inoculations of Fl^- bacilli frequently prevented active infections with Fl^+ *Y. pestis*. 7 rats developed remarkable lesions filled with purulent material and Fl^- *Y. pestis*. Buboes were first detected 2–3 months after inoculation of Fl^- *Y. pestis* and increased in size with time. Infections with Fl^- *Y. pestis* persisted over a year in rats.

Discussion. Laboratory mice are more susceptible than rats to fatal disease from Fl^- *Y. pestis*, and similar differences in susceptibility may exist among species of wild rodents, which differ in their susceptibility to Fl^+ *Y. pestis*[9–12]. Experimental data illustrate how Fl^- *Y. pestis* might arise[5,6] in wild rodents, persist via chronic infections, and immunize animals against acute plague, thereby reducing the potential for epizootic outbreaks in plague foci.

1 Williams, J.E., Harrison, D.N., Quan, T.J., Mullins, J.L., Barnes, A.M., and Cavanaugh, D.C., Am. J. Public Health *68* (1978) 262.
2 Poland, J., and Barnes, A., in: CRC handbook series in zoonoses, vol. 1, section A, p. 515. Ed S.F. Steele. CRC Press, Boca Raton 1979.
3 Cavanaugh, D.C., and Williams, J.E., in: Fleas, Proc. int. Conf. fleas, p. 245. Aston Wold, Peterborough, UK, 21–25 June 1977, Balkema, Rotterdam 1980.
4 Winter, C.C., Cherry, W.B., and Moody, M.D., Bull. Wld Hlth Org. *23* (1960) 408.
5 Burrows, T.W., Nature *179* (1957) 1246.
6 Williams, J.E., Harrison, D.N., and Cavanaugh, D.C., Trans. R. Soc. trop. Med. Hyg. *69* (1975) 171.
7 In conducting the research described in this report, the investigators adhere to the 'Guide for the Care and Use of Laboratory Animals'; as promulgated by the Committee on Care and Use of Laboratory Animals of the Institute of Laboratory Animal Resources, National Research Council.
8 Bahmanyar, M., and Cavanaugh, D.C., in: Plague manual, p. 16, 17 and 26. World Health Organization, Geneva 1976.
9 Pirie, J.H.H., Publs S. Afr. Inst. med. Res. *3* (1927) 119.
10 Kartman, L., Prince, F.M., Quan, S.F., and Stark, H.E., Ann. N.Y. Acad. Sci. *70* (1958) 668.
11 Baltazard, M., WHO Chronicle *14* (1960) 419.
12 Isaäcson, M., Arntzen, L., and Taylor, P., J. Infect. Dis. *144* (1981) 80.

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Size and shape in *Poecilia reticulata*

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Summary. In this paper some aspects of size and shape variation in 3 inbred lines of *Poecilia reticulata* reared under different environmental conditions are described. The results obtained suggest that size variation is principally due to environmental and/or developmental modifications; differences in shape, on the other hand, seem to be mainly correlated with a different genetic constitution of the inbred lines considered.

The difficulty of separating genetic from environmental variation of polygenic traits led to a situation in which studies which measure the degree of genetic variation within and between populations became rather rare[1]. However, since modern theories on evolutionary change stress the unity of the genotype[2], many researchers have again begun to carry out quantitative studies on morphometric variations of size and shape.

Spielman[3], in his study of anthropometric resemblance between men and women from the same and different villages, has shown that differences in shape and size can be correlated to genetic and environmental differences respectively. Festing[4] has shown that the shape of mandible in mice is a highly heritable trait, and that it can be used to determine single individuals as members of different inbred strains. The shape of the head has been also used by Templeton[5] to distinguish between 2 sympatric species of *Drosophila* which were otherwise very similar by electrophoretic and cytogenetic criteria. Finally, Atchley[6] in his study on the genetic components of size and shape in different lines of rats has pointed out that the allometric relationships estimated by him were highly heritable and would thus respond to selection.

The aim of this paper is to show the results of a preliminary investigation on size and shape estimates made in inbred strains of *Poecilia reticulata* reared under different environmental conditions and measured at different times of their post-embryonic development.

Materials and methods. The experiment was performed with 3 lines of *Poecilia reticulata* derived from 3 subsequent full-sib matings. All these lines, called A, B and C, were started with a single inseminated female (W) from a free breeding population. The complete scheme of breeding is described in a previous paper by Vanelli et al.[7].

Fish from each line were reared individually under 3 different environmental conditions: environment 1 = pots with 2000 ccm of water, environment 2 = pots with 250 ccm, environment 3 = pots with 100 ccm. The water was composed of $\frac{2}{3}$ tap water and $\frac{1}{3}$ distilled water. The environmental temperature was maintained at $25 \pm 1\,°C$, with a photoperiod of 12 h. The fish were fed with standard dry food.

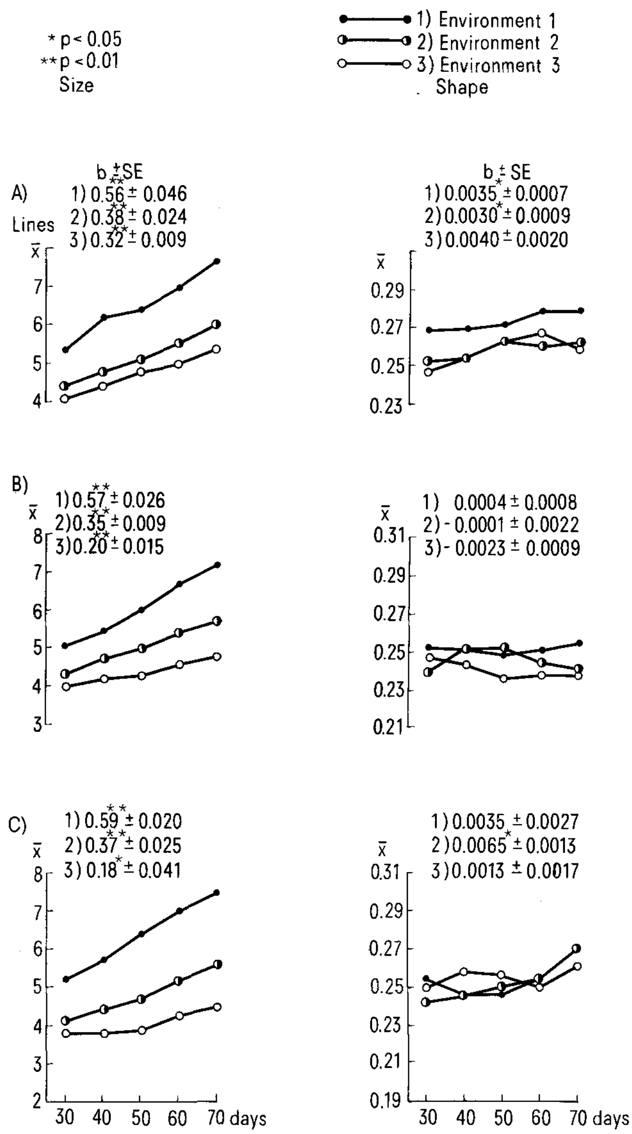
Body length and height were measured for each fish after anesthesia; the 1st measurement was from the distal opercular edge to the end of the spine, excluding the caudal pin; the 2nd was from the fore portion of the dorsal pin to the fore portion of the anal pin. These measurements were made in units of a micrometer (1 unit corresponds to 1.56 mm) and were collected fro fish aged 30, 40, 50, 60 and 70 days without sexual identification.

The values for size and shape were obtained from a system of Cartesian coordinates constituted by the X-variable = body length and by the Y-variable = body height. Each single individual can be identified in this Cartesian plane by a point P_i characterized by the pair of measures x_iy_i. The length of the vector connecting the measurement point P_i to the origin defines the size of the pth individual and the angle in radiants between the vector and the X-axis defines the shape of the same individual.

Table. a) Sources of variance, degrees of freedom and expected mean squares for two-way analysis of variance on size and shape; b) components of variance and percentage contribution of each component to the total variance

a) Source of variation	d.f.	Expected mean squares	b) Size	Shape
Between lines	2	$\sigma^2_E + 64.11\,\sigma^2_{G\times A} + 192.33\,\sigma^2_G$	σ^2_E = 0.296 24%	σ^2_E = 0.00037 82%
Between environments	2	$\sigma^2_E + 64.11\,\sigma^2_{G\times A} + 192.33\,\sigma^2_A$	$\sigma^2_{G\times A}$ = 0.038 3%	$\sigma^2_{G\times A}$ = 0.000014 3%
Lines × environments	4	$\sigma^2_E + 64.11\,\sigma^2_{G\times A}$	σ^2_A = 0.870 70%	σ^2_A = 0.000015 3%
Error	568	σ^2_E	σ^2_G = 0.028 2%	σ^2_G = 0.000054 12%
			σ^2_{Tot} = 1.233	σ^2_{Tot} = 0.00045

σ^2_E = component of variance due to differences between individuals; σ^2_A = component of variance due to environmental differences; $\sigma^2_{G\times A}$ = component of variance due to lines × environments interaction; σ^2_G = component of variance due to genetical differences.



Mean values of size and shape for the 3 inbred lines in the different environments at 5 subsequent intervals. b = linear regression coefficients of the mean values over the time.

Results and discussion. The mean values of size and shape for fish aged 30, 40, 50, 60, 70 days for each line in each environment are reported in the figure. The respective linear regression coefficients of the mean values on the time are also shown there. It can be seen that the trait 'size' follows a post-embryonic development that is rather well described by a linear interpolation. The shape, on the contrary, seems to change very little during the period of development considered. The mean increase in size, expressed as a linear regression coefficient, is always very similar for the 3 lines, but shows a remarkable sensibility to the different conditions of rearing, decreasing from environment 1 to environment 3.

These first results seem to suggest that it is possible to estimate from the trait 'size' both developmental variability and environmental variability, depending on the different conditions of rearing. The trait 'shape', on the contrary, does not seem to be a good index for this kind of variability.

In order to evaluate the contribution of the different components to the total variability, a scheme of two-way variance analysis (lines and environments) has been applied. The scheme of analysis, the values of the individual estimated components and the percentage contribution of each component to the total variance are reported in the table. The results show that the interaction component is very small in the analyses performed both on size and on shape. As far as the other components are considered, size and shape behave differently. In fact, for size the greatest contribution to the total variance is due to differences between environments, whereas the genetic differences are the smallest there. On the other hand, for the shape, the smallest estimates count for environmental differences, whereas the contribution due to genetic variance is 6 times greater than the same component for size.

A last observation can be made for the residual component σ^2_E which is smaller for size than for shape. This might indicate that under the same conditions of genetic heterogeneity between the individuals belonging to the same group, the size is strongly canalized toward a 'common' phenotype, while the individual shape is maintained on a phenotypic level.

The reported results seem to suggest that in *Poecilia reticulata*, as in other organisms, size and shape could be utilized to recognize genetic variability through the shape and environmental and/or developmental variability through the size. These traits could thus be used for a better understanding and analysis of quantitative variability.

1 Wright, S., Evolution and the genetics of populations, vol. 4. University of Chicago, 1978.
2 Lewontin, R., The genetic basis of evolutionary change. Columbia University Press, New York 1974.
3 Spielman, R.S., Am. Nat. *107* (1973) 694.
4 Festing, M., Genet. Res. *21* (1973) 121.
5 Templeton, A.R., Evolution *31* (1977) 630.
6 Atchley, W.R., and Rutledge, J.J., Evolution *34* (1980) 1161.
7 Vanelli, M.L., Pancaldi, C., Alicchio, R., and Palenzona, D.L., Can. J. Genet. Cytol. *23* (1981) 141.

0014-4754/83/040409-02$1.50 + 0.20/0