1. INTRODUCTION

Plant-derived foods that are rich in flavonoids are regularly touted in the popular press for their benefits in ameliorating age-related diseases. A majority of these reports focus on the antioxidant characteristics of flavonoid-rich diets and their enhancement of cardiovascular health. However, a growing number of reports in the pharmacology literature characterize flavonoid interactions with cellular components implicated in neurological pathologies and cancer. As the effective flavonoid concentrations employed in pharmacological studies utilizing cell cultures are often orders of magnitude higher than the serum concentrations seen in humans, some discrimination is required when interpreting these reports. Further, as flavonoids often mimic endogenous mammalian receptor ligands (Ciolino et al., 1999; Hunter et al., 1999; Virgili et al., 2004) or interfere with the uptake of substrates not found in plants, the applicability of such studies to plant models requires caution. However, studies of flavonoid function in animal cells often provide important insights into their functions as signal molecules in plants.

Nearly every class of flavonoid has been shown to have biological activity, with a majority related to antioxidant properties. In plants, flavonoids appear to contribute to a general reduction of reactive oxygen species and therefore impact cellular processes sensitive to REDOX effects. However, flavonoids also have been implicated in more direct interactions with transport and signal transduction pathways. One well-documented example is the role of flavonoids in fertility: while a few flavonoid-deficient plants are able to germinate, grow, and set fertile seed,
most plants require flavonoids for fertility and normal pollen development. Another is flavonoid modulation of auxin transport as well as localized auxin accumulations observed during nodulation. Perhaps the best-studied example of flavonoid signaling is that of flavonoid mediation of interactions between the plants and other organisms in the environment at both competitive (allelopathy/defense) and cooperative (mycorrhizal association) levels.

In the balance of this chapter, we review potential and known molecular targets of flavonoid signaling and plant processes where flavonoids have been implicated in regulatory functions. We then describe flavonoid-dependent internal signaling processes and extraorganismal biotic interactions mediated by flavonoid signaling.

2. MOLECULAR TARGETS OF FLAVONOID ACTION

At the molecular level, potential targets of flavonoid regulation in plants range from transcription factors and kinases to ATP-binding cassette (ABC) transporters and aminopeptidases. Some of these targets are suggested primarily by similarities between plant and mammalian signaling mechanisms. Other endogenous or exogenous targets, such as receptors, ABC transporters, and hydrolases, have been directly demonstrated in planta or in vivo. Most of these interactions have been shown to be developmentally regulated. These potential and known targets are categorized below.

2.1. Transcription

Nuclear localization of flavonoids has been reported in many plant species, suggesting that flavonoids may function in transcriptional regulation of endogenous gene expression. Reports of sulfonated flavonols in nucleus in Flaveria chloraeofolia, (Grandmaison and Ibrahim, 1996) and unidentified phenolic compounds in Brassica napus also were localized in the nucleus but not nucleolus (Kuras et al., 1999; Stefanowksa et al., 2003). Nuclear localization of flavonols also has been shown in Arabidopsis thaliana (Peer et al., 2001; Buer and Muday, 2004; Saslowsky et al., 2005) and flavanols in Tsuga canadensis, Taxus baccata, Metasequoia glyptostroboides, Coffea arabica, Prunus avium, and Camellia sinensis (Feucht et al., 2004a, 2004b). Catechin binding of histone proteins has been demonstrated in plants (Polster et al., 2003; Feucht et al., 2004b), suggesting that catechins might modulate nonspecific gene transcription. Naringenin chalcone and apigenin also may influence flavonoid biosynthesis by regulating transcription of flavonoid biosynthetic enzymes (Pelletier et al., 1999) (see Chapter 4 for more details). Recent evidence that the flavonoid biosynthetic enzymes chalcone synthase (CHS) and chalcone isomerase (CHI) are localized in the nucleus, in addition to the cytoplasm, in A. thaliana suggests that flavonoid regulation of transcription is developmentally regulated at the subcellular level (Saslowsky et al., 2005). This observation also is consistent differential localization of phenolics in subcellular compartments observed throughout seed development and germination (Kuras et al., 1999; Stefanowsksa et al., 2003).