Int. Congress Microbiol., 1962, 91.
7. ———, *Cancer Res.*, 1962, in preparation.
8. Plagemann, P. G. W., Gregory, K. F., Swim, H. E., Chan, K. K. W., *Can. J. Microbiol.*, 1962, in press.
9. Warburg, O., *Die Wasserstoffübertragenden Fermente*, Saenger, Berlin, 1948.
10. Reitman, S., Frankel, S., *Am. J. Clin. Path.*, 1957, v28, 56.
11. Bessey, O. A., Lowry, O. H., Brock, M. J., *J. Biol. Chem.*, 1946, v164, 321.
12. Goldbarg, J. A., Rutenberg, A. M., *Cancer*, 1958, v11, 283.
13. Sibley, J. A., Lehninger, A. L., *J. Biol. Chem.* 1949, v177, 859.
14. Slein, M. W., *Methods in Enzymology*, Acad. Press, Inc., New York, N. Y., 1955, vI, p304.
15. Notkins, A. L., Greenfield, R. E., PROC. SOC. EXP. BIOL. AND MED., 1962, v109, 988.
16. Dixon, M., Webb, E. C., *Enzymes*, Acad. Press, Inc., New York, 1958, p630.
17. Plaut, G. W., Sung, S. C., *J. Biol. Chem.*, 1954, v207, 305.
18. Delbrück, A., Zebe, E., Bücher, T., *Biochem. Z.*, 1959, v331, 273.
19. Eichel, H. J., Bukovsky, J., *Nature*, 1961, v191, 243.
20. Schmidt, E., Schmidt, F. W., *Klin. Wochenschr.*, 1960, v38, 810.
21. Wróblewski, F., Ladue, J. S., PROC. SOC. EXP. BIOL. AND MED., 1956, v91, 569.
22. Sibley, J. A., *Ann. N. Y. Acad. Sci.*, 1958, v75, 339.
23. Warburg, O., Christian, W., *Biochem. Z.*, 1943, v314, 149.
24. Riley, V., *Science*, 1961, v134, 666.

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Genetic Differences in Growth Potential on Amino Acid Deficient Diets.* (27912)

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The chicken, unlike many mammalian species, has a well-defined requirement for arginine(1). It has been observed over a period of many years that body-weight gains of growing chickens given rations containing insufficient amounts of arginine show great variation(2,3,4). This variation is so striking that, on diets containing about half the arginine level considered necessary for optimum growth of the average chick, it is not uncommon to find some birds growing at a near normal rate, while others only maintain themselves. Whether the ability to grow on low-arginine intake by some but not all birds is genetically conditioned within a randomly bred flock is thus a question.

McDonald(5) and Miller *et al.*(6) have shown a breed difference in conversion of methionine into cystine in chickens, and Hegsted *et al.*(7) found that White Leghorns had a higher arginine requirement than Barred Plymouth Rocks. Goodman(8) had reported strain differences among mice in utilization of the optical isomers of certain amino acids. In the present study we are reporting on the apparent heritability of differences in the growth pattern on an arginine-deficient diet for offspring from different dams in a randomly bred flock of Leghorns. Subsequently we also extended these inquiries to another amino acid (lysine).

Methods. Fifteen hens and one cockerel were taken at random from a flock of Cornell Randombred(9) Leghorn chickens. The hens were trapnested to identify the origin of each egg, and the eggs were incubated at regular intervals. All chicks that hatched were grown in battery brooders for 4 weeks on a casein-glucose ration that provided approximately half the quantity of arginine which is considered necessary for optimum growth of the average chick receiving a casein diet. At the end of the 4-week period all birds were sexed.

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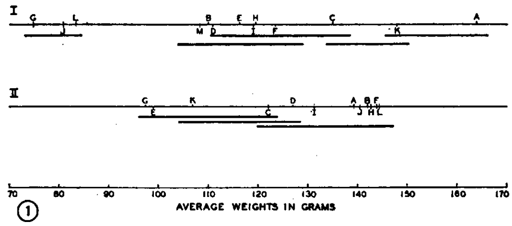
After 3 separate hatches the cockerel was changed, and 2 more hatches were obtained from the eggs of the same hens. Over the entire period, 13 of the 15 hens provided sufficient offspring to justify inclusion in the experiment.

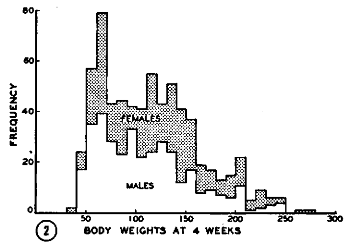
In the second part of the study 2 further hatches were made from the same matings, and a sesame meal-glucose diet, providing approximately half the quantity of lysine necessary for optimum growth of the average chick on this diet, was given to the offspring. During this part of the study only 12 of the hens produced sufficient eggs (*i.e.*, offspring) to be of value for this comparison. The chicks were again grown to 4 weeks of age, at which time the sex of each was determined.

Results. No important differences in body weights of the offspring could be attributed to the 2 cockerels used in the mating. The results for all the chicks from any one dam given the arginine-deficient diet were therefore combined.

As expected, the total population of chicks grown on this diet showed considerable variation in body weight. An analysis of variance showed highly significant differences ($P<0.01$) among dams with respect to growth rate of both male and female offspring. Since these differences were of a similar nature for chicks of both sexes from any given dam, all offspring from each dam were considered together and Duncan's multiple range test(10) was used to find significant differences among dam families with regard to the 4-week weights of the offspring (Fig. 1). It is evident that dams G, J, and L produced slow-growing chicks on the arginine-deficient diet, whereas others (C, K, A) primarily produced offspring that grew significantly better on this diet. The average weight of chicks from all dams with its standard deviation, based on individuals, was 115 ± 42, with a coefficient of variation of 37%.

When similar analyses were made for the chicks that had been given the lysine-deficient diet, a much smaller spread in body weight was observed (Fig. 1), although there were still some significant differences among





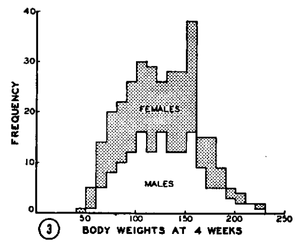


FIG. 1. Average 4-week weights of chicks originating from dams listed by letter; I, chicks grown on arginine-deficient diet, II, chicks grown on lysine-deficient diet. Differences between dams not connected by bold-face line are significant at 1% level.

FIG. 2. Frequency distribution of 4-week weights from chicks given an arginine-deficient diet.

FIG. 3. Frequency distribution of 4-week weights from chicks given a lysine-deficient diet.

dam families. The average for all chicks on this experiment was 126 ± 32, with a coefficient of variation of 25%. Aside from the smaller coefficient of variation for the chicks on the lysine-deficient diet, we also noted an interesting difference in distribution of the chick weights at 4 weeks of age, as shown in Fig. 2 and 3. While the frequency distribution for chicks on the lysine-deficient diet approaches a normal or Gaussian distribution, the histogram for the arginine-deficient chicks shows a curve which is strongly skewed to one side.

We deemed it important to compare the growth potential of chicks from the dams, mentioned previously as having extremely slow- or fast-growing offspring on the arginine-deficient diet, when these were given a standard growing ration. Table I lists, in

TABLE I. Growth of Offspring of 6 Dams on Arginine- and Lysine-Deficient and Conventional Diets.

Dam	4-week wt (g) Arginine-deficient	Lysine-deficient	Conventional
A	164	140	301
K	148	107	278
C	135	122	266
L	83	144	244
J	80	141	253
G	75	98	191
Coefficient of variance	33	26	13

decreasing order, the average weights of chicks raised on the arginine-deficient diet, and compares these with the weights of the offspring, from the same dams, given the conventional and the lysine-deficient diet. The growth potential on the conventional diet ranked the dams in practically the same order as that for the arginine-deficient diet.

It should also be mentioned that there were some differences in egg, and therefore body-weight, of the day-old chicks. Covariance analysis was used to evaluate the importance of these differences on the 4-week (final) weights. This analysis indicated that the variation in day-old weights among the offspring could not explain more than a small portion of the variation in 4-week weights.

Discussion. This study shows the existence of inherited differences in the growth potential of chicks on an amino-acid-deficient diet. It is noteworthy that the growth potential of the offspring of any one dam on the arginine-deficient diet appears to be unrelated to the potential on the lysine-deficient diet. Thus, dams J and L produced offspring that grew slowly on the arginine-deficient diet, but relatively well on the lysine-deficient diet. Dam G appears to be an exception, since her offspring did poorly on all rations tested. On the other hand, the growth potential on the standard starting ration was clearly similar to the potential on the arginine-deficient diet, except for a reduced coefficient of variation. It remains to be seen whether supplementation with arginine would further diminish the body weight differences in chicks receiving the standard diet.

Nesheim and Hutt(11) recently reported differences in the arginine requirement for early growth among 3 strains of Leghorn chickens, and significant differences among sire families within strains. In our work we show significant differences among dams in the growth potential of their offspring on arginine- and lysine-deficient diets. Differences among sire families cannot be ruled out, however, since only 2 cockerels were used in our study.

Summary. Chicks from hens from a random-bred flock were raised to 4 weeks of age on either an arginine- or a lysine-deficient diet. The results showed an inherited growth potential for chicks given either amino-acid-deficient diet. In most cases, offspring of any one dam behaved differently on the 2 deficient diets. The ranking of dams on the basis of growth potential of offspring given a complete ration was similar to that obtained on the arginine- but not the lysine-deficient ration. The coefficient of variation of 4-week weights was greatest on the arginine-deficient diet and least on the complete diet.

1. Leveille, G. A., Fisher, H., *J. Nutrition,* 1959, v69, 289.

2. Fisher, H., Salander, R. C., Taylor, M. W., *ibid.,* 1956, v59, 491.

3. Snyder, J. M., Morrison, W. D., Scott, H. M., *Poultry Sci.,* 1956, v35, 852.

4. Wietlake, A. W., Hogan, A. G., O'Dell, B. L., Kempster, H. L., *J. Nutrition,* 1954, v52, 311.

5. McDonald, M. W., *Austral. J. Agri. Res.,* 1958, v9, 161.

6. Miller, E. C., O'Barr, J. S., Denton, C. A., *J. Nutrition,* 1960, v70, 42.

7. Hegsted, D. M., Briggs, G. M., Elvehjem, C. A., Hart, E. B., *J. Biol. Chem.,* 1941, v140, 191.

8. Goodman, R. M., *J. Exp. Zool.,* 1956, v132, 189.

9. King, S. C., Carson, J. R., Doolittle, D. P., *World's Poultry Sci. J.,* 1959, v15, 139.

10. Duncan, D. B., *Biometrics,* 1955, v11, 1.

11. Nesheim, M. C., Hutt, F. B., *Science,* 1962, v137, 692.

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