Functions for fish mucus

Kerry L. Shephard

The Clore Laboratory for Life Sciences, The University of Buckingham, Buckingham, Bucks. MK18 1EG, United Kingdom

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Introduction

The range of roles which fish mucus is said to play is very large (Jakowska 1963; Negus, 1963; Ingram, 1980; Ellis 1981). Proposed roles in respiration, ionic and osmotic regulation, reproduction, excretion, disease resistance, communication, feeding, nest building and protection potentially make mucus a highly multifunctional material. While it is likely that mucus is involved in many of these, interpreting an ‘action or involvement’ as a ‘function’ is a fundamental step which, in particular, defines a purpose for mucus. In this sense, functional interpretation is, inevitably, teleological. In biology, the process of natural selection provides some justification for a teleological approach as natural selection accounts for the appearance and development of purposeful design. Mucus may have a specific action which enables the fish to survive where, otherwise, it might not. Its presence is, therefore, adaptive and is likely to be selected for. To interpret an action as a function, therefore, it is important to stress the adaptive consequences of the action and, for this purpose, to investigate the mechanisms involved as far as possible. Indeed the most appropriate question is probably ‘how does it work?’ rather than ‘what does it do?’ An answer to this former question requires information about the processes involved. An answer to the latter question might not, but will inevitably be a more subjective interpretation of what is happening.
Other constraints have imposed themselves on this review. While an analysis of mechanism provides the basis for functional interpretation, some information on mechanism is a prerequisite for analysis. Some proposed roles for mucus have very little supporting information on the relevant actions of mucus. The review also sets out to concentrate on the 'usual' rather than on the 'unusual'. Thus, although sticklebacks (Wootton, 1984) and, perhaps, Siamese fighting fish (Betta splendens, Belontidae) secrete mucus to glue nest materials together; and although some parrotfishes probably avoid predation at night by secreting a mucous cocoon to mask olfactory and tactile stimuli passing to foraging eels (Winn and Bardach, 1959); and, although anemone fish probably do use specific components of mucus to inhibit discharge of nematocysts (Nelson, 1984), these are all fairly specific roles for fish mucus. Most fish do not hide in anemones, secrete cocoons or build nests, and still produce mucus. While it is important to benefit from an understanding of the actions of mucus in these specific cases it is, perhaps, more important to concentrate on actions of greater general relevance to fish.

Information has been drawn from the fish biology literature and from other sources where a comparative approach is helpful. Furthermore, mucus is considered predominantly on the general skin surface and gills, but also from the gut lining; indeed on all epidermal surfaces that mark the interface between the fish and external world.

Basic biology of mucus

Production and composition

For most practical purposes 'mucus' is synonymous with slime and slime is the material that makes fish slippery to touch when we try to catch them. Its 'slipperiness' is the result of its high water content and the presence of high-molecular-weight, gel-forming, macromolecules. In most vertebrates, including fish, the predominant gel-forming macromolecules are glycoproteins (mucins) (Asakawa, 1970; Fletcher et al., 1976). In other organisms a wide range of macromolecules contribute to slimes: polysaccharides in algae and higher plants (Percival, 1979) and mucopolysaccharides in invertebrates (Hunt, 1970). What these macromolecules have in common is their ability to swell in water and to interact with one another, either by entanglement or via chemical bonding, to give a three-dimensional structure to water. Where inter-macromolecular interactions are too few to produce gels, or are broken, high-viscosity fluids are produced (Silberberg, 1989).

The glycoproteins in fish mucus appear to be similar in make up to mammalian mucins (Harris and Hunt, 1973; Alexander and Ingram, 1992). They may be neutral but are often made acidic by the presence of sialic acid (a carboxylated monosaccharide) or sulphated monosaccharides (Fletcher et al., 1976; Pickering and Macey, 1977). Fish mucus has often been shown to contain other materials. As with mammalian studies it is debatable whether these materials naturally exist in fish mucus or whether they are released as a result of disease, stress or injury. The extent to which they influence the physical and chemical properties of slime and their ability to contribute to the functioning of mucus is also, often, debated. These points are discussed later. In particular glycosaminoglycans have been found in fish mucus (van de Winkel et al., 1986). This material also appears in mammalian mucus (Reid and Bhaskar, 1989). Other known ingredients include: lysozyme (Bullock et al., 1978), immunoglobulins (Fletcher and Grant, 1969), complement (Harrell et al., 1976), carbonic anhydrase (Wright et al.,