5. Physiology of Host Response to Infection

5.1 Permeability Alterations in Diseased Plants

H.E. Wheeler

1. Introduction

To remain alive in diverse environments, cells must regulate the kinds and quantities of substances they take in and release. Maintenance of this vital property, cell permeability, requires expenditure of metabolic energy. Any drastic disruption of cell permeability, unless quickly repaired, leads to death.

Altered cell permeability was shown to be a characteristic early host response to a variety of plant pathogens more than three decades ago by Thatcher (1939, 1942, 1943). Following Thatcher’s investigations, this area of disease physiology remained dormant until interest was revived by the discovery that toxic metabolic products of certain plant pathogens cause rapid and drastic changes in permeability of plant cells (Gäumann, 1958; Wheeler and Black, 1963).

To date, a single general review of the subject of this Chapter has appeared (Wheeler and Hanchey, 1968). In addition, a number of reviews have dealt in whole or in part with effects of phytotoxins on permeability (Gäumann, 1958; Wheeler and Luke, 1963; Owens, 1969; Luke and Gracen, 1972; Scheffer and Yoder, 1972; Page, 1972). These reviews cover all but the most recent literature from a variety of viewpoints. In view of the availability of this material, comprehensive coverage will not be attempted. Instead, attention will be focused on current theories of cell permeability and the relation of alterations in permeability to other pathological events that occur during pathogenesis.

2. Cell Permeability Theories

2.1 Membrane Theory

Most scientists in the Western Hemisphere regard the living cell as a protoplasmic mass which contains a variety of subcellular organelles and is bounded by a selectively permeable membrane, the cell membrane or plasmalemma. In this model, the plasmalemma functions not only to retain internal solutes which are mostly in the free state but also, through passive and active mechanisms, to control uptake of external materials. In essence, membrane theory holds that cell permeability, as it relates to the movement of materials into and out of the protoplast, is primarily, if not solely, controlled by the plasmalemma. Internal membranes, and especially the tonoplasts which surround vacuoles in vacuolated cells, are thought to function in a similar manner to provide internal compartmentalization.
The literature on membrane chemistry, function, and structure is, quantitatively and qualitatively, indigestible. Merely to describe the membrane models which have been proposed would require an entire chapter. The summaries which follow provide only a brief introduction to the vast and conflicting data available.

2.1.1 Membrane Chemistry and Function

Chemical analyses of membranes indicate that proteins and lipids are the major components making up 90–98% of the total dry mass. Carbohydrates attached to proteins or lipids, and inorganic ions, account for the remainder. Ratios of protein to lipid for a variety of membrane systems, mostly from animal cells and microorganisms, have been tabulated by GUIDOTTI (1972). Myelin membranes have the lowest (0.23) and mitochondrial inner membranes the highest (3.2) protein-to-lipid ratios. Plasmalemma ratios are intermediate, averaging about 1.0. As GUIDOTTI points out, these ratios appear to reflect differences in function. Myelin membranes, rich in lipid, function primarily as permeation barriers or insulators, whereas inner mitochondrial membranes, rich in protein, have in addition a large number of enzymatic functions which include those involved in oxidative phosphorylation. The fact that the plasmalemma has about equal amounts of protein and lipid is consistent with the concept that this membrane acts not only as a permeation barrier but also as the site of enzymes which function in transport processes.

Membrane proteins can be separated into two general types: one termed peripheral or extrinsic, the other integral or intrinsic (SINGER, 1971; GREEN and BRUCKER, 1972). Peripheral proteins are weakly bound and can be removed by mild treatments (hypotonic washes or salt solutions). In contrast, integral proteins appear firmly bound, and treatment with detergents, bile acids, or organic solvents is required to dissociate them from membranes. It has been suggested that only the integral proteins are essential for the structural and functional integrity of membranes (SINGER and NICOLSON, 1972; GREEN and BRUCKER, 1972). The concept that a large fraction of the proteins of all membranes is of a special kind essential for structure (structural proteins) has been discarded for lack of supporting evidence (GUIDOTTI, 1972).

Despite great variation in kind and abundance, the vast majority of membrane lipids have one characteristic in common: they are amphipathic (VANDENHEUVEL, 1971; ROTHFIELD, 1971). Phospholipids, which are major components of all membranes examined, are typical amphipathic molecules. They are structurally asymmetric with one polar and one nonpolar end. Such molecules, dispersed in an aqueous medium, form lamellar, globular, or cylindrical micelles. The micellar phase formed is dependent on the type of molecule, temperature, state of hydration, and the ionic concentration of the medium (VANDENHEUVEL, 1971).

Membrane carbohydrates occur as glycoproteins, glycolipids, and glycolipoproteins. The sugar residues of these complexes are thought to be located on the exterior surface of the membrane, and they may contribute to membrane asymmetry and the fuzzy appearance of the outer surface of the plasmalemma (GINSBURG and KOBATA, 1971). Glycosphingolipids are constituents of animal membranes; hence, the related inositol containing phosphosphingolipids found in higher plants and fungi may also be associated with membranes (WIEGANDT, 1971).