Table 1. Transmission of corn stunt agent by *Dalbulus elimatus* injected with mycoplasma cultures isolated from corn plants infected with the Rio Grande strain. Twenty noninjected insects from stock colonies were tested in each experiment and all were noninfective. All the infective colonies transmitted to two or more test plants.

Exp. No.	Age of culture (days)	No. insect colonies infective/ tested	Mycoplasma-like cells present in inoculum*
1	5	1/5	Yes
2	8	18/21	Yes
3	8	0/12	No
4	14	0/5	No
5	14	11/14	Yes

* Samples of the inoculum were placed on Formvar-coated grids, stained with 2 percent phosphotungstate acid, pH 7.0, and examined by electron microscopy.

tions of various mycoplasma species that infect man and other higher animals (*12*). The primary cultures containing mycoplasma-like cells occasionally contained some plant debris, but this material usually disintegrated and disappeared within 1 to 2 weeks and only the mycoplasma cells remained in culture. Organisms resembling fungi, bacteria, or viruses were never observed in the pure cultures. In experiments 3 and 4, injected insects did not transmit corn stunt, and mycoplasma-like cells were not observed in the inocula by electron microscopy. Control cultures prepared from healthy plants never contained organisms that resembled mycoplasma.

The corn stunt agent is not stable in simple buffer at room temperature for more than 4 hours, but it can be maintained for several weeks in a complex cell-free artificial medium. Electron microscopy of negatively stained samples from 4- to 6-day-old cultures and from 14-day-old cultures generally revealed a higher number of organisms in the older cultures, but precise quantitative experiments were not conducted. Turbidity in the culture tubes usually increased slightly during the experiment; however, it is well known that viable counts of mycoplasma do not necessarily parallel turbidity (*13*). Several attempts were made to subculture the organism. In some, 0.2 to 0.5 ml of the primary culture that contained the mycoplasma organisms was added to 3 ml of fresh medium. In one experiment, electron microscopy of samples from 12 tubes containing subcultures that were 43 days old revealed the highest concentration of mycoplasma-like cells (Figs. 1C and 2, A and B). Samples of these subcultures were injected into 50 healthy adult leafhoppers. Three out of 30 surviving insects transmitted corn stunt to corn seedlings. Forty-five noninjected control insects were noninfective. The data suggest that multiplication has occurred under these culturing conditions.

Diseased plants from experiments 2 and 5 (Table 1) were used for preparing primary corn stunt cultures. The cultures prepared from these plants contained organisms that resembled mycoplasma (Fig. 1, D and E). The reisolation of an organism that was indistinguishable from the one injected into the leafhopper vectors from primary cultures (Fig. 1, A and B) satisfies the last criterion of Koch's postulates: (i) the mycoplasma was consistently associated with corn stunt disease and was consistently isolated from plants infected with corn stunt disease; (ii) the organism was isolated in pure culture; (iii) the disease, with characteristic symptoms, was reproduced in plants (healthy leafhoppers artificially injected with pure mycoplasma cultures transmitted the agent to healthy corn plants); and (iv) the mycoplasma was reisolated from the inoculated plants and identified with the one originally isolated.

We believe that the hypothesis of organismal etiology has been proved for the corn stunt disease and that this report demonstrates the pathogenicity of a mycoplasma to plants. We must now recognize a new class of organisms causing diseases in plants. The agent of corn stunt disease has been shown to multiply in its insect vector, *Dalbulus maidis* (DeLong & Wolc.) (*14*), and it has been demonstrated that the Rio Grande strain of corn stunt agent is pathogenic to the vector *D. elimatus* (*15*). Accordingly, this report also establishes a new class of organisms that infect invertebrates.

TSEH-AN CHEN
Department of Entomology and Economic Zoology, Rutgers University, New Brunswick, New Jersey 08903
ROBERT R. GRANADOS
Boyce Thompson Institute for Plant Research, Inc., Yonkers, New York

References and Notes

1. Y. Doi, M. Teranaka, K. Yora, H. Asuyama, *Ann. Phytopathol. Soc. Jap.* **33**, 259 (1967); T. Ishiie, Y. Doi, K. Yora, H. Asuyama, *ibid.*, p. 267.
2. R. R. Granados, *Contrib. Boyce Thompson Inst. Plant Res.* **24**, 173 (1969).
3. R. F. Whitcomb and R. E. Davis, *Annu. Rev. Entomol.*, in press.
4. R. R. Granados, R. D. Gustin, K. Maramorosch, W. N. Stoner, *Contrib. Boyce Thompson Inst. Plant Res.* **24**, 57 (1968).
5. L. O. Kunkel, *Arch. Ges. Virusforsch.* **4**, 24 (1968).
6. R. R. Granados, K. Maramorosch, E. Shikata, *Proc. Nat. Acad. Sci. U.S.* **60**, 841 (1968); K. Maramorosch, E. Shikata, R. R. Granados, *Ann. N.Y. Acad. Sci.* **30**, 841 (1968).
7. R. R. Granados, *Phytopathology* **59**, 1556 (1969).
8. R. O. Hampton, J. O. Stevens, T. C. Allen, *Plant Dis. Rep.* **53**, 499 (1969).
9. R. R. Granados, K. Maramorosch, T. Everett, T. P. Pirone, *Contrib. Boyce Thompson Inst. Plant Res.* **23**, 275 (1966).
10. R. F. Whitcomb, D. D. Jensen, J. Richardson, *J. Invert. Pathol.* **12**, 192 (1968).
11. Solution 1 contained: T.C. 199 medium (IX), 100 ml; Schneider's drosophila medium, 50 ml; Difco CMRL-1066, 50 ml; Yeastolate, 2 g. Solution 2 contained: Difco PPLO broth base, 1.5 g; sucrose, 8.5 g; double-distilled water, 69.0 ml. The three liquid mediums in solution 1 and the horse serum were purchased from Grand Island Biological Company.
12. H. P. Chu and R. W. Horne, *Ann. N.Y. Acad. Sci.* **143**, 190 (1967); D. R. Anderson and M. F. Barile, *J. Nat. Cancer Inst.* **36**, 161 (1966).
13. M. D. Eaton and I. E. Low, *Ann. N.Y. Acad. Sci.* **143**, 375 (1967).
14. K. Maramorosch, *Phytopathology* **42**, 663 (1952).
15. R. R. Granados and D. J. Meehan, personal communication.
16. Supported in part by an experimental research grant from Fairleigh Dickinson University, Teaneck, New Jersey. We thank I. Greenberg for technical assistance.

4 September 1969; revised 12 December 1969 ■

Differentiation of Populations

Ehrlich and Raven's provocative paper (*1*) never makes clear whether large-scale, intermittent gene flow is being relegated to the same never-never land as the steady, "trickle" variety. Extreme, unpredictable, and largely unexplained fluctuations in numbers occur widely in natural populations, even in *Euphydryas aurinia* (*2*), a European butterfly which shares many biological characteristics with Ehrlich's *E. editha*. The lack of gene flow during the period of observation of a given situation implies nothing about the past or the future. The Hesperiid butterfly, *Euphyes bimacula*, is a well-known colonial species (*3*) in which gene exchange among demes cannot as a rule be observed. Still, it had a "population explosion" all over the northeastern United States in 1968 (*4*) which produced extensive mixing of populations, at least in upstate New York. Had the Stanford group been studying *E. bimacula* for 10 years through 1967, they could have stated

confidently that "there is almost no gene flow in this species over gaps of as little as X meters. . . ." Does it seem likely that the current outbreak of the coral-eating starfish, *Acanthaster planci*, throughout the Pacific Ocean (*5*) is without genetic consequences? The potential evolutionary significance of intermittent gene flow associated with fluctuations of population size has been considered by Brown (*6*) in a paper which, although not cited by Ehrlich and Raven, offers an alternative explanation of "bipolarity."

ARTHUR M. SHAPIRO
Department of Entomology and Limnology, Cornell University, Ithaca, New York 14850

References and Notes

1. P. R. Ehrlich and P. H. Raven, *Science* **165**, 1228 (1969).
2. E. B. Ford, *Ecological Genetics* (Methuen, London, 1965), pp. 12–16. Whether gene flow actually occurred as a result of the expansion of the Cumberland colony of *E. aurinia* is problematical, but the potential was certainly present.
3. A. B. Klots, *Field Guide to the Butterflies* (Houghton Mifflin, Boston, 1951), p. 258.
4. See Annual Summary for 1968, *Lepid Soc. News* (15 April 1969), pp. 17–20.
5. J. H. Barnes, *Austral. Nat. Hist.* **15**, 257 (1966); *Smithson. Inst. Center for Short-lived Phenomena, Reports 532, 535, 563, 600, 617, 636, 687, 738* (1969).
6. W. L. Brown, Jr., *Quart. Rev. Biol.* **32**, 247 (1957).

1 October 1969

In the 10-year period during which we have observed three colonies of *Euphydryas editha* populations on Jasper Ridge, a number of "population explosions" have been observed (*1*). For instance, population in area C increased from roughly 70–90 to 1000–1200 individuals (1962–1968), and in area G from 130–150 to 3000–5000 (1960–1965). No increase in "mixing" occurred; indeed, our data show that interpopulation exchange of individuals decreased. There is no reason to believe that the "explosion" of *E. aurinia* discussed by Ford and Ford (*2*) resulted in substantially increased interpopulation mixing or gene flow.

Whatever the degree of exchange of individuals, gene flow, to be of evolutionary importance, must constitute a source of novel genetic information that is incorporated into the recipient population. Whether or not such incorporation will occur will depend largely on the selective situation. If a great deal of individual movement occurs in a species which depends largely on phenotypic adjustment to different local conditions, there will not be important gene flow because immigrant individuals will be genetically similar to those already in residence. In species where adaptation is largely genetic the moving genes usually will be promptly selected out of the population, and gene flow will not have been significant. It seems to us that the greatest evolutionary potential for gene flow might occur in the introduction of entire coadapted gene complexes into a population, complexes which are somewhat less likely than mutations to have been previously "tried" by the recipient population.

If the Stanford group had been studying *Euphyes bimacula* for 10 years, we would be able to make reasonably confident statements about gene flow among the populations investigated, a subject on which the lepidopterists' reports (*3*) of "veritable outbreaks in places as far apart as Maine and Pennsylvania" casts no light whatsoever.

PAUL R. EHRLICH
PETER H. RAVEN
Department of Biological Sciences, Stanford University, Stanford, California 94305

References

1. P. R. Ehrlich, *Evolution* **19**, 327 (1965); and unpublished.
2. H. D. Ford and E. B. Ford, *Trans. Entomol. Soc. London* **78**, 345 (1930).
3. Annual Summary for 1968, *Lepid. Soc. News* (1969).

9 January 1970

Many genecologists will welcome the article by Ehrlich and Raven (*1*) that points out the importance of studying natural selection as a stabilizing force in evolution as well as an agency producing divergence. They will surely praise the authors' emphatic view that such studies must be conducted at the population level rather than by treating species as "evolutionary units." Their article is unexceptionable except where they suggest that gene flow within and between flowering plant populations must be low because the usual pollen vectors are relatively inefficient in spreading grains around. But pollen dispersal is not the only way in which gene flow can be achieved with plants; seed dispersal is often as effective and may be even more effective. Until we can be more quantitative in our estimates of gene flow through seed dispersal (including long-distance seed dispersal) we would be in error to ignore it.

However, I was delighted to read the comment that "The most basic forces involved in the differentiation of populations may be antagonistic selective strategies, one for close 'tracking' of the environment and one for maintaining 'coadapted' genetic combinations—combinations which have high average fitness in environments which are inevitably variable through time." Several of us (*2*) have put forward similar views (with evidence) and I am assembling evidence for their substantiation in a number of other plant genera (*3*).

HERBERT G. BAKER
Department of Botany, University of California, Berkeley 94720

References and Notes

1. P. R. Ehrlich and P. H. Raven, *Science* **165**, 1228 (1969).
2. For example, J. M. Thoday, *Symp. Soc. Exp. Biol.* **7**, 96 (1953); H. G. Baker, in *The Genetics of Colonizing Species*, H. G. Baker and G. L. Stebbins, Eds. (Academic Press, New York, 1965), p. 147; H. G. Baker, *Taxon* **16**, 293 (1967).
3. NSF grant GB8593, "The genecology of colonizing species with wide adaptation—studies of *Lythrum, Cortaderia,* and *Veronica.*"

2 October 1969

Bed Forms in Base-Surge Deposits: Lunar Implications

Fisher and Waters (*1*) have described bed forms of sedimentary deposits which could reasonably have been formed by a base-surge mechanism near meteor craters and volcanoes. Because some telescopically observed surface features of the moon show surface patterns similar to base-surge deposits on earth, and because base surges are observed for large explosive events on earth, they conclude that base surges may have been important in dispersing and depositing debris on the lunar surface, irrespective of the kind of cratering mechanisms.

Because base surge is an important phenomenon in the distribution of radioactivity from shallow water and shallowly buried nuclear blasts, it has received intensive study by physicists interested in nuclear weapons effects. Both theoretical and model studies (*2*) have shown that the base surge is a two-fluid gravity flow. Water droplets or dust particles in the stem of the familiar mushroom, when they start to fall, entrain the air in the hollow stem. The laden air then acts as a fluid with a density on the order of 1.5 times that of the surrounding atmosphere. At the