INHERITANCE OF RATE OF GROWTH IN DOMESTIC FOWL.* II. GENETIC VARIATION IN RATE OF GROWTH FROM TWO TO EIGHT WEEKS OF AGE IN S. C. WHITE LEGHORNS.

by

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In a previous report (Lerner and Asmundson, 1932) methods for a genetic study of rate of growth were presented. The rates of growth from three to eight weeks of Anconas, Light Sussex and their hybrids (F_1, F_2 and backcrosses) were reported, but due partly to small numbers and partly to variability within the breeds it was not possible to draw final conclusions with regard to the mode of inheritance of rate of growth in these breeds. The variability in the growth rate of birds of the same breed suggested the existence of genetic differences. To determine whether such differences exist, growth data for S. C. White Leghorns, collected at the University of British Columbia, were analyzed and are presented in this report.

Data for 340 individually pedigreed S. C. White Leghorn chicks were used for this study. The chicks were hatched in four lots at fifteen day intervals from March 10 to April 24, 1931. They were removed from the incubator when approximately 24 hours old, banded and weighed. They were also weighed at 2, 4, 6, 8, 12, 20 and 24 weeks of age, as counted from the day the chicks were banded.

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The chicks in all lots were fed alike on a standard ration. As shown by Figure I, the growth of the chicks to eight weeks was satisfactory.

The chicks were divided in two groups, those in the first two hatches formed one, and those in the third and fourth hatches the other. This was considered permissible since there was little difference in the rate of growth of the chicks from the first two hatches, nor was there a significant difference between the chicks from the third and fourth hatches. The weighted average differences in rate of growth were only 2.2 and 2.6 per cent. respectively. The males and females were considered separately. There were thus four groups. This division was followed throughout.

It will be seen (Fig. I) that the rate of growth apparently changed from week to week, but since it was not practicable to consider the growth rate for each two-week period separately, some longer period had to be adopted. The selection of a suitable period was based on rates of growth for various age intervals calculated from average weights of S. C. White Leghorn and Barred Plymouth Rocks. These figures will be considered in greater detail elsewhere. It may be stated, here, however, that the period from 2 to 8 weeks was chosen as the most suitable since growth in that period was more rapid than in subsequent periods. Moreover, the difference between the rate of growth of the two breeds was as great in that period as in any other time interval considered.

The starting point of the period for the present study of genetic differences in rate of growth was taken at 2 weeks of age rather than earlier, partly because of the influence exerted by the size of the egg on the weight of the chick when hatched, and partly because there appears to be relatively little variation in rate of growth during the first 2 weeks after hatching.

The modified formula of Minot (Brody, 1927)

$$R = \frac{W_2 - W_1}{\frac{1}{2}(W_2 + W_1)} 100 \quad \text{------------------------} \quad 1$$

where W_1 = the weight of the chicks at 2 weeks and W_2 their weight at 8 weeks of age, was applied to the data for each chick. The period from 2 to 8 weeks was considered as a unit.

The mean rates of growth, the standard deviations and coefficients of variability for the four groups into which the chicks were divided, are presented in Table I. The earlier hatched chicks grew more rapidly than the late hatched chicks, and the males grew more rapidly than the females. These differences are statistically significant as is shown in Table 2. It will be observed that the differences are even more pronounced between earlier and later hatched chicks of the same sex than between males and females of the same hatch. There is also some indication that the difference between the rate of growth of the two sexes is greater when they grow relatively rapidly. Frequency distributions of the mean rate of growth are skewed towards the higher rate.

The standard deviation from the mean rate of growth is slightly lower for the earlier than for the later hatched chicks, but there is no consistent difference between the males and females. The relative variability in rate of growth, as measured by the coefficient of variation, is significantly greater for the later hatched males than for the earlier hatched males, and is also greater for the later hatched females than for the earlier hatched females, although in this case the difference is not statistically significant. As in the case of the standard deviation there is no evidence here that the sexes differ consistently in variability of rate of growth.

The difference between the rates of growth of the earlier and later hatched groups demonstrate the influence exerted by the environment on rate of growth. This emphasizes the importance of considering the environment when studying the inheritance of a physiological character, such as rate of growth. Only such individuals as are raised under identical conditions can be compared or, if groups raised under similar conditions are considered together for comparison, they should, as in this case, show the same average rate of growth. Despite the limitations imposed by the conditions under which these birds were raised, it was found possible to use some of the data on the rate of growth of this flock of S. C. White Leghorns to determine whether there are genetic differences between families (the progeny of a single pair) with respect to rate of growth. Before proceeding to a comparison of individual families the progeny of different males will be briefly dealt with.

The 340 chicks were all the progeny of six males, but families of 15 or more chicks were only available from three of these six males. The progeny of these three males were divided into four groups as for Table 1, and the means and coefficients of variation for rate of growth calculated. No constant or significant differences were found between the progeny of these males, due partly, no doubt, to the fact that each group represents several different families. Furthermore, the progeny of these males did not differ significantly from the total population in mean rate of growth or in variability in rate of growth.

The six largest families were selected for the purpose of comparing their rates of growth. Four of these families were the progeny of females, No.I 17171, K 2132, K 2138 and X 2191, which were mated to male No. L 1520, and two were from females K 2136 and J 373 which were mated to male K 585. All these families were more or less closely related.

The differences between the means of the male and female progeny of these six hens are presented in Table 3. These six progenies (families) fall roughly into three classes or groups on the basis of rate of growth. In the group with the highest rate of growth are the progeny of K 2138, K 2136 and I 17171. The progeny of K 2191 and K 2132 form an intermediate group, while the progeny of J 373 show the slowest rate of growth. The differences between the families within these groups are not statistically significant. When, however, families in different groups are compared most of the differences are significant, especially so when the progenies that differ most are compared. Thus it is evident from Table 3 that the progeny of J 373 differ significantly from the progeny of K 2138, K 2136 and I 17171 in rate of growth from two to eight weeks.

That families differ in rate of growth is substantiated in Table 4, which shows the average (mean) differences in the rates of growth of the six families, and the odds that these differences are significant as calculated by the "Students" method. In this table heavy lines separate differences which are significant from those that are not. The differences are small and insignificant within the group in which the progeny had the highest rate of growth. Thus the progeny of K 2138, K 2136 and I 17171 do not differ significantly in rate of growth, but the first two families (progeny of K 2138 and K 2136) have a higher rate of growth than the families with an intermediate rate of growth (progeny of K 2132 and K 2191) and the differences of over 4 per cent. are statistically significant. The progeny of I 17171 appear to be intermediate between those of K 2138 and K 2136 on the one hand, and K 2132 and K 2191 on the other. The progeny of J 373 are shown here to have grown at a significantly slower rate from two to eight weeks of age than the progeny of any of the other five hens, the differences ranging from slightly over 6 per cent. to over 10 per cent. In contrast to these differences the progeny of K 2132 differ by less than one per cent. in rate of growth from the progeny of K 2191, which is comparable to the difference between the progeny of K 2136 and K 2138.

The differences in the rates of growth of these six families indicates that the hens differ in genetic constitution with respect to rate of growth. In this connection it is of interest to note that K 2136 whose progeny are second highest in average rate of growth is a half sister of J 373, the mother of the slowest growing family. Moreover, these two hens were mated to the same male, so that the coefficient of relationship of their offspring is .3125. In spite of the close relationship, the growth rates of the two progenies differ by 10.5 per cent., which, as shown by the odds of 690 : 1 is statistically significant. Clearly, these two hens transmitted different gene complements to their progeny.

The evidence so far considered indicates that there are genetic differences with respect to rate of growth within the White Leghorn breed, and that such differences can be demonstrated to exist between even such closely related individuals as full sisters (J 373 and K 2136).

It has previously been suggested (Lerner and Asmundson, 1932) that rate of growth is determined by multiple factors. Some of the differences shown in Table 4 have a bearing on this question. If the differences between the groups with the highest and the lowest rates of growth are averaged, these differences are found to equal 10.155 per cent. The average difference between the groups with the medium and the lowest rates of growth is 6.652 per cent. The average difference between the groups with the medium and the highest rates of growth should then be 10.155 - 6.652 = 3.503 per cent, if the factors for high rate of growth lacking in the medium group are the same as some of those lacking in the group with the lowest rate of growth. The actual average difference between the groups with the medium and the highest rates of growth is 3.516 per cent, which is identical to the first decimal place with the expected figure. This may be interpreted as additional evidence indicating that rate of growth depends on multiple factors.

SUMMARY.

The rate of growth from two to eight weeks of age was computed for 340 S. C. White Leghorn chicks by a modified formula of Minot. The chicks were divided into four groups on the basis of sex and time of hatch. Comparisons were made between the progeny of three males and between six more or less closely related families, each of 15 or more chicks. The results obtained may be summarized as follows:

1. The males grew more rapidly than the females and the earlier hatched chicks grew more rapidly than the later hatched chicks.
2. There was no significant difference in the average rate of growth of the progenies of the three males.
3. The six families could be divided approximately into three classes: (a) three families with a comparatively rapid rate of growth (average per cent. 143.36); (b) two families with an intermediate rate of growth (average per cent. 139.86), and (c) one family with the slowest rate of growth (average per

cent. 133.21). There was no significant difference in rate of growth between families within any one of these classes, the differences ranging from 0.8 to 1.8 per cent. Families, not in the same class, differed in rate of growth by from 2.0 to 10.8 per cent., and these differences were, in most cases, statistically significant. The average difference between classes (a) and (b) was 3.50 per cent.; between classes (b) and (c) 6.65 per cent.; and between classes (a) and (c) 10.15 per cent., which equals (a - b) + (b - c).

These results point to two general conclusions:

(a) That there are genetic differences with respect to rate of growth within this strain of the White Leghorn breed, and

(b) that these differences in rate of growth are determined by multiple factors.

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APPENDIX

TABLE I.

Constants for Rate of Growth from Two to Eight Weeks of Age for the Four Groups of S.C. White Leghorn Chicks.

Sex	Hatch	No. of Chicks	Mean	Standard Deviation	Coefficient of Variation.
Male	1 + 2	54	146.468 ± .384	4.184 ± .272	2.857 ± .186
"	3 + 4	110	136.730 ± .551	8.572 ± .390	6.269 ± .284
Female	1 + 2	53	141.044 ± .500	5.392 ± .353	3.823 ± .251
"	3 + 4	123	134.298 ± .390	6.420 ± .276	4.780 ± .206

TABLE 2.

DIFFERENCES BETWEEN THE VARIOUS GROUPS OF CHICKS CALCULATED FROM TABLE I.

Difference between:	Mean	D/E	Coefficient of Variation	D/E
Males, H.1+2 - Males, H.3+4	9.738±.672	14.5	-3.406±.338	10.1
Females, H.1+2 - Females, H.3+4	6.746±.635	10.6	- .952±.325	2.9
Males, H.1+2 - " H.1+2	5.424±.631	8.6	- .972±.312	3.1
Males, H.3+4 - " H.3+4	2.432±.676	3.6	1.482±.349	4.2

TABLE 5.

Differences in Rate of Growth from Two to Eight Weeks Between Six Families of S.C. White Leghorns.

HEN NO.	Sex	Hatch	J 373 Difference	J 373 D/E	K 2132 Difference	K 2132 D/E	K 2191 Difference	K 2191 D/E	I 17171 Difference	I 17171 D/E	K 2136 Difference	K 2136 D/E
K 2138	♂	1+2	5.665±2.004	2.8	0.500±.998	0.5	0.724±1.134	0.6	- .500±1.605	0.3	-3.500±1.025	3.4
		3+4	17.167±1.785	9.6	6.667±1.389	4.8	7.667±1.849	4.1	1.167±1.508	0.8	3.167±1.054	3.0
	♀	1+2	11.500±1.944	5.9	6.100±.656	9.3	2.500±1.357	1.8	1.333±1.383	1.0	2.890± .852	3.4
		3+4	9.200±1.663	5.5	5.288±1.666	3.2	4.400±1.735	2.5	5.150±2.338	2.2	-1.172±1.847	0.6
K 2136	♂	1 2	9.165±1.940	4.7	4.000±.860	4.7	4.224±1.015	4.2	3.000±1.522	2.0		
		3 4	14.000±1.479	9.5	3.500±.965	3.6	4.500±1.557	2.9	-2.000±1.127	1.8		
	♀	1 2	8.610±2.013	4.3	3.210±.838	3.8	-.390±1.453	0.3	-1.557±1.477	1.0		
		3 4	10.372±1.409	7.4	6.460±1.412	4.6	5.572±1.493	3.7	6.322±2.615	3.0		
I 17171	♂	1 2	6.165±2.299	2.7	1.000±1.504	0.7	1.224±1.598	0.8				
		3 4	16.000±1.829	8.7	5.500±1.446	3.8	6.500±1.892	3.4				
	♀	1 2	10.167±2.289	4.4	4.767±1.374	3.5	1.167±1.816	0.6				
		3 4	4.050±2.010	2.0	.138±2.012	0.1	-.750±2.070	0.4				
K 2191	♂	1 2	4.941±1.999	2.5	-.224±.986	0.2						
		3 4	9.500±2.121	4.5	-1.000±1.800	0.6						
	♀	1 2	9.000±2.273	4.0	3.600±1.350	2.7						
		3 4	4.800±1.257	3.8	.588±1.261	0.5						
K 2132	♂	1 2	5.165±1.924	2.7								
		3 4	10.500±1.734	6.1								
	♀	1 2	5.400±1.938	2.8								
		3 4	3.912±1.161	3.3								

TABLE 4.

Difference Between Progenies of Different Females
Calculated by Student's Method.
(see Table 6)

HEN NO.	J 373		K 2132		K 2191		I 17171		K 2136	
	Diff.	Odds on significance	Diff.	Odds on significance	Diff.	Odds on significance	Diff.	Odds on significance	Diff.	Odds on significance
K 2138	10.833	97.0	4.639	42.5	3.823	23.9	1.788	7.4	.932	2.4
K 2136	10.537	690.6	4.293	195.0	3.477	24.6	1.441	2.7		
I 17171	9.096	48.3	2.851	14.5	2.010	6.0				
K 2191	7.060	171.0	.816	3.1						
K 2132	6.244	81.6								

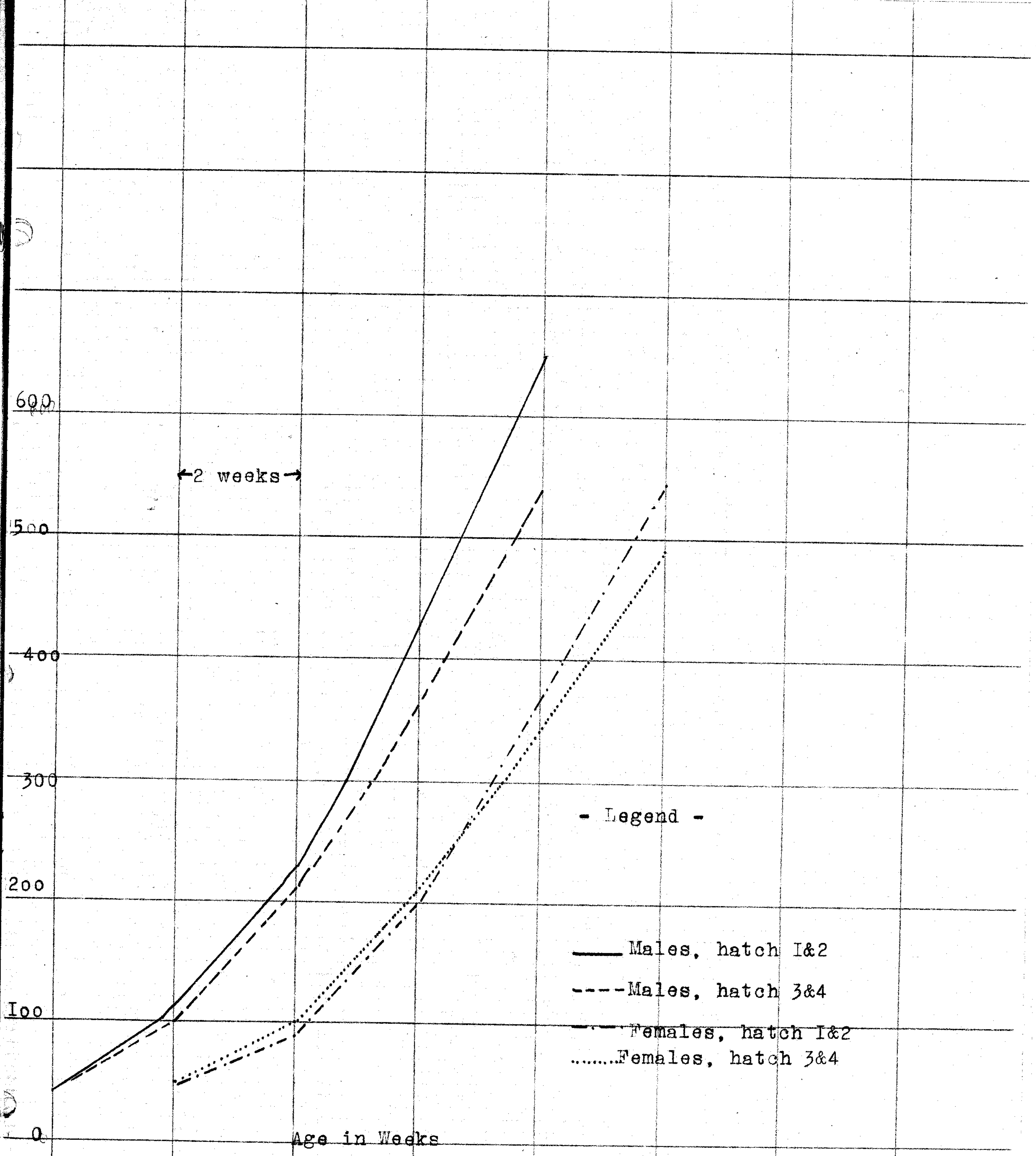

Figure I

Cumultative growth curves for four groups of S.C. White Leghorns.

TABLE 5

Constants for Rate of Growth from Two to Eight Weeks of Age for the Progenies of Three S.C. White Leghorn Males.

MALE NO.	Male progeny Hatches 1 & 2			Male progeny Hatches 3 & 4			Female progeny Hatches 1 & 2			Female Progeny Hatches 3 & 4		
	No.	Mean	Coeff. of Variation	No.	Mean	Coeff. of Variation	No.	Mean	Coeff. of Variation	No.	Mean	Coeff. of Variation
L 1520	32	145.70±.44	2.52±.21	34	138.01 ± .76	4.74±.39	22	142.04±.73	3.59±.37	36	135.78±.59	3.90±.31
K 585	15	147.55±.86	3.36±.41	23	132.12±1.37	7.36±.73	14	140.81±.98	3.86±.49	38	134.53±.73	4.98±.38
L 2001				30	137.55±1.13	6.70±.58	1	145.60		24	134.62±.74	3.97±.39

TABLE 6.

Relationships Between Six Families of S.C. White Leghorns

Family No.	Mother	Mother's father	Mother's mother	Father	Father's father	Father's mother
3	I 17171	420 G	D 2444	L 1520	K 2390	I 17140
5	K 2132	H 488	I 17171	"	"	"
1	K 2138	"	"	"	"	"
4	K 2191	"	I 17130	"	"	"
2	K 2136	H 587	H 11917	K 585	H 488	"
6	J 373	"	H 755	"	"	"

TABLE 3.

Mean Rates of Growth from Two to Eight Weeks of Age of
Six S.C. White Leghorn Families.

Family & Hen No.		1 (K2138)		2 (K2136)		3 (I17171)		4 (K2191)		5 (K2132)		6 (J 373)	
Sex	Hat-ch	No. chi-cks	Mean Rate of Growth	No. chi-cks	Mean Rate of Growth	No. chi-cks	Mean Rate of Growth	No. chi-cks	Mean Rate of Growth	No. chi-cks	Mean Rate of Growth	No. Chi-cks	Mean Rate of Growth
Male	1 2	5	146.450 .809	6	149.950 .631	6	146.950 1.386	9	145.726 .795	4	145.950 .584	3	140.785 1.834
"	3 4	6	142.117 1.027	2	138.950 .239	6	140.950 1.102	5	134.450 1.538	5	135.450 .935	4	124.950 1.460
Female	1 2	2	146.450 .477	9	143.560 .706	6	145.117 1.298	3	143.950 1.270	5	140.350 .451	4	134.950 1.885
"	3 4	5	141.350 1.448	7	142.522 1.147	4	136.200 1.836	8	136.950 .956	9	136.062 .824	5	132.150 .818