strong dark line at –2.2 eV corresponds to the 3*d* band of copper.

Comparison between the bands of the liquid and the solid phase reveals strong similarities but also large differences. Band **1** broadens only slightly, indicating that the electronic states conserve their character through the solid-to-liquid transition. For band **3**, the states change from extended states in the solid to highly localized ones in the liquid, as seen by the large broadening of this band and the decrease in intensity. As discussed in (*1*), the states of band **3** no longer fulfill the basic condition for a delocalized state (*6*). Rotenberg *et al.* have reported a similar observation in quasicrystalline materials (*7*).

Why do bands **1** and **3** behave so differently in the liquid phase? The reason may lie either in the symmetry or in the wavelength of the wave function. Baumberger *et al.* attribute the difference to the symmetry of the atomic wave functions. The bands of the inner Fermi surface have a negative group velocity (that is, the band energy decreases with increasing electronic wave vector); a behavior that is characteristic of *p*-type wave functions, which change their phase at the site of the atomic nucleus. In the solid, the band minimum lies at the Brillouin zone boundary, but in the liquid, this zone boundary no longer exists.

The results reported by Baumberger *et al*. (*1*) open up new possibilities for studying liquid metals and show that angular resolved photoemission can be a powerful tool for that. However, more experiments are needed. In particular, it will be interesting to study in detail the importance of the wavelength and the symmetry of the wave function by analyzing different liquid/solid interfaces. The effect of the substrate should also be carefully studied. Finally, experiments on quasicrystals should also be pursued, because they present some similarities with a liquid at an interface: The electronic states show a dispersion relation (*7*) that corresponds to the potential distribution of the local environment, but with strongly damped amplitudes.

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10.1126/science.1106676

ECOLOGY

A Head Start for Some Redstarts

Geoffrey E. Hill

For the past 50 years, most field ornithologists studying migratory birds that breed in North America and Europe have concentrated on analyzing their breeding ecology. Molt and migration have received scant attention, as has the time these migratory birds spend at their wintering grounds, even though this period may occupy 8 months of a bird's annual cycle (*1*). It is easy to understand why ornithologists, most of whom live in the United States, Canada, and Europe, have concentrated on the breeding biology of migratory birds. Not only are there many interesting questions that can be addressed through breeding studies, but also migratory birds are accessible in the spring and summer, are predictable in their movements, and conspicuous in song. After breeding, territories are abandoned, home ranges expand greatly, and birds begin their nocturnal southward movement, making it impossible to track individuals of most species. However, as Norris *et al.* (*2*) demonstrate on page 2249 of this issue, new technologies are helping ornithologists to overcome these obstacles, bringing studies of molt and migration to the fore. Norris and co-workers analyze the ratio of stable-hydrogen isotopes in the feathers (*3*) of individual American redstarts (*Setophaga ruticilla*) of known reproductive history to determine when and where molting takes place.

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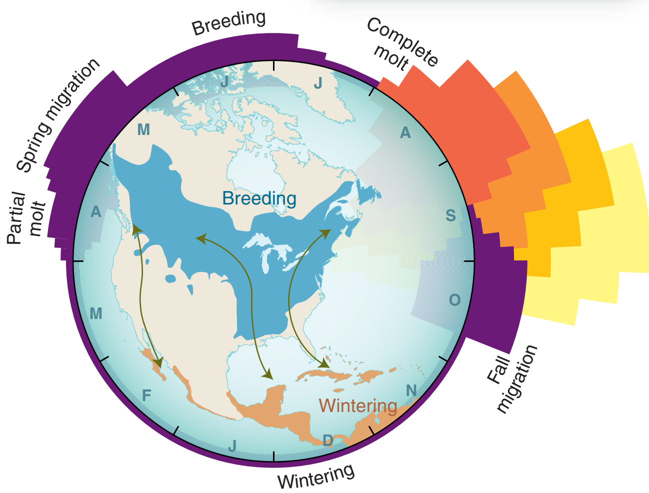
Redstarts are typical Neotropical migratory birds that breed in the eastern United States and Canada and winter in Central America and the Caribbean (see the figure). Norris *et al*. observed that the stable-hydrogen isotope signature of feathers grown while male birds reside at their breeding grounds in Ontario differs from that of feathers grown by birds on the migratory pathway much farther south. Thus, by analyzing feathers for their isotope content, Norris *et al*. could tell the latitude at which individual redstarts molted. They found that some redstarts completed their fall molt on the breeding grounds after they had finished nesting, thereby temporally separating the three most energetically costly activities of the year: breeding, molt, and migration. Other redstarts molted as they migrated. Most significantly, these investigators found evidence for a trade-off between energy investment in current reproduction, timing of the molt (a critical aspect of self-maintenance), and sexual signaling by males through feather color (a key determinant of future reproduction). Male redstarts that invested more energy in reproduction, including breeding later into the summer, completed their molt farther south on the migratory route, with greater overlap of molt and migration, and these males grew less colorful nuptial plumage. Analysis of stable-hydrogen isotopes in feathers is the only technique by which this striking pattern could have been revealed—there is essentially no chance of finding and accessing individual study birds during migration, even with radio telemetry.

Being forced to molt while migrating sounds like an energetically costly endeavor compared to molting on the breeding grounds before migration, but is there evidence for such a cost? Norris *et al*. looked at the carotenoid-based coloration of tail feathers. Male redstarts have a striking orange and black nuptial plumage, and individual tail feathers have a black tip with an orange base (see the figure). The authors found a negative correlation between plumage coloration and molting latitude—birds that grew their feathers while they migrated had less saturated orange coloration than birds that molted on the breeding grounds. Carotenoid pigments must be ingested by birds to be used in color displays (*4*). In other species of songbirds, expression of carotenoid-based plumage coloration signals a male's condition that is used by females in choosing mates or by rival males in assessing fighting ability (*4*). A reduction in ornamental coloration could have a direct negative impact on future reproductive success.

Loss of red coloration is a striking cost of reproduction, but there are likely to be other, more-difficult-to-detect costs of delaying molting into the migratory period. Most redstarts arrive in their wintering areas by flying over the Gulf of Mexico, a feat that requires substantial fat reserves (*5*). If the energetic demands of molting compete with premigratory fattening, then late-molting birds may have to attempt trans-Gulf migration with lower fat reserves. Molting during migration may also slow males, causing them to arrive later and get less preferred wintering sites. These speculations underscore a problem with the Norris *et al*. data: All of the males in the study were necessarily survivors. Males had to return to the same breeding grounds 1 year after breeding to have their



There is a season—turn, turn, turn. The annual life cycle of the American redstart, which breeds in the deciduous forests of temperate North America and Canada and winters in the Caribbean and Central America. Height of the colored bars indicates approximate relative daily energy expenditures during the major events in the redstart's annual life cycle: breeding, molt, migration, and wintering. The true energy costs of these activities are not known. Male redstarts that invest more energy in reproduction during the breeding season molt later, often during their southward migration. As a result, there is a greater overlap of molting with migration, and the energy cost results in these males growing drabber nuptial feathers (illustrated in the off-set histograms by decreased redness and color saturation with increasing overlap between molting and migration). Reduction in nuptial coloration may affect the reproductive success of these males during the next breeding season.

tails plucked for their molt location and coloration to be determined. Any birds that died as a result of reproductive effort were eliminated from the study. It seems unlikely that eliminating birds that died would have created the patterns that make this study so interesting, but eliminating such birds from the analysis might dilute the estimated cost of reproduction.

The Norris *et al*. study is not the first high-profile study of American redstarts using stable isotopes. Marra *et al*. (*6*) examined stable-isotope ratios in muscle tissue to show that the quality of wintering habitat affects timing of arrival at breeding grounds and hence reproductive success. The studies by Marra *et al*. and Norris *et al*. fit together like missing pieces of a complex life-history puzzle. Winter habitat affects spring arrival, territory quality, and date of nesting initiation. Timing of breeding affects timing of the fall molt and migration, and likely the arrival date of migrating birds at their wintering grounds. Birds are squeezed at both ends of their life cycle, as well as during their movements in between. What happens on one side of the continent has a direct and important impact on what happens on the other side. The implications of these studies for the conservation and management of migratory birds are inescapable—if we focus exclusively on the breeding biology of migratory birds we are missing at least half of the picture.

On the island of Jamaica, redstarts are called Christmas Birds because they are conspicuous during the Christmas season. For most ornithologists working in temperate climes, the redstart is a distant memory at Christmas—out of sight and out of mind. But for the growing number of ornithologists using tools like stable isotopes to take a more comprehensive approach to the study of migratory birds, it is becoming clear that what happens in the winter in the tropics and on the way there and back has a large impact on individual migratory birds and the populations in which they reside.

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10.1126/science.1107749

MICROBIOLOGY

Peptide Signals Sense and Destroy Target Cells

Danielle A. Garsin

Bacteria are not isolated solitary organisms, but actively "speak" to one another by sending and receiving transmissions in the form of chemical signals. In a process called "quorum sensing," bacteria measure the concentration of these signaling molecules in order to assess the size of the bacterial population. Once a "quorum" is reached, certain biological programs—such as sporulation, or the production of light, biofilms or virulence factors, depending on the species and context—are activated synchronously throughout the population (*1*, *2*). There are also examples where the chemical transmissions of one species can be detected by another, suggesting that these signals may be used for intraspecies as well as interspecies communication (*3*). On page 2270 of this issue, Coburn *et al.* (*4*) reveal a remarkable example of a bacterial quorum-sensing molecule that is used not only for bacterial communication but also for direct detection of eukaryotic target cells.

In Gram-positive bacteria such as the enterococci, small peptides are the quorum-sensing signals of choice (*1*). Some of these peptides have additional biological activities such as the ability to lyse target cells. Cytolysin produced by the human pathogen *Enterococcus faecalis* is one of these special peptides (*5*) and has been designated a virulence factor because it enhances virulence in a variety of animal models (*6*–*9*) and is associated with increased mortality among infected humans (*10*). When the activity was first discovered 70 years ago, the cytolysin of *E. faecalis* was termed a "pseudohaemolysin" because it seemed only to lyse blood cells when the bacteria were grown on blood agar plates. Intriguingly, this "blood-bashing" activity could not be detected in the supernatants of *E. faecalis* liquid broth cultures (*11*). As Coburn and colleagues now argue in their new study (*4*), the cytolysin of *E. faecalis* should be called a "smart-

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