

others zooplankton, but the toxicity of the extracts to cristispira was not noticeably affected by the proportion of the constituent organisms.

The question whether the oxidizing activity induced by the combined action of the style peroxidase and a food constituent is responsible for the toxicity of the mixed extracts to cristispira still remains open. It may depend on a constituent of plankton organisms entirely unrelated to their participation in the oxidase activity, which is quite general in the styles of lamellibranchs (7), though relatively few of them harbor cristispira.

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### Evidence for Mixed Cytoplasm in Heterocaryons of *Colletotrichum lagenarium*

**Abstract.** Spores of race 2 but not of race 1 of *Colletotrichum lagenarium* are ingested by myxamoebas of strain NE-30 of the slime mold *Acrasis rosea*. Sporulating colonies of three heterocaryons of *C. lagenarium* involving auxotrophic strains with different color markers of races 1 and 2 were inoculated with myxamoebas. Although spores of race 1 produced on homocaryons were not ingested by the myxamoebas, they were ingested when produced on heterocaryons involving race 2. Spores from sectors of the heterocaryons yielded colonies of race 1; spores from these colonies were not ingested by the myxamoebas.

Although the intermingling of nuclei of different genotypes has been emphasized in considering heterocaryosis, it is reasonable to assume that the component strains not only contribute nuclei but also cytoplasm in the fusion of their hyphae to produce a heterocaryon (1). Results from a study of the ingestion of spores of heterocaryons of *Colletotrichum lagenarium* (Pass.) Ell. & Halst., the fungal incitant of anthracnose of cucurbits, by myxamoebas of strain

Table 1. The component strains of heterocaryons of *Colletotrichum lagenarium*. Abbreviations: cho, choline; nic, nicotinic acid; try, tryptophan; gly, glycine; pdx, pyridoxine; ade, adenine.

Heterocaryon	Resistant strain			Susceptible strain		
	Race	Color	Nutritional requirements	Race	Color	Nutritional requirements
A	1	Black	cho, nic, or try	2	Orange	gly, pdx
B	1	Yellow	cho, nic, or try	2	Orange	gly, pdx
C	1	Yellow	cho, nic, or try	2	Black	ade

NE-30 of the slime mold *Acrasis rosea* Olive & Stoianovitch indicated that these heterocaryons may have a mixture of cytoplasm characteristic of each component strain.

Spores of race 2 but not of race 1 of *C. lagenarium* are ingested by the myxamoebas of strain NE-30 of *A. rosea* (2). For convenience, the former race has been termed "susceptible," and the latter, "resistant." When myxamoebas are added to the surface of a sporulating colony of race 2 and incubated at 22°C for 10 days, the area of ingested spores resembles a crater; the spores of race 1 are not ingested and the area of inoculation is not altered in appearance. The mycelium of a susceptible colony is not ingested.

Three heterocaryons (Table 1) involving auxotrophic strains of races 1 and 2 which differed in the color of their spore masses and mycelium were prepared (3). With prolonged incubation on bean agar, the heterocaryons displayed obvious sectors with the color of one or the other component strain. Mycelial fragments of young heterocaryotic colonies were transferred to bean agar and incubated until the sectors exhibited spore masses. Myxamoebas of strain NE-30 were added to the surface of large sectors and incubated.

Spore masses on all sectors of each heterocaryon were ingested by the myxamoebas, regardless of the color of the sector. In heterocaryon A, for example, spore masses on the black and on the orange sectors were ingested. Spore masses on the control colonies of the black component strain were not ingested. These observations indicated that the spores of the resistant race produced by a heterocaryon involving susceptible and resistant races could be ingested by the myxamoebas.

Mycelial fragments were taken from sectors displaying the color associated with the resistant component strain, transferred to bean agar, and incubated until spore masses appeared. At this time, the colonies were not sectorized

and resembled those of the resistant component. Myxamoebas were added to the surface of the colonies, which were then incubated. Some colonies were susceptible and others were resistant. With continued incubation, all susceptible and no resistant colonies developed sectors. In other words, the former colonies were heterocaryotic, and the latter, presumably, homocaryotic. Since sectoring was not detected in three to five serial transfers from the resistant colonies, it may be assumed that these colonies were indeed homocaryotic.

Spore masses were taken from sectors with the color associated with the resistant component strain in each of the heterocaryons and suspended in water; appropriate dilutions of each suspension were plated on bean agar to obtain individual colonies. Many spore masses yielded only colonies with the color of the resistant strain; 5 percent of the colonies from some spore masses displayed the color of the susceptible component. No colonies were sectorized. Depending on their color, the colonies were either susceptible or resistant. For example, spores from the black sectors of heterocaryon A gave black resistant or orange susceptible colonies. These observations indicated that resistant colonies had been produced from susceptible spores produced by the heterocaryons.

Colonies of susceptible and resistant strains involved in each heterocaryon were grown on bean agar so that they were either in contact or almost in contact at the time of sporulation. Myxamoebas were added to the center of each colony. The spore masses of susceptible but not resistant strains were ingested. This observation indicated that diffusible materials probably had not been responsible for the ingestion of spore masses on sectors with the color associated with the resistant strain.

In summary, spores produced from mycelium that was heterocaryotic for susceptibility and resistance are sus-

ceptible, whereas those produced from homocaryotic mycelium have properties dependent on their nuclear constitution. The nuclear and cytoplasmic constitution of the mycelium from which spores are formed presumably determines the nature of the wall and surface of the spores. It is reasonable to assume that the nature of the wall or surface of the spores of *C. lagenarium* may play a significant role in determining susceptibility or resistance to ingestion by myxamoebas of *A. rosea*. Since the spores of *C. lagenarium* are uninucleate, it is possible that the susceptibility of spores from heterocaryotic mycelium may have been determined by the mixed cytoplasm of the heterocaryon (4).

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### Retention as a Function of Degree of Overlearning

**Abstract.** The effects of overlearning on retention were investigated with serial lists of words of high and low frequency of linguistic usage. For both types of materials, amount recalled showed a positively accelerated increase with degree of overlearning. These increases in recall resulted from improved retention of relatively difficult parts of the lists. Speed of relearning to complete mastery was a direct function of degree of overlearning.

This study reexamines the effects of overlearning, that is, practice past the point of complete mastery, on the retention of verbal materials. A classical experiment by Krueger (1) led to the conclusion that overlearning favors retention but yields diminishing returns when it is carried beyond a moderate level. With lists of 12 nouns as learning materials and retention intervals from 1 to 28 days, Krueger found that recall and saving scores increased sharply at first, and then much more slowly, as degree of overlearning was varied from 0 through 50 to 100 percent.

In the light of recent analyses of the conditions of retention, the generality of these results is open to question. Krueger used well-practiced subjects who served in several conditions of the experiment. It is now known that the amount recalled by practiced subjects is drastically depressed by the cumulative effects of proactive interference from prior lists learned in the laboratory (2). As a case in point, Krueger's subjects retained less than 2 percent of a list 7 days after learning to criterion. When interference is massive, practically all items must be overlearned in order to be recalled. A moderate amount of overlearning will be sufficient for the easiest items in the list, whereas more difficult items will require extensive additional practice. Hence, retention will increase with overlearning at a negatively accelerated rate. In the absence of heavy proactive interference, on the other hand, only relatively difficult items will require overlearning. The beneficial effects of overlearning on retention may then be expected to develop gradually and to show initial positive acceleration. To test this prediction, naive subjects who learned and recalled a single list were used in the present study.

The experimental lists consisted of 12 two-syllable nouns. The word frequency of the items was varied in order to assess the interaction between pre-experimental language habits and the effects of overlearning. There were two types of lists drawn from the extremes of the frequency range in the Thorndike-Lorge word count (3). For the words in the high-frequency lists the number of occurrences in the "L" count was between 1000 and 3300 in 4.5 million; for the low-frequency lists the range was between 1 and 3 in 4.5 million. At each level of frequency there were two lists and two different serial orders of each list. The lists were presented on a Hull-type memory drum at a 2-second rate, with a 6-second interval between trials. Learning was by the method of serial anticipation. There were three degrees of overlearning: 0 percent, 50 percent, and 100 percent. For 0-percent overlearning, practice was terminated at a criterion of one perfect recitation. For 50-percent overlearning, practice was continued beyond the point of mastery for half as many trials as had been required to reach criterion; for 100-percent overlearning the number of trials was doubled. The lists were re-

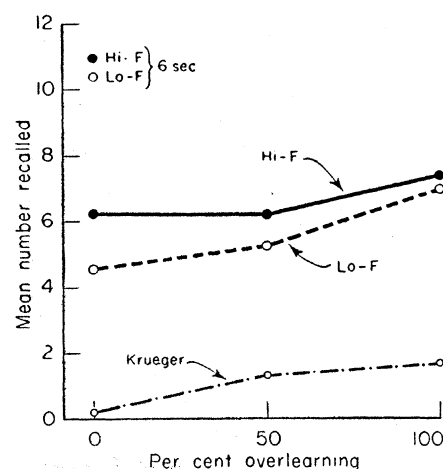


Fig. 1. Mean numbers of items recalled 7 days after the end of original learning as a function of word frequency and degree of overlearning. Points marked "6 sec" show amounts recalled on the first trial after criterion was reached. Krueger's data for the same retention interval are also shown.

learned to criterion 7 days after the end of original learning.

There were no significant differences in speed of learning to criterion among the groups tested with a given type of list. The mean number of trials to criterion was 19.25 for the high-frequency lists, and 25.48 for the low-frequency lists. This difference is significant ( $t = 3.42$ ,  $df = 94$ ,  $P < .01$ ). Figure 1 shows the mean numbers of items recalled on the first trial of relearning. (Krueger's data for a 7-day retention interval are included for comparison.) Since associative strength at criterion varies di-

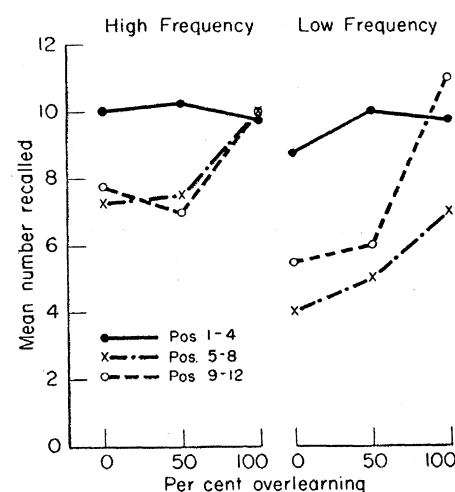


Fig. 2. Mean numbers recalled from the initial, middle, and terminal sections of the serial lists after different degrees of overlearning. The numbers of subjects giving correct responses are averaged over the four serial positions in each section.