15	.08
	2Y	.10	.04	.02	.07	.21	.19
W	6M	.12	.08	.05	.04	.07	.07
	1Y	.11	.08	.10	.08	.10	.11
	2Y	.27	.22	.19	.19	.23	.27

TABLE 3
*Genetic correlations between various characters in 334 daughter-dam
 pairs at 6 mo., 1 yr., and 2 yr. of age*

		D	L	C	G	W
H	6M	.53	.69	.35	.41	.42
	1Y	.78	.69	.80	.23	.67
	2Y	.78	.69	.79	.24	.70
D	6M		.46	.99	.54	.85
	1Y		.24	.98	.38	.65
	2Y		.61	.95	.35	.77
L	6M			.11	.54	.64
	1Y			.49	.32	.81
	2Y			.61	.22	.70
C	6M				.37	.70
	1Y				.41	.87
	2Y				.48	.84
G	6M					.88
	1Y					.68
	2Y					.86

TABLE 4
Heritability of size at various ages among 334 daughter-dam pairs

	Birth	6 mo.	1 yr.	2 yr.
H	—	.34	.44	.86
D	—	.24	.34	.79
L	—	.17	.19	.63
C	—	.18	.28	.55
G	—	.25	.29	.41
W	.56 ^a	.14	.21	.53

^a Based on 295 pairs.

Heritabilities were calculated by doubling the intrasire regression of offspring on dam and are presented (Table 4).

DISCUSSION

Two sources of evidence indicate that the importance of various genetic factors relative to each other change with age. In each case the evidence agrees with Touchberry's (3) classification into general, group, and specific factors. The two group factors are (a) skeletal, which affects wither height, body length, chest depth, and weight, and (b) flesh, which affects chest girth, chest depth, paunch girth, and weight.

The first source of evidence is the way phenotypic correlations between characters on the same animal change with age. Table 1 shows that the correlations at 6 mo. and at 1 yr. are consistently higher than those at 2 yr. However, the correlations involving one skeletal and one flesh character change more than the correlations involving two skeletal or two flesh characters. Where a character is affected by both skeletal and flesh factors, the changes are intermediate.

Some decrease in the relationship between two measurements might be expected if environmental effects which affect one type of growth but not the other have had more chance to express themselves. However, decrease due to genetic effect also might occur. As a simple example, suppose that growth of

each character is stimulated by two genes, one which operates on that character alone, and one which affects each character within that group but has no effect on characters in another group. This situation could be pictured thus:



Gene *h* would affect wither height only, gene *l* would affect body length only, gene *g* would affect paunch girth only, and gene *c* would affect chest girth only; whereas, gene *hl* would affect wither height and body length in the same direction but would not affect chest girth or paunch girth, and gene *cg* would affect chest girth and paunch girth in the same direction, but not the others. The larger the effects of genes *h*, *l*, *c*, and *g*, the more would all correlations be decreased; whereas, the effect of genes *hl* and *cg* would be to increase the correlations between wither height and body length and between chest girth and paunch girth, but to decrease the correlations between wither height and chest girth, wither height and paunch girth, body length and chest girth, etc. If we could further suppose a gene *hlcg* which would affect all four characters in the same way (i.e., to stimulate or deter growth), that gene would tend to increase the correlations among all of them. If the organism were so ordered that gene *hlcg* expressed its effects earlier in life than the others, there would be a tendency for correlations to be high in the younger animals and to decrease irregularly as the animals aged. The evidence in the correlations (Table 1) seems to support this possibility, particularly since it is difficult to imagine a set of environmental conditions which would result in the pattern of decreases shown. That distinctive gene effects are often delayed in their expression is evident from the pattern of embryonic development, wherein the characteristics which distinguish genera, species, etc., unfold in precise sequence.

The second source of evidence is the increase of the genetic correlations as age increases (Table 3), when two measures from the same group are involved, and the decrease when one member from each group is involved.

The evidence from these two sources indicates that the effect of general factors is more evident in early growth, whereas later growth shows larger effects of group and specific factors.

Two other sources of evidence indicate that the importance of genetic factors relative to environmental factors changes with increasing age. The first of these may be seen by comparing the heritabilities at three ages (Table 4). All heritabilities increased with age. Since heritability is defined as the portion of the total variance that is genetic, and since it is reasonable to expect that environmental variance itself would increase, it would seem that the increase in importance of genetic effect could be attributed to genes which show their effect in later life.

The second source of evidence of increased importance of genetic factors is the increase with age of the reciprocal correlations involving each measurement in the dam and each measurement in the offspring (Table 2). Growth of the correlated parts occurred at times separated by more than 2 yr.; therefore, this increase in relationship seems independent of environmental effects and, accordingly, should be attributed to genes whose effects are more manifest in later than in early growth.

These evidences of the increasing influence of genes with group and special effects in later development may partly explain the limited accuracy of predicting the type of a cow from its conformation as a calf.

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