conclusion that endotoxin acts on the nerve terminal by increasing the number of quanta released in response to an applied stimulus.

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References and Notes

1. J. Reilly, E. Rivalier, A. Compagnor, R. LaPlane, H. DuBuit, *Ann. Med. Paris* **37**, 241 (1935).
2. A Delanney, J. LaBrun, M. Contereau, *Ann. Inst. Pasteur* **73**, 765 (1947).
3. A. Penner and A. Bernheim, *J. Exp. Med.* **111**, 145 (1960).
4. C. Palmerio, S. Ming, E. Frank, J. Fine, *ibid.* **115**, 609 (1962).
5. C. Palmerio, B. Zetterstrom, J. Shammash, E. Euchbaum, E. Frank, J. Fine, *New Engl. J. Med.* **269**, 709 (1963).
6. B. Zetterstrom, C. Palmerio, J. Fine, *Proc. Soc. Exp. Biol. Med.* **117**, 373 (1964).
7. M. Alper, C. Palmerio, J. Fine, *ibid.* **124**, 537 (1967).
8. I. Parnas and F. E. Russell, in *Animal Toxins*, F. E. Russell and P. R. Saunders, Eds. (Pergamon, Oxford, 1967), p. 401.
9. I. Parnas and H. L. Atwood, *Comp. Biochem. Physiol.* **18**, 701 (1966).
10. I. Parnas, D. Avgar, A. Shulov, *Toxicon* **8**, 67 (1970).
11. A. van Harreveld, *Proc. Soc. Exp. Biol. Med.* **34**, 428 (1936).
12. A. Nowotny, Temple University, Philadelphia.
13. R. B. Reinhold and J. Fine, *Proc. Soc. Exp. Biol. Med.*, in press.
14. R. Rahammimmoff, *J. Physiol.* **195**, 471 (1968).
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A Correlation between Gametophytic and Sporophytic Characteristics in Zea mays L.

Abstract. *If a mixture of types of corn pollen, identified by genetic markers, is applied to the silks of other inbred lines, the rate of pollen tube growth often varies with type of pollen. This gametophytic differential is correlated with a sporophytic differential—relatively heavier seeds in seed mixtures result from fertilization by gametes from faster growing tubes. The increased seed weight is due to greater competitive ability of the zygotes thus formed.*

Differential rates of pollen tube growth have been described in several plant species (*1*). The selective consequences of such differentials could be great, but only if a substantial proportion of the genetic system functions in both gametophytic and sporophytic phases of the life cycle (*2*). This study demonstrates, in *Zea mays* L., a significant relationship between a gametophytic character, relative speed of pollen tube growth, and a sporophytic character, relative seed weight. Thus, it must be concluded that some genetic factors expressed in the gametophyte function also in the sporophyte.

The analysis is based on the observation (*3*) that if a mixture of pollen types is applied to stigmas and if these types, tagged by markers, penetrate stylar tissues at different relative speeds, then the probability of the faster type reaching ovules first will be proportional to the style length. This is because not all pollen tubes start at the same position. Accordingly, random effects will be more significant when styles are short. With long styles, relative speed of growth will outweigh these random effects. Since the styles for basal kernels on an ear of corn are longer than the styles of apical kernels, any basipetal increase in frequency of fertilization by one pollen type will be a measure of that pollen type's greater relative speed. If the composition of the resultant seed mixture is determined at different points within the ear, the slope of a regression of percentage of one seed type against distance from the apex will express the relative speed of the pollen tubes associated with that seed type. This, of course, assumes that both types are capable of reaching the basal ovules.

Two marker systems, each represented in several inbred lines, were used; one for white (*yy*) or yellow (*Y-*) endosperm and another for aleurone color (A_1-) (or a_1a_1 for colorless). Pollen from one dominantly marked plant and one recessively marked plant were mixed in approximately equal proportions and then applied to silks of recessive lines (other than that in the pollen mixture). Components of the mixtures were also applied singly to the same recessive lines. Mixed crosses were replicated five times, unmixed crosses were replicated three to five times; unfilled ears were discarded. The ears were divided transversely into five nearly equal segments; seeds from the mixed crosses were separated according to color, and average weights were obtained. In all, 30 ears in eight mixtures were analyzed. Ears pollinated by a single pollen type were treated similarly.

The regression for change in percentage composition of each seed mixture from apex to base was calculated. The slopes of the positive regression in each mixture (the increasing, thus faster type) were taken as a measure of the relative speed of pollen tube growth.

Relative seed weight was the sporophytic character selected for study. Average seed weight is an indicator of heterosis (*4*), at least when compo-

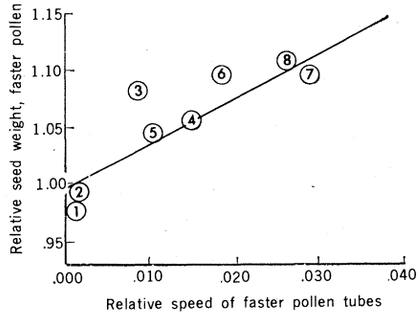

Fig. 1. Relation between relative speed of pollen tubes and the relative average weight of resultant seeds. Relative speed of the faster pollen is expressed as slope of regression for change in proportion of seed type from apex to base of the ears. Relative average seed weight with faster pollen as staminate parent is the average seed weight from the faster divided by average seed weight from the slower. The regression is significant at the 2 percent level, with a *Y*-intercept of 0.9951 ($t = 3.672$, d.f. $= 6$, $R = 0.8319$). Mixes 5, 6, and 8 (circled numbers) included five replications each, mix 2 included four, mixes 1, 3, and 4 included three replications each, and mix 7 included two. If all 30 replicates are plotted separately, a regression also significant at the 2 percent level is obtained (*Y*-intercept, 1.017; $t = 2.520$, d.f. $= 28$, $R = 0.4299$). The lower R value likely reflects not only the smaller size of each sample, but also the finding (*7*) that within highly inbred populations there may be significant heterogeneity between families.

nents of seed mixtures on an ear are compared. Total seed weight per ear is usually not influenced by paternal genotype (*4*).

Relative seed weight for each cross was expressed as follows:

$$\text{Relative seed weight} = \frac{\overline{X}_{f1}}{\overline{X}_{s1}} + \frac{\overline{X}_{f1+1}}{\overline{X}_{s1+1}} \cdots + \frac{\overline{X}_{f5}}{\overline{X}_{s5}}$$

Where $\overline{X}_{fi}$ is the average seed weight with faster pollen as staminate parent in segment i; $i = 1$, for the apical segment and $i = 5$ for the basal segment; $\overline{X}_{si}$ is the average weight of seeds with the slower staminate parent. This procedure corrected for any differences resulting from position on the ear. (Otherwise, the value for the faster type would be distorted because basal seeds tend to be heavier than others.)

For each pollen mixture, relative speed of growth of pollen tubes was plotted against relative seed weight (Fig. 1). The greater the relative pollen tube speed, the greater will be the relative weights of the resultant seeds; when there is no differential in pollen tube speed, there is no differential in seed weight.

The unmixed pollinations indicated not only that all pollen types were capable of reaching basal kernels, but also confirmed reports (*4*) that the paternal genotype does not influence total kernel weight per ear. Thus, differences within seed mixtures result from competitive interactions between seeds.

Three possible mechanisms may be considered to explain the correlation between pollen tube speed and weight (or competitive ability) of resultant seeds: (i) faster pollen tubes give resultant zygotes a temporal advantage over zygotes of later fertilizations, (ii) a paternal genotype which produces rapidly growing pollen tubes produces relatively vigorous zygotes, (iii) gametes from pollen tubes that function well in a particular stylar environment give rise to heterotic zygotes. The argument of a temporal advantage is greatly weakened by a study (*5*) in which components of a mixture were applied 1 week apart to a single corn inflorescence. Pollen giving rise to relatively large seeds when in mixtures did so despite the delay in application. The second possibility, that paternal genotype gives an overwhelming advantage to both pollen tubes and resultant zygotes, may be correct, but when the same mixture is applied to different pistillate types, the competitive abilities of pollen types sometimes change drastically. This suggests significant interactions between pollen tube and stylar tissues. Stylar effects upon the outcome of pollen tube competition are well established (*6*). That such interactions should parallel those between paternal and maternal genotypes in the zygote is reasonable since style and egg should share any genetic factors for which the maternal parent is homozygous. The third, and most likely, explanation for the observed results refers to these interactions. Thus, some genetic factors are expressed in both phases of the life cycle. This evidence is interesting in that it suggests that gametophytic competition in some plants may have a significant effect upon sporophytic characteristics. The implications of this evidence include the possibility that the gametophytic phase in angiosperms may serve to eliminate deleterious genetic traits. Also suggested is a possible explanation for the heterozygosity observed in some plants even after many generations of inbreeding.

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References and Notes

1. J. Harding and C. L. Tucker, *Evolution* **23**, 85 (1969).
2. ". . . The average fitness of a population at anytime is uneffected by prezygotic factors . . . *provided that prezygotic factors and postzygotic factors are uncorrelated* [italics mine]," from D. L. Hartl, *Evolution* **24**, 415 (1970).
3. C. Correns, *Handb. Vererbungswiss.* **2**, 1 (1928).
4. D. F. Jones, *Selective Fertilization* (Univ. of Chicago Press, Chicago, 1928), pp. 1–155; T. A. Kiesselbach, *Nebr. Agr. Exp. Sta. Res. Bul.* **33**, 1 (1926).
5. G. N. Collins and J. H. Kempton, *U.S. Dep. Agr. Bur. Plant Indus. Circ. No. 124* (1913), p. 9.
6. P. L. Pfahler, *Genetics* **57**, 513 (1967).
7. R. W. Allard, S. K. Jain, P. L. Workman, *Advan. Genet.* **14**, 55 (1968).
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Adenosine 3′,5′-Monophosphate in Nervous Tissue: Increase Associated with Synaptic Transmission

Abstract. *Brief periods of stimulation of the preganglionic nerve fibers produced a severalfold increase in the content of adenosine 3′,5′-monophosphate in superior cervical sympathetic ganglia, whereas postganglionic stimulation did not. These and other experiments indicated that the increased concentrations of adenosine 3′5′-monophosphate were closely associated with the process of synaptic transmission. This increase occurred primarily in postsynaptic cells.*

There is considerable evidence which suggests that adenosine 3′,5′-monophosphate (cyclic AMP) may be involved in regulation of metabolism and function in the nervous system. Several reviews of this subject have appeared recently (*1*). Included in the evidence is the finding that electrical stimulation of brain slices results in an increase in the concentration of cyclic AMP (*2*). However, it was not possible to conclude from those experiments whether the effect on

Table 1. Effect of preganglionic stimulation on the content of cyclic AMP in rabbit superior cervical sympathetic ganglia. One ganglion from each rabbit was stimulated at a frequency of 10 per second. The contralateral ganglion served as an unstimulated control. The data have been calculated as the mean ± standard error for the number (*N*) of rabbits indicated in the second column. In the last column, the concentration of cyclic AMP in the stimulated ganglia is expressed as the percentage of that in the unstimulated control ganglia. Temperature, 33°C.

Duration of stimulation (min)	*N*	Cyclic AMP (picomoles per milligram of protein)			Percentage of control
		Unstimulated ganglion	Stimulated ganglion	Absolute increase	
0.5	5	23.2 ± 5.5	43.4 ± 11.2	20.3 ± 13.0	249 ± 113
1.0	5	13.1 ± 1.3	61.8 ± 6.1	48.7 ± 5.2	479 ± 39
2.0	11	18.0 ± 1.7	70.2 ± 9.1	52.1 ± 8.2	399 ± 40
4.0	4	14.2 ± 2.9	57.0 ± 3.0	43.5 ± 4.3	483 ± 136
8.0	4	16.4 ± 1.0	72.0 ± 4.5	55.7 ± 4.6	445 ± 41