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15 September 1964

Transitional Ordovician Bivalve with Both Monoplacophoran and Lucinacean Affinities

Abstract. *The rare and problematic Ordovician molluscan genus* Babinka *is a probable evolutionary link between the bivalve superfamily Lucinacea and some monoplacophora-like ancestral mollusc.* Babinka *provides the first direct evidence of a transition between the class Bivalvia and more primitive molluscan ancestors.*

The recognition of the significance of multiple muscle scars in fossil monoplacophorans and the subsequent dramatic discovery of the recent monoplacophoran *Neopilina* have aroused interest in all early fossil molluscs with multiple muscle scars. One such fossil which has attracted wide attention is the rare Ordovician bivalve genus *Babinka,* which was first described by Barrande in 1881 (*1*). *Babinka* is known only from rocks of lowest Middle Ordovician (Llanvirn) age in the vicinity of Prague, Czechoslovakia and is among the first bivalves to appear in the fossil record. Barrande's original illustrations show a peculiar series of radial muscle scars in the dorsal region, and this muscle pattern led Vokes (*2*) to suggest that *Babinka* might be an evolutionary transition between the Bivalvia and some metameric ancestral mollusc. Vokes's proposal has been widely accepted by students of molluscan phylogeny (*3*).

A further study of all available specimens of *Babinka* has shown that the pattern of the muscle scars and the general morphology are more complex than had been suspected previously (*4*). *Babinka* has normal bivalve adductor and pallial muscles, but is unusual in having eight pairs of pedal muscles, instead of the normal bivalve pattern of two to five pairs. In addition, *Babinka* has a unique linear series of very small muscle scars below the third through seventh pairs of pedal muscle scars. These smaller scars probably represent the sites of gill muscle attachment. The pattern of pedal and gill muscle scars in *Babinka* is almost identical to the pattern in recent *Neopilina* and in some early fossil Monoplacophora (Fig. 1). These close similarities support Vokes's suggestion that the muscle pattern in *Babinka* is an inheritance from a monoplacophora-like ancestral mollusc. In all features except the pedal and gill muscle scars, *Babinka* is a typical isomyarian bivalve.

Babinka is both morphologically and chronologically an ideal ancestor for the large bivalve superfamily Lucinacea, which appears abruptly in the fossil record in Middle Silurian deposits. Among the morphological features of *Babinka* that are indicative of lucinoid affinities are the characteristic shape, elongate anterior adductor scar, nonsinuate pallial line, and typical lucinoid hinge, dentition, and ligament.

Functional morphological studies of recent Lucinacea by Allen (*5*) have shown that all members of the group share unusual adaptations for life as deeply buried suspension feeders. Unlike most deeply buried bivalves, lucinoids do not have posterior siphons for channeling nutrient-laden water into the mantle cavity. Instead, all Lucinacea have the peculiar ability to use the cylindrical foot for construction of a mucous-lined, anterior inhalant tube to the sediment surface. This habit is reflected in lucinoid shell morphology, for the characteristic anteriorly expanded shape and elongate anterior adductor muscle provide ciliary sorting surfaces for incoming food particles. Morphologic comparisons of *Babinka* and recent lucinoids suggest that *Babinka* was also an infaunal suspension feeder which used the foot to maintain an anterior inhalant opening to the surface of the sediment. The lucinoid habit of feeding through an anterior inhalant tube is apparently a very early bivalve specialization for an infaunal, suspension-feeding mode of life, for lucinoids appear in the fossil record long before the first typical siphonate bivalves. Such forms first occur in the Carboniferous, and do not become really abundant until Mesozoic time.

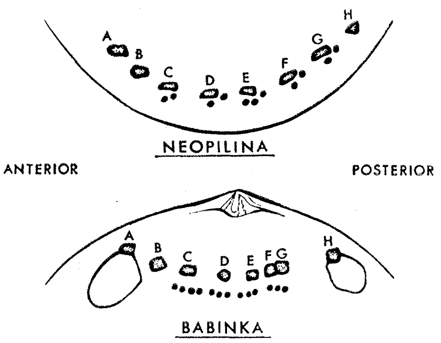

Fig. 1. Comparison of the patterns of the pedal and gill muscle scars in the Ordovician bivalve *Babinka* and the recent monoplacophoran *Neopilina.* The muscle scars labeled *A* through *H* are the attachment sites of the eight pairs of pedal muscles. The small solid dots below the pedal scars show diagrammatically the positions of the attachment scars of the gill muscles. In both *Babinka* and *Neopilina* the gill scars are associated with pedal scars *C* through *G*.

Babinka provides the first direct evidence of a transitional evolutionary link between the Bivalvia and some more primitive molluscan ancestor (Fig. 2). The phylogenetic position of *Babinka* indicates that the Lucinacea arose directly from monoplacophora-like ancestral molluscs. There is no strong zoologic or paleontologic evidence to suggest that the Lucinacea have given rise to other major groups of the Bivalvia, with the probable exception of the Leptonacea. This raises the possibility that the Bivalvia had a "polyphyletic" origin from less specialized ancestral forms. The early origin and separate evolutionary development of lucinacean bivalves suggests that the group should be assigned to a separate

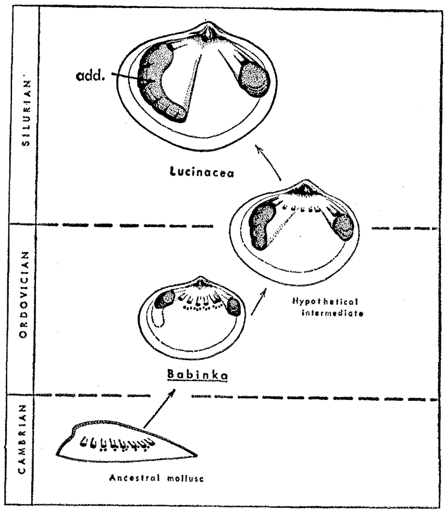

Fig. 2. Evolutionary relations of *Babinka.* The genus represents a transition between a monoplacophora-like ancestral mollusc and the large Silurian to recent bivalve superfamily Lucinacea. In the Lucinacea the pedal and gill muscles have been reduced while the anterior adductor (*add.*) muscle has expanded in size.

higher taxon of the Bivalvia. The Lucinacea are probably unrelated to most other "heterodont" bivalves with which they are commonly associated because of vaguely similar patterns of dentition.

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Electrolytic Growth of Silver Dendrites

Abstract. *The growth rates of silver dendrites formed in narrow capillaries by electrodeposition under various physical conditions have been determined. Dissolution of such dendrites as well as their growth can be reliably controlled. This principle may be used in the design of components for adaptive electronic systems.*

The formation of dendrites occurs in many modes of crystal growth, but the phenomenon appears to have been studied relatively little, owing to the complexity of the situation and to the lack of an experimental approach which enabled quantitative investigations to be made. Theories of the formation of dendrites from dilute solutions have been advanced by Papapetrou (*1*) and by Seeger (*2*), and Saratovkin (*3*) has considered dendritic growth from a melt. Silver dendrites formed by electrolytic processes have been described by Fischer, Wranglen, Yang, *et al.*, and by Faust and John (*4*).

In an electrolytic cell in which a metal is being deposited, each ion arriving at the cathode can either be added to one of the crystals already present or it can form the nucleus of a new crystal. The physical conditions in the cell determine which of these situations is more likely to occur. If ions are added to existing crystals, a few large crystals will be formed. If ions form nuclei of new crystals, a conglomeration of small crystals will result. Sometimes the large crystals grow outward from the cathode and form dendritic structures.

A number of factors influence the type of deposit, the most important being the presence or absence of inhibitors, the current density, and electrolyte concentration. Inhibitors are substances or conditions which reduce the tendency for crystals to grow and which generally discourage the formation of dendrites. The form of some deposits, however, has been attributed to the presence of inhibitors through selective action on different crystal faces (*5*).

The effects of current density and electrolyte concentration are in many ways complementary. In a cell in which inhibition is slight the tendency is for crystals to grow into regions where the metal ion concentration is greatest. If the electrolyte concentration is small, as the current is raised the ions in the neighborhood of the cathode will rapidly be removed, and the crystals will grow outward to the richer regions. If the electrolyte concentration is greater, it is possible to raise the current to a greater level before the cathodic regions become depleted in metal ions and dendritic crystals are formed.

Most investigators have postulated a number of crystal types and then determined the type of crystal which grows under given conditions (*6*). This approach is quite satisfactory for small crystals, but with increase in crystal size (greater than 1 mm in length) the crystal "type" becomes a continuous, rather than a discrete, quantity so that the "types" chosen are to some extent arbitrary.

As the crystals grow in an unrestricted electrolyte they alter the electrical field and ionic concentration distribution in their own neighborhood, and thus change the conditions which influence their growth. The dynamics of crystal formation cannot be studied.

If the cathode of a cell connects with the main compartment (containing the anode) only by way of a narrow channel such as a capillary tube, any crystal growth which occurs must take place along this channel (Fig. 1). If the cur-

Fig. 1. Dendritic growth in a capillary tube.

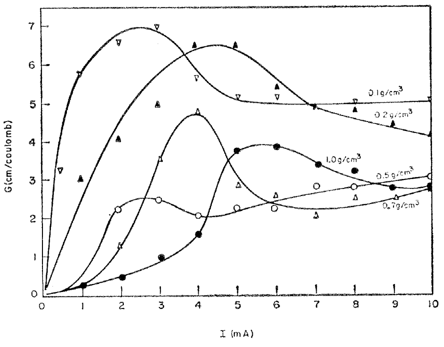

Fig. 2. Axial growth rate per unit current (*G*) versus current (*I*) for silver dendrites grown in electrolytes containing various concentrations of silver nitrate. The capillary tube had a diameter of 1 mm.

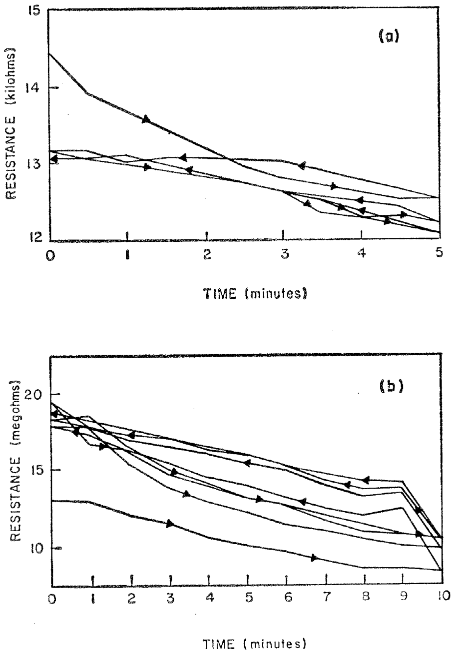

Fig. 3. Reversible growth and dissolution of silver dendrites. *a*, Concentration 1.0 g/cm^3, 4.0 ma; *b*, concentration 0.1 g/cm^3, 0.1 ma. The incomplete dissolution of the dendrite shows itself in *a*. After the initial growth of the dendrite, the range of resistance change is reduced by small pieces of silver remaining in the tube. These sometimes become incorporated in new dendrites. The "loops" in *b* are thought to be due to polarization.