The Desmosome: 
Fine Structural Studies with Freeze-Fracture Replication
and Tannic Acid Staining of Sectioned Epidermis *

Douglas E. Kelly and Frances L. Shienvold
Department of Anatomy, University of Southern California School of Medicine, Los Angeles, California, and
Department of Biological Structure, University of Miami School of Medicine, Miami, Florida, USA

Summary. Desmosomes of larval and post-metamorphic newt epidermis have been studied by freeze-fracture replication both with and without prior glutaraldehyde fixation. Characteristic particles of a diameter (70–130 Å) similar to that of typical membrane associated particles are found clustered on the exposed internal faces of adherent desmosomal membranes. They remain attached to the B-face in unfixed material, but occupy the desmosomal A-face after fixation. Membrane associated particles of nondesmosomal surfaces are found predominantly on the A-face in both fixed and unfixed epidermis. Suitably oriented replicas of unfixed desmosomes reveal profiles of apparent fine filaments extending from the region of tonofilament loops through the desmosomal plaque to traverse the cytoplasmic leaflet of the plasmalemma. They can be traced onto the B-face. Their position correlates to fine linear profiles noted in tannic acid/glutaraldehyde-fixed and sectioned desmosomes. The possibility that these represent a mechanism for anchorage of tonofilaments to the plaque and to the membrane is discussed. These and other fine structural features are compared and contrasted to the properties of hemidesmosomes described in the preceding report.

Key words: Skin – Epithelia – Attachment – Desmosomes – Freeze-fracture.

Introduction

Electron microscopy of sectioned epithelia has amply recorded the fundamental fine structural components of a common macular site of cell-to-cell attachment – the desmosome or macula adhaerens (Fawcett, 1961; Odland, 1958; Farquhar...
and Palade, 1963; Kelly, 1966; Campbell and Campbell, 1971; Krawczyk and Wilgram, 1973; Staehelin, 1974). This attachment site is generally conceded to be a rather permanent and firm bond between adjacent cells. It is also the focus for converging intracellular tonofilaments which appear to be welded to the cell membrane at the desmosome, thus providing anchorage for a supportive cytoskeletal framework.

While a broad spectrum of structural variations exists, desmosomes are characterized by several common subcomponents. There is an abundance of intercellular adhesive material, probably of mucopolysaccharide nature (Benedetti and Emmelot, 1967; Overton, 1962, 1968, 1974; Borysenko and Revel, 1973) with a characteristic density aligned midway between the two involved cell membranes. Occasionally this intercellular material displays a periodic organization (McAlear, 1962), especially in intercalated disc desmosomes impregnated with lanthanum hydroxide (Rayns et al., 1969). Within the adjacent cells a dense, probably proteinaceous plaque (Douglas et al., 1970), approximately oval in shape, lies near the cell membrane and seems attached to it by some mucopolysaccharide vehicle (Kelly, 1966). Cytoplasmic tonofilaments converge toward the plaque, but most or all of them pass by the plaque at a distance of several hundred Å. In some epithelia, this tonofilamentous excursion occurs in an arching or looping configuration. In other cases, the tonofilaments course past the plaque in a direction essentially parallel to it. In either case, the morphology suggests that some mode of attachment must exist between the plaque and the nearby tonofilaments, but no exact assessment of this attachment has yet been provided. Likewise, the nature of the plaque and its mode of attachment to the cell membrane is not fully understood.

A number of studies (Overton, 1962, 1968, 1974; Campbell and Campbell, 1971; Krawczyk and Wilgram, 1973) have concentrated on the normal development of desmosomes or their behavior in dissociated or drug treated cells. While providing additional information about the morphology and sequence of appearance or removal of desmosomal components, these studies have not clarified the mechanism that insures the integrity of attachment between filament, plaque, membrane, and extracellular cementing materials.

Prior studies employing freeze-fracture methods (Reed et al., 1968; Reed and Rothwell, 1970; Breathnach et al., 1972; Breathnach et al., 1973; McNutt et al., 1971; McNutt and Weinstein, 1973; Orwin et al., 1973; Staehelin, 1974) have shown that desmosomes can be identified in replicas of epithelia from a wide variety of sources. Moreover these studies have indicated that fine particles are characteristically clustered within the cell membranes of fractured desmosomes. The reported polarity of desmosomal particle localization varies among the different investigations, i.e., in some tissues more desmosomal particles appear on the A-face, whereas in others the B-face bears more particles. It is possible that these reported differences in polarity are attributed to preparative technique, specifically with regard to whether or not the tissue was fixed prior to fracture, since nearly all the authors cited above utilized either unfixed or glutaraldehyde-fixed material, but not both (see Table 1). In his recent review, Staehelin (1974) reports on desmosomes of both fixed and unfixed rodent intestinal epithelium and concludes that the polarity of particle localization is indeed reversed by fixation.