

rects lateral aggregation of chains during fibrillogenesis (12). Glucose, a polyol, might interfere with such hydrophobic interactions.

Since fibril formation is an early event in collagen synthesis (13), we speculate that the high glucose environment in diabetes may prevent fibril formation and the subsequent cross-linking reaction that occurs soon after synthesis of collagen. It has been shown that 30 percent of newly synthesized collagen is degraded in the skin of streptozotocin-induced diabetic rats, while only 13 percent is degraded in control rats (3). Our observations may explain the enhanced catabolism of newly synthesized collagen in diabetics. Collagen from diabetic tissues has been suggested to be more highly cross-linked because of its observed higher resistance to collagenase and to extraction with acetic acid in comparison to normal tissue (14). Because collagen becomes progressively more cross-linked with age, and because newly synthesized collagen is not cross-linked and is less stable than the preexisting collagen in diabetic tissue, the selective depletion of newly synthesized collagen may leave tissues composed predominantly of preexisting, more highly cross-linked collagen. The net result then would be an increase in the degree of cross-linking and a decrease in the quantity of interstitial collagen in diabetic tissues.

The specific effect of glucose on fibril formation may also explain the tissue-specific changes of collagen in diabetics. A net loss of interstitial collagen mass occurs in intact skin (2), wounds (1), and bone (15), whereas a net accumulation of basement membrane collagen mass occurs in the intestine (2) and glomerulus (16). Interstitial collagen forms fibrils, whereas basement membrane collagen does not (17). The accumulation of basement membrane collagen in diabetic tissue may be due to enhanced synthesis (17), decreased degradation (18), and some additional mechanisms (19). Thus, glucose specifically stimulates the catabolism of interstitial collagen—which requires cross-linking for persistence—and does not affect the catabolism of basement membrane collagen.

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References and Notes

1. W. H. Goodson III and T. K. Hunt, *J. Surg. Res.* **22**, 221 (1977).
2. M. Schneir, J. Bowersox, N. Ramamurthy, J. Yavelow, J. Murray, E. Edlin-Folz, L. Golub, *Biochim. Biophys. Acta* **583**, 95 (1979).
3. M. Schneir, N. Ramamurthy, L. Golub, *Diabetes* **31**, 426 (1982).
4. C. A. Vater, E. D. Harris, R. C. Siegel, *Biochem. J.* **181**, 639 (1979).
5. R. C. Siegel, *Proc. Natl. Acad. Sci. U.S.A.* **71**, 4826 (1974).
6. T. Hayashi and Y. Nagai, *J. Biochem. (Tokyo)* **72**, 749 (1972).
7. S. R. Pinnell and G. R. Martin, *Proc. Natl. Acad. Sci. U.S.A.* **61**, 708 (1968); W. Traub and K. A. Piez, *Adv. Protein Chem.* **25**, 243 (1971); M. L. Tanzer, *Science* **180**, 561 (1973).
8. R. C. Siegel and J. C. C. Fu, *J. Biol. Chem.* **251**, 5779 (1976).
9. S. L. Schneider and R. R. Kohn, *J. Clin. Invest.* **66**, 1179 (1980); A. le Pape, J.-P. Muh, A. J. Bailey, *Biochem. J.* **197**, 405 (1981).
10. M. P. Cohen, E. Urdanivia, M. Surma, V. Wu, *Biochem. Biophys. Res. Commun.* **95**, 765 (1980); A. le Pape, J.-D. Guitton, J.-P. Muh, *ibid.* **100**, 1214 (1981).
11. P. J. Higgins and H. F. Bunn, *J. Biol. Chem.* **256**, 5204 (1981).
12. R. L. Trelstad and K. Hayashi, *Dev. Biol.* **71**, 228 (1979).
13. M. J. Capaldi and J. A. Chapman, *Biopolymers* **23**, 313 (1984).
14. C. R. Hamlin, R. R. Kohn, J. H. Luschin, *Diabetes* **24**, 902 (1975); L. M. Golub *et al.*, *Biochem. Biophys. Acta* **534**, 73 (1978); K. Chang *et al.*, *Diabetes* **29**, 778 (1980).
15. M. E. Levin, V. C. Boisseau, L. V. Avioli, *N. Engl. J. Med.* **294**, 241 (1976).
16. M. P. Cohen and A. Khalifa, *Biochem. Biophys. Acta* **500**, 395 (1977); M. Brownlee and R. G. Spiro, *Diabetes* **28**, 121 (1979).
17. P. Bornstein and H. Sage, *Ann. Rev. Biochem.* **49**, 957 (1980).
18. H. Fushimi and S. Tarui, *J. Biochem.* **79**, 265 (1976); A. Y. Chang, *Biochem. Biophys. Acta* **522**, 491 (1978); R. Weil, III, *et al.*, *Arch. Pathol. Lab. Med.* **100**, 37 (1976).
19. R. Vracko, *Diabetes* **23**, 94 (1973).
20. We thank D. Sansoe for technical assistance. Supported by a grant from the Shriner's Hospital for Crippled Children, San Francisco Unit (R.S.).

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16 April 1984; accepted 14 June 1984

Flotation of the Bivalve *Corbicula fluminea* as a Means of Dispersal

Abstract. *Small specimens of the Asiatic bivalve Corbicula c.f. fluminea (Müller) secrete long mucous threads through their exhalant siphons that act as draglines to buoy the animal into a water column. These mucous strands, secreted in response to water current stimuli, are produced by dense accumulations of ctenidial mucocytes and may help in the downstream or interstream dispersal of this rapidly spreading exotic clam.*

The spread of the freshwater Asiatic clam *Corbicula c.f. fluminea* (Müller, 1774) across North America since its accidental introduction about 50 years ago (1) has led to controversy over the mode of transport that could account for its invasiveness. Most often cited are theories of human transport (2–4), incidental transport of small byssate juveniles attached to bird feet or feathers or carried within fish or bird gastrointestinal tracts (3, 5), and direct transport of larvae or juveniles swept along stream bottoms with water currents (2, 3, 6). Although each of these transportation modes is feasible, there is little evidence to support any one of them as a primary means of dispersal. For instance, the viability of *Corbicula* in bird gastrointestinal tracts during transport is questionable, and high clam mortality has been suggested to occur (5, 7). Mackie (8), discussing possible methods of dispersion for other sphaeriid bivalves, concluded that their transport within bird intestinal tracts is unlikely (again because of mortality) but that external transport on bird feet or wings or on insect legs are still viable options. While this might be possible, although with probably low frequency, it is still, as with all the other proposed transport modes, a passive activity. In each case

the transport is accidental, and the bivalves play no active role in dispersion. We now report an unusual active participation in transport by small adult *Corbicula* that may account for much of their downstream and perhaps interstream invasiveness.

Small adult *Corbicula* (shell length, 7 to 14 mm) collected in March 1984 from Tallahala Creek near Runnelstown, Mississippi, were found to be capable of floating after being exposed to gentle water currents produced by an aquarium filtration system (current speeds, 10 to 20 cm/sec). The behavior of the clams was consistent (Fig. 1). After initial exposure to the water flow, the clams would right themselves from the bare aquarium floor with their active and muscular foot. The clams would come to lie with their valves perpendicular to the substratum and with siphons directed upward. In contrast to its normal pumping activities (as seen during feeding or respiration), the exhalant siphon of each clam was abnormally distended with a wide luminal space. After a period of 2 to 8 minutes, during which the clams continued to pump actively, they would gently lift off the substratum, often with their foot extended, and drift into the water column of the aquarium with the current flow. The upright posture of the

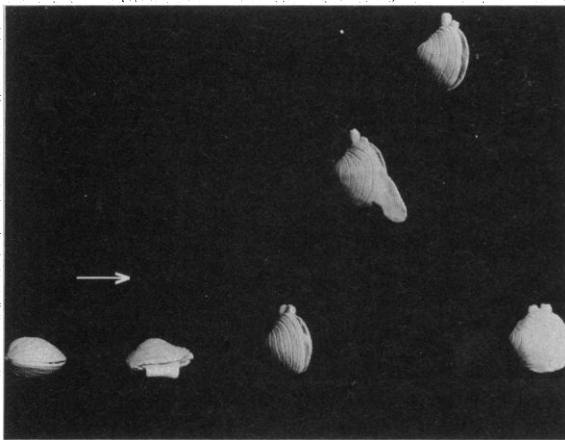


Fig. 1. Sequential representation of the lift-off and floating behavior of *Corbicula*. From left to right the sequence shows initial position on substratum, protrusion of foot, righting to perpendicular position with siphons protruded, initial lift-off with foot protruded and exaggerated exhalant siphon, floating with foot retracted but continued siphonal activity, and initial resettlement on substratum.

bivalve, usually elaborated by extension of the foot, allowed water to flow beneath as well as around it. This increased the lifting power of the water current.

Before they lifted off, the clams produced long, relatively viscous mucous threads that extended upward into the water flow from within the exhalant siphon (Fig. 2). This produced sufficient drag to lift the clams above the substratum. This kite-like effect lifts the small clams into the water column in much the same way as the silk threads of some spiderlings act in aerial dispersal (9). While floating, the clams maintained an abnormally expanded exhalant siphon, probably a reflection of the production of the mucous thread. Within the water column the clams were relatively nonresponsive to tactile stimuli that would ordinarily cause adduction and withdrawal of siphon and foot. This insensitivity might be important in preventing early adduction while floating. Adduction usually broke the connection between the clam and mucous thread. Upon adduction and corresponding loss of mucus, the clams sank. The clams also gradually sank without adduction or loss of the mucous thread when out of the influence of a water current of adequate velocity. Thus, in aquaria when the water flow was terminated the clams sank but at a rate two to four times slower than an adducted clam without mucous threads (9-mm clams adducted without mucous sank 22 mm in less than 3 seconds; clams of the same size adducted with mucous threads sank 22 mm in 6 to 12 seconds).

The mucus produced was transparent and difficult to see unless it had attached water column debris. The clams were able to produce large amounts of this viscous substance. Using Zenker's fluid to fix specimens that were floating, we were able to identify the ctenidium as the exact source of mucous threads. After

fixation, specimens were embedded in paraffin wax, cut into 7- μ m sections, and stained with toluidine blue. Large mucocytes, which react beta-metachromatically, were found densely packed along the inner demibranchs of the ctenidia (Fig. 3). Apparently the water current stimulus prompted the expansion of the exhalant siphon and corresponding active pumping of water across the gills. The inner demibranch mucocytes secret-



Fig. 2. Carbon black-stained mucous thread of recently floating *Corbicula* still attached to clam that has adducted.



Fig. 3. Histological longitudinal section through posterior ctenidial inner demibranch showing dense banks of large mucocytes. Sections through typical gill filaments are shown in the upper left. Zenker's fixative, toluidine-blue stain, and 7- μ m section. Horizontal field width, 610 μ m.

ed large amounts of mucus that was transferred, along with the pumped water, out the exhalant siphon. As long as the valves remained abducted, the connection between gills and mucous thread remained intact. The delay in initial lift-off (2 to 8 minutes) reflected the time required for the clams to produce sufficient mucus for adequate increase in frictional drag. The buoyancy of the clams may be a reflection of the low density of this hydrophilic substance. The widely abducted valves, maintained during floating, and the extended foot may also serve to increase the surface area exposed to water currents and thus to increase drag.

Flotation of small *Corbicula* was confirmed in a field test in the Black River near Brooklyn, Mississippi, in early April 1984. Several small specimens (7 to 14 mm long) were collected along a gravel bank and placed in a shallow enamel pan along the river edge. Currents crossing and entering this pan were between 35 and 70 cm/sec. Within 10 minutes, several of the clams produced long mucous threads which extended from their exhalant siphons; these clams then floated out of the pan. The clams were tracked and seen to be transported only a short distance (<2 m) before they were entrapped along the river bottom by blocking gravel. While moving along the bottom they bounced on and above the gravel substratum until being wedged within a crevice. We are uncertain whether the clams repeated this type of movement, traveling downstream in a punctuated fashion. On smooth sand substrata the clams would be carried farther.

Many species of gastropod molluscs are known to raft or float on mucous bubbles [for example, *Janthina* (10), *Helcion* (11), and *Hydrobia* (12)]. Stressed and moribund *Corbicula* are believed to crawl to the substratum surface and, because of the production of gases during decomposition of their soft parts, become buoyant (13). These clams may retain the gases between adducted valves sealed with mucus (13). Ours appears to be the first report of a healthy freshwater bivalve using mucus as a water-column dragline for flotation. This is important for *Corbicula* in view of its dispersal and invasive capacities.

The dispersal of *Corbicula* larvae is well known, and pediveligers are frequently taken in plankton tows (1). Larvae are produced in large numbers [for example, 400 larvae per clam per day in Lake Arlington, Texas (14)], but these larvae and subsequent juveniles are subject to high mortalities (1). The hermaph-

roditic *Corbicula* attains sexual maturity when it reaches 7 to 10 mm in length (3). Histological sections of clams in this study also revealed mature ova in clams as small as 6 mm. That the clams may reach sexual maturity at this size range, in conjunction with their ability to disperse by flotation, indicates that rapid population blooms could occur in areas previously devoid of *Corbicula*. Also, because they reach maturity in 4 to 6 months (1) and because of their brooding capabilities, gravid or potentially brooding adults can quickly populate a new area rather than there being a delay in population growth resulting from larval settlement.

There have been sporadic reports of juvenile *Corbicula* composing important parts of the drift fauna of various streams. Numerous small *Corbicula* (3 percent of the total drift fauna) were recovered during a study of the lower Mississippi River (15). These clams were recovered in particularly high concentrations in June and August, times that may reflect reproductive peaks for this clam. Small adult or juvenile clams may settle out from a flotation mode in a relatively (or at least temporarily) static area, where they would fall out of the drift. Thus rapidly growing juveniles and mature but small adults could populate a relatively calm area. With the high degree of fluctuation seen in southern North American streams, the clams may be carried downstream from this static area in spurts and bounds.

Reports of population dynamics from a single area must be regarded with care, since the populations reported may not represent a single grouping but may instead be the result of multipopulation invasions over relatively short periods of time. This type of transport may be reflected in the variety of size classes seen in a given lotic population. In some Mississippi streams, *Corbicula* populations usually break down into three discernible size classes. Typically, however, there are anomalous intermediate sizes, which have frequently been allocated to individual growth variations. We cannot any longer assume that these intermediates are part of a single population. Instead, they may reflect a growth stage from a different upstream population that recently drifted in. Also, small adults may drift together and settle in an already populated environment, adding a secondary and artificial growth stage for that given locality.

Britton and Morton (3) maintain that "the genus *Corbicula* contains species primarily adapted to flowing water environments . . . periodically subjected to

seasonal flooding." Flooding may allow floating clams to transfer stream systems. In view of this potential mode of transport, we must add active dispersal behaviors to the morphological and physiological invasive advantages that this "weed" species has evolved.

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References and Notes

1. J. C. Britton, in *Proceedings of the Symposium of Recent Benthological Investigations in Texas and Adjacent States* (Texas Academy of Sciences, San Angelo, 1982), pp. 21-31.
2. R. M. Sinclair and B. G. Isom, *Further Studies on the Introduced Asiatic Clam (Corbicula) in Tennessee* (Tennessee Department of Public Health, Nashville, 1963).
3. J. C. Britton and B. Morton, in *Proceedings,*

First International Corbicula Symposium (Texas Christian University Research Foundation, Fort Worth, 1979), pp. 249-288.

4. Human transport includes spread by fishermen using the clam as bait, as a food source by early Chinese immigrants, and by pet shop dealers (2, 3).
5. R. F. McMahon, *Nautilus* **96**, 134 (1982).
6. L. L. Eng, in *Proceedings, First International Corbicula Symposium* (Texas Christian University Research Foundation, Fort Worth, 1979), pp. 39-68.
7. G. M. Thompson and R. E. Sparks, *Am. Midl. Nat.* **98**, 219 (1977).
8. G. L. Mackie, *Bull. Am. Malacol. Union Inc.* **1979**, 17 (1979).
9. N. I. Platnick, *Syst. Zool.* **25**, 101 (1976).
10. J. E. Morton, *Molluscs* (Hutchinson, London, 1979), p. 40.
11. O. Vahl, *Sarsia* **68**, 209 (1983).
12. R. Newell, *Proc. Zool. Soc. London* **138**, 49 (1962).
13. R. F. McMahon, *The Mollusca* (Academic Press, Orlando, Fla. 1983), pp. 505-561.
14. D. W. Aldridge and R. F. McMahon, *J. Molluscan Stud.* **44**, 49 (1978).
15. A. Obi, thesis, Louisiana State University, Baton Rouge (1978).

16 April 1984; 16 May 1984

Event-Related Brain Potentials in Boys at Risk for Alcoholism

Abstract. *Recent neurophysiological findings have demonstrated that abstinent chronic alcoholics manifest deficits in event-related brain potentials. To explore possible biological antecedents of alcoholism the present study examined boys at high risk for alcoholism. Event-related brain potentials were recorded from biological sons of alcoholic fathers and matched control boys. Differences in the P3 component of the potentials were obtained between the high-risk and control subjects.*

Brain dysfunction or brain damage has been observed with the use of neuropsychological and neuroradiological techniques in chronic alcoholics (1). Studies of evoked brain potentials (EP's) have demonstrated a number of functional aberrations in chronic alcoholics (2). Several investigators have studied auditory brain stem potentials in chronic alcoholics and have reported electrophysiological evidence of increased neural transmission time (3). Moreover, event-related potential (ERP) studies in chronic alcoholics have demonstrated deficits in the P3 component with the use of information processing paradigms (4). The presence of these deficits in the central nervous system has been presumed to reflect the consequence of chronic alcohol abuse (toxic effects of alcohol on the brain, nutritional deficits, or an interaction of alcohol and nutrition-related factors). Although the neurophysiological deficits observed in chronic alcoholics are presumed to be alcohol-related effects, it is possible that some of these deficits may be present in subjects at high risk for alcoholism and therefore antecede the onset of alcohol abuse.

Genetic factors may be involved in the development of alcoholism. Sons of alcoholic fathers represent a special group at high risk for developing alcoholism (5)

even when they are separated from their biological parents soon after birth. Studies of male adoptees indicate that the biological rather than the adoptive parent is predictive of later drinking problems (6). Further evidence for a genetic predisposition comes from twin studies indicating that the concordance rate for alcohol abuse among identical twins is almost double the rate for fraternal twins (7); patterns of alcohol consumption are also highly concordant among identical twins (8). This evidence suggests that a genetic factor may be involved in the presence of neural pathophysiology associated with alcohol abuse.

The identification of a suitable biological marker that is genetically transmitted is important in identifying individuals before the onset of the disease. Moreover, biological markers can provide fundamental data on the etiology of alcoholism. The search for such a marker must focus on a biological variable known to be genetically determined and prevalent in abstinent chronic alcoholics. There is good evidence to indicate that EP waveforms are genetically determined. Monozygotic twins manifest EP waveforms that are as concordant with each other as those obtained from the same individual tested twice (9).

We now report the presence of P3