obtained proton magnetic resonance spectra of polywater (*8*), since the ring current causes a deshielding of the end protons which will produce a downfield shift of the right magnitude. A definitive and quantitative assessment will require that *ab initio* calculations, with balanced basis sets of the type carried out for the bifluoride ion system (*3*), be performed on these models of "polywater" to ascertain fully the importance of the effect discussed here.

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Vocal Imitation and Individual Recognition of Finch Calls

Abstract. *American goldfinch females recognize individual males by their individually distinctive flight calls. Goldfinches and other cardueline finch species are also capable of learning new flight calls by imitation during pair and flock formation. Vocal imitation can occur between members of different species as well as between members of the same species. Learning of new flight calls differs in several respects from typical passerine song learning.*

Traditionally, bird vocalizations have been classified as songs or calls. Most songs are rather long, complex, territorial defense, and mate-attracting signals primarily sung by males in reproductive condition; calls are generally shorter, simpler signals, and many calls are neither restricted to a given season nor to a given sex (*1*). Normal song development in many passerines involves learning (*2*). Such song learning is generally characterized by: (i) a predisposition to learn the species-typical pattern, (ii) a "critical period" in the young male's first year when learning must occur, and (iii) the absence of further modification of song pattern once song has "crystallized" and the critical period has passed (*3*). In contrast to song, bird calls are generally considered to be inherited, unlearned species-specific signals (*2*), although a few apparent exceptions are recorded (*4*). In this report I present evidence that several species of cardueline finches learn new flight calls by imitation. Unlike song learning, the learning of new flight calls is not restricted to a critical period; an individual bird continues to learn new calls throughout its lifetime.

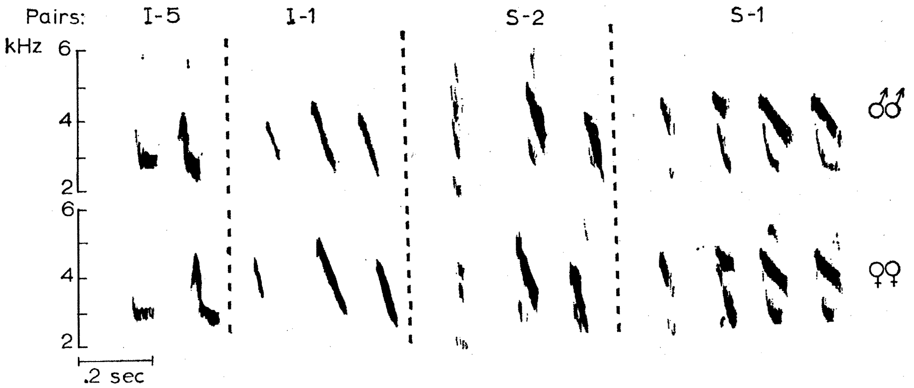

Fig. 1. Similarity of call pattern within pairs of wild American goldfinches. All pairs nested in 1967 in fields near Ithaca, New York. Pairs I-5 and I-1 were neighbors in one field, and S-2 and S-1 were neighbors in a second field. The spectrographic analysis of sounds illustrated in this and following figures presents frequency along the ordinate and time along the abscissa.

I recorded and analyzed on the sound spectrograph changes in the flight calls of individual adult European siskins *Carduelis pinus*, American goldfinches *Carduelis tristis*, and pine siskins *Carduelis pinus* (*5*). All three finches possess flight calls which a field observer usually hears when flocks or isolated individuals are in flight but which may also be given when the birds are perched. When perched, these birds usually give flight calls just before or after flight, although these calls may also occur in other perched situations, such as during courtship feeding (*6*). Flight calls are species-specific, but, within the constraints of species specificity, they are also individually variable. For example, sonograms of representative flight calls of 24 male American goldfinches recorded from populations breeding in fields near Ithaca, New York, and Oxford, Ohio, revealed that each male possessed one to three versions of the flight call, at least one of which was individually distinctive. This individual variation in flight call patterns of goldfinches permits individual recognition, which facilitates the coordination of the reproductive behavior of nesting pairs.

Individual vocal recognition can be demonstrated in the field with free-flying, breeding adults. During the nesting season, incubating and brooding female goldfinches are regularly fed at the nest by their mates. By vocal and postural display these females solicit immediately prior to and during a bout of feeding, and the male's flight call is one of the stimuli that evokes this soliciting. The following field experiment tested whether a given female goldfinch solicits only in response to her mate's flight call, or to the calls of other males. Fourteen experimentally naive incubating females were tested by playback of tapes that presented 10 seconds of the mate's flight call (a sequence of five calls); 30 seconds of silence; and then, as a control, 10 seconds of five flight calls from a different male (*7*). The occurrence of female soliciting during or immediately following playback of a given sequence of five flight calls was scored as a positive response; silence during and immediately following playback of a sequence of five calls was scored as no response. All fourteen females failed to respond to the flight call of the control male, but seven of these females responded positively to playback of their mate's flight call. Females discriminate between the flight call of their mate and those of other

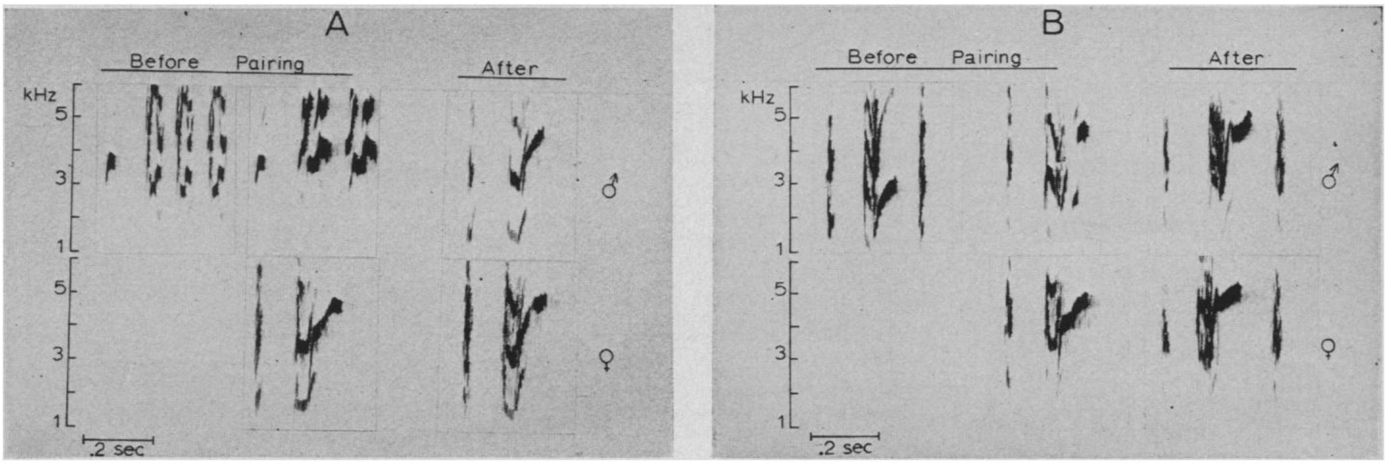

Fig. 2. Vocal imitation by members of siskin pairs. (A) Vocal imitation within a mixed species pair (male pine siskin × female European siskin). After pairing the male added to his repertoire an imitation of the female's flight call, while the female's repertoire of one call pattern was unchanged. (B) Imitation within a pair of European siskins. The pattern the birds share after pairing is somewhat intermediate to the pattern(s) each bird gave before pairing.

males ($P = .0028$ Fisher Exact Test), which implies individual recognition.

Although individual males have distinctive calls, the members of a pair of breeding goldfinches possess almost identical flight-call patterns (Fig. 1). It is thus possible that the female's recognition of her mate is aided by her possession of an identical call. The existence of such pair-specific flight calls also suggests that learning by imitation might be involved in the development of a flight-call pattern common to a given pair of goldfinches.

Experiments with captive pine and European siskins provide additional evidence that adult finches learn new flight-call patterns by imitation. In the first of two such experiments, which indicate that vocal imitation occurs during flock formation as well as pair formation, one mixed species pair (pine siskin male × European siskin female) and five European siskin pairs were formed from our stock of captive birds. The males had no history of previous contact with the females. All birds were recorded individually before pairing and the males' flight calls were recognizably different from the females' calls. The pairs were formed during January to April 1969 by placing a male and female together in a large cage or breeding aviary. Each pair was observed and recorded over periods ranging from 9 to 20 weeks. All pairs engaged in courtship feeding and three of the six pairs successfully nested and reared young. Vocal imitations of flight calls (Fig. 2) occurred in four of the six pairs; in the fifth pair the female closely approximated her mate's distinctive flight call; and I found no evidence of imitation of the flight call in the sixth pair. The results also revealed that either sex may imitate. In one instance the pair-specific pattern appeared to result from changes by both members of the pair (Fig. 2B). In the second experiment, an all male flock was formed 20 January 1969 by caging together four male European siskins that had no history of contact. When first caged together each male possessed his own exclusive repertoire of one to three flight-call patterns. These birds were individually recorded 1, 3, 6, 7, and 10 weeks after flock formation. After 10 weeks, when the flock was disbanded for breeding purposes, three of the four males had imitated at least one flock-mate, and one male possessed imitations of all three of his flock-mates (Fig. 3). The extent of vocal imitation expressed by these male siskins also seemed to correlate with flock integration. On the basis of weekly observations of flock hierarchy throughout the 10-week period, the two males at the top of the hierarchy were mutually hostile, were never observed to courtship feed with each other (*6*), and neither imitated the other. On the other hand, the two lowest ranking males were less hostile to their flock-mates, were seen to engage in courtship feeding bouts with flock-mates, and they evidenced the greatest extent of imitation.

Although the ontogeny of these finch flight calls is unknown, the data reported here support the interpretation that changes in the flight-call repertoires of individual adult finches are the result of learning. The results from the mixed-species pair (Fig. 2A) are especially relevant. The appearance of a European siskin flight call in the repertoire of an adult pine siskin must surely be attributed to learning rather than to the emergence of a latent motor pattern under the control of genetic factors common to these two species.

The imitation resulting from the mixed-species pairing also illustrates a qualitative difference between the learning of new flight calls and song learning, that is, the absence of a critical period in flight-call learning that is related to age. The male pine siskin had been wild-caught 7 years prior to his learning the European siskin call and 6 years prior to his first exposure to any European siskin. Also, two of the European siskin males and all of the females used

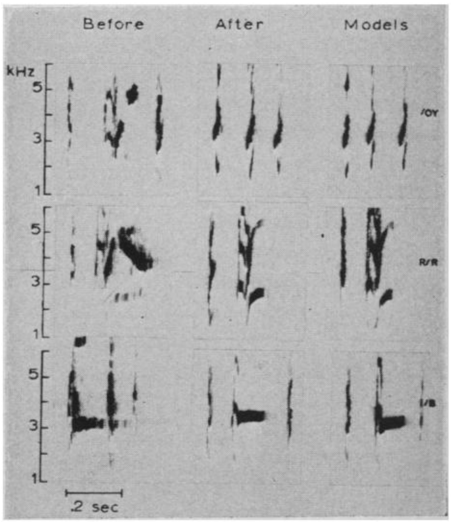

Fig. 3. Vocal imitations by a male European siskin placed in a newly forming flock. The repertoire of three different types of flight calls recorded from this male before flocking was replaced by three new calls, each an imitation of a different bird, after 8 weeks of being caged together with three initially strange male European siskins (/OY, R/R, and /B).

in these experiments were known to be over a year old. Clearly the learning of new flight calls is not limited to a critical period in the first year of life. Absence of an age-limited critical period permits a bird, throughout its lifetime, to learn new calls as its social environment changes.

Call and song learning may also differ in the nature of their reinforcement. Flight-call learning may occur in the context of courtship feeding, a behavior frequently seen during integration of flocks and pairs. Within a bout of courtship feeding, the two participating individuals frequently utter their characteristic flight calls. If courtship feeding is associated with the learning of new calls, then social factors or possibly even food (*6*) may serve as a source of the external reinforcement. Although social or emotional factors have been suggested as possible sources of reinforcement in song learning in some highly social passerines (*8*), there remain many examples of song learning that occur in the absence of any obvious external reinforcement (*3*).

In addition to providing evidence for individual recognition, learning, and the absence of a critical period, these data demonstrate the ability of finches to imitate. Taken as a whole the data provide support for the hypothesis (*9*) that avian vocal imitation is sometimes employed for recognizing and maintaining contact with other members of the species, and particularly with the mate (*10*). Related to this, Thorpe believes the ability of parrots and mynahs to mimic man may be biologically understandable if in nature these birds employ their mimetic powers for recognizing species members and maintaining contact with them (*11*). We do not as yet know if parrots and mynahs do in fact imitate conspecifics as part of their social behavior, but since the data reported here indicate that goldfinches and siskins do it seems pertinent to point out that the canary, a close relative of goldfinches and siskins, is also known to produce crude renditions of human speech (*12*). Thus, like the pine siskin's mimicry of a European siskin flight call, avian mimicry of the human voice may be a manifestation of interspecific social integration occurring in unnatural circumstances.

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5. The American goldfinch and pine siskin are often placed in the genus *Spinus*. Regardless of problems of nomenclature, ornithologists agree that the pine and European siskins are more closely related to each other than either is to the American goldfinch.
6. What is called "courtship feeding" in carduelne finches varies from a brief touching of bill tips to prolonged bouts involving the insertion of bills and the transfer of food. I have only observed the transfer of food during the nesting season. Courtship feeding is usually considered as a component of reproductive behavior; however, it is observed throughout the year in flocks of captive carduelines and it can involve a pair of males or females as well as a heterosexual pair. This suggests that courtship feeding has social functions beyond those of reproduction.
7. In ten tests the control flight call was presented first; in four tests the mate's flight call was played first. The control male was a neighboring male in some tests, a strange male in other tests. All playbacks were done in the field with the speakers and the observer located about 10 m from the nest.
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Metobromuron: Acetylation of the Aniline Moiety as a Detoxification Mechanism

Abstract. p-*Bromoaniline is rapidly acetylated by four soil microorganisms. Two fungal species convert metobromuron to* p-*bromoacetanilide, but a bacterial and an algal species do not metabolize metobromuron. Acetylation may serve as a detoxification mechanism by competing with azobenzene formation in utilizing the aniline formed by metabolism of substituted urea herbicides.*

Chloroacylanilide herbicides are degraded in soil to the corresponding anilines, which in turn are oxidatively coupled to azobenzenes (*1*). We have observed an alternative pathway. We studied the bromine-containing herbicide 3-(*p*-bromophenyl)-1-methoxy-1-methylurea (metobromuron) at 10 times the concentrations recommended for field application, rather than the much higher concentrations (up to 1000 times the recommended rates) previously used. In contrast to the results with chlorine-substituted acylanilides, we found that the aniline moiety of metobromuron is not converted to an azobenzene by soil microorganisms but is instead acetylated to the less toxic acetanilide.

Pure culture studies were made of the soil microorganisms *Talaromyces wortmanii, Fusarium oxysporum*, and *Chlorella vulgaris* and of a *Bacillus* species. The organisms were incubated with 10 μg of [C_6H_6-^{14}C]metobromuron per milliliter of synthetic medium for 18 days at 24°C and aerated on a gyratory shaker. The parent compound and its metabolites were extracted with two volumes of chloroform. Partial purification was accomplished by filtering the chloroform extracts through a layered column of unactivated Florisil and charcoal. The resulting solutions were concentrated and analyzed by thin-layer chromatography [Brinkmann precoated TLC plates, silica gel F-254, developed with ethyl acetate; chromatograms developed with a mixture of chloroform and acetic acid (60 : 1, by volume)]. The location of radioactive spots on chromatograms was determined by autoradiography. The quantity of each radioactive compound was determined by scraping the spot into a scintillation solution and counting in a scintillation counter. The metabolites were identified on the basis of their chromatographic properties and their mass spectra. The latter were obtained by extracting TLC spots with ethyl acetate, evaporating the extracts in quartz capillaries, and introducing the capillaries into the solid inlet system of a Perkin-Elmer model 270 GC-DF mass spectrometer.

The extracts from the fungal cultures gave one TLC spot with an R_F value of 0.19, which was shown by its mass spectrum to be *p*-bromoacetanilide [molecular ion at *m*/*e* (mass to charge) 213/215; base peak, *m*/*e* 171/173 (C_6H_6-BrN)+]. *Talaromyces wortmanii* converted more than 5 percent of the herbicide to *p*-bromoacetanilide, while a trace of the derivative was formed by *Fusarium oxysporum*. Neither of the other two organisms formed this derivative. In no case was *p*-bromoaniline or *p*-bromoazobenzene observed. To discount the possibility that acetylation of *p*-bromoaniline is an artifact of the TLC solvent system, a pure standard