

school structure. The most dramatic example is represented in Fig. 1. Fish in the front half and along the sides of the school were dense and highly polarized. Toward the center the fish were less polarized and swam slowly in various directions. In the back one-third of the school the fish were extremely dense, often in actual contact, completely unpolarized, and actively roiling the surface of the water. Individual fish appeared to rise to the surface and then retreat below. This activity constantly mixed the entire rear of the school, producing a turnover in the position of its members. Oxygen reductions of 22.6, 24.7, and 28.8 percent were obtained from three traverses through the school. In each instance the oxygen declined abruptly rather than gradually from the front to the back of the school. When we had completed the first oxygen profile and while the electrode was still at the back of the school, an unusual event took place. The entire rear portion of the school broke into several small schools and swam off in several directions (see inset, Fig. 1). While most of these small schools rejoined the large school during the next few minutes, at least one group did not. We conclude that the disruption of school behavior resulted from the abrupt and severe metabolic reduction of environmental oxygen and also an increase in the amount of carbon dioxide or, at least, from some undetected consequence of this metabolism [possibly release of a substance akin to "schreckstoff" (8)]. Avoidance of low oxygen has been demonstrated, however, for a number of species of fish (9). Field tests reveal that schooling alewives (*Alosa pseudoharengus*), when presented with a choice, consistently enter water with the least free carbon dioxide, if the difference presented exceeds 0.3 part per million (10). While these results do not conclusively demonstrate that the behavior of fish can be influenced by reasonably small gradients of respiratory gas concentrations, the results are consistent with our hypothesis. Not all structural changes in the school can be expected to result from group metabolic effects. For example, the constant slow interchange of position between individual fish in mullet schools is probably not caused by the effects of group metabolism, although metabolic effects may enhance the rate of interchange. That the interchanges are not the result of

group metabolism is shown by the experimental demonstration that isolated schooling fish alter position relative to a moving visual field even though orientation to general movement of the field is maintained (5). This seems to represent an innate optomotor response which may be species specific. One functional result of this type of behavior is school turnover or mixing. We consider interchange adaptive, perhaps preadaptive to the formation of large dense schools, in the sense that it acts to equalize the time of exposure of each member of a school to the full metabolic impact of the group.

Whether the hypothesis may be generalized to other species must be demonstrated. It seems reasonable to expect, however, that dense schooling species as represented by many herrings and anchovies must change environmental gases through group metabolism. It is important in this regard that the hypothesis suggested here was first formulated from our limited observations of the behavior of small schools of the northern anchovy, *Engraulis mordax*, and not from our study of striped mullet.

Position within a school can expose a fish to a considerable reduction in oxygen. This condition can alter the physiology and behavior of a fish so that its chance for survival, relative to other members of the school, may be diminished if corrective action is not taken.

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## Aucuba Strain of Tobacco Mosaic Virus: An Unusual Aggregate

Plant and animal viruses are particulate and, being uniform in size and shape within a given strain, have the capacity to form aggregates of surprising size and symmetry. Many of the spherical viruses aggregate in large and regular crystals with cubic symmetry (1). Particles of the common tobacco mosaic virus (TMV) are rod-shaped (15 by 300 m $\mu$ ) and form several types of inclusions in the cells of host plants (2). Some of these, such as the large hexagonal inclusions visible in infected epidermal cells under the light microscope, are truly crystalline and show a repetition of identical units in a regular three-dimensional hexagonal lattice. Others, such as the needle "crystals" and the longer spike- or spindle-like bodies, are paracrystalline. In the latter, virus particles lie parallel to the long axis of the inclusion and exhibit only two-dimensional symmetry (3).

During experimentation with the aucuba mosaic virus (4), which has particle size and shape similar to the common tobacco mosaic virus and is believed to be a strain of the latter, an unusual type of aggregate was observed. The cover illustration is an electron micrograph ( $\times 44,000$ ) of a thin section of a strip from an infected leaf of Turkish tobacco (*Nicotiana glauca* L.) killed in an osmium tetroxide solution. The cross-hatched figures which appear in the micrograph are cross sections of aggregates of virus particles that extend well above and below the plane of section. In longitudinal section, the aggregates are elongate and are crossed by parallel dark lines and rows of dots, believed to represent the individual particles cut at different angles. These figures are interpreted to indicate that the aucuba aggregates are made up of layers of 12 to 16 parallel virus particles, one layer placed over another at an angle of approximately 60°, giving the three-dimensional cross-hatching observed. The ends of the particles often project from the sides of the aggregates—as fibers being used to weave a basket

might do. In the case of the virus aggregate, however, the particles appear not to be interwoven, but simply to lie in layers crossed at definite angles, and stacked one over another.

Although the particles tend to form aggregates as wide as one particle is long, in many cases compounding is evident. This appears to arise from the extension of a layer of the parallel virus rods in one direction to form a compound aggregate of two, three, four, or more of the individual units (cover illustration). The individual elongate elements may appear singly or in small clusters in the cytoplasm, or they may group together in bundles of up to a hundred or more, as shown in the figure. It is believed that these are the individual units in the fibrous bundles visible under the light microscope of fresh mounts of leaf hairs and epidermal cells infected with this virus.

These unusual aggregates have not been observed in sections of leaves infected with type TMV (5). They differ strikingly, both under the light and electron microscopes, from the large, plate-like hexagonal crystals produced by type TMV. They also differ from the spike-like paracrystals in that they have the particles oriented at right angles to the length of the aggregate, rather than along it.

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## Genetics of Mitochondria

The comment by Van Valen (1) on our demonstration of complementation between two kinds of mitochondria in maize (2) is interesting.

The possibility that mitochondria from  $F_1$  heterozygotes are superior in oxidative activity to a 1:1 mixture of mitochondria from the two parental lines was not overlooked. We indicated that the mixture "approaches the behavior of the hybrid." It did appear to us at the time that the problem may be resolved either (i) by statistical analyses of additional data or (ii) by a close scrutiny of mitochondria of  $F_1$  hybrids and their parents. We chose to follow the more definitive second alternative since the phenomenon of complementation by two kinds of mitochondria suggested that such mitochondria are different from one another.

Maize is polymorphic with respect to its mitochondria (3). Specifically, Ohio 45 has one type of mitochondria, as revealed by density-gradient centrifugation; Wf9 has two types, one of which is identical to mitochondria of Oh45; Wf9/Oh45 has three types, two of which are identical to those of Wf9 and a third type not found in either parent. Thus the hybrid has parental types of mitochondria plus a hybrid-specific type.

Behavior of these mitochondria, as determined by rate of oxidation of cytochrome *c*, is as follows: the single type of mitochondria of Oh45 exhibits complementation with either of the two types of mitochondria from Wf9; parental types of mitochondria from the  $F_1$  hybrid also exhibit complementation. However, the hybrid-specific type of mitochondria accounts for an additional 30 percent of the total activity of the mitochondria of the hybrid.

Thus our original statement that 1:1 mixtures of parental mitochondria approach the activity of hybrid mitochondria is verified. While parental mitochondria—whether extracted from parental lines or separated out from the hybrid—exhibit complementation, the hybrid is still superior because it has an additional type of mitochondria.

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## Antipodal Location of Continents and Oceans

Harrison (1) considers the antipodal location of continents and oceans to be nonrandom, and presumably due to convection currents. His use of Monte Carlo methods to solve an otherwise intractable problem is admirable. However, his conclusion about the unlikelihood of the continents and oceans being randomly arranged is less impressive from a statistical point of view. He concludes that "... there is less than 1 chance in 14 that the present antipodal distribution of continents and oceans is the result of a random process." One's confidence in this statement is lowered to considerably less than 13 to 1 by the "eyeball" selection of antipodality as a striking phenomenon worthy of testing, rather than some other hypothesis of randomness.

On the other hand, perhaps his statement was not as strong as it might have been, if we view the problem in a different way. Harrison takes 82.6 percent of the total continental area to be antipodal to ocean. But Runcorn (2) says "... only 4 percent of the area of the continent is antipodal to continent," which leaves 96 percent antipodal to ocean. From Harrison's Fig. 1, the random chance of 96 percent of the land being antipodal to ocean is far less than 1 in 14, perhaps 1 in 1000.

Harrison's use of six circular or triangular continents also seems somewhat on the conservative side. Both Eurasia and South America have three shield areas, which suggests overlapping subcontinents, especially in the case of India. Neither the circles nor the triangles were allowed to overlap in Harrison's study; this probably reduced somewhat the correlation between continent locations, and slightly increased the weight of the tails of the distribution of the portion of continent antipodal to continent. One may gain insight into the effects of his use of six continents, rather than ten, and also of his use of smooth figures rather than ragged continents, by breaking the continents up into incremental islands. If the islands are scattered independently (other than not overlapping), then the expected portion of land antipodal to ocean is  $1 - p$  if the land is portion  $p$  of the total surface of the earth. Harrison uses  $p = 0.334$ , so the expected portion of land antipodal

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