

## Review Article

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# Molecular Genetic Regulation of Stamen Development: Insights from the ABC Model and Anther Ontogeny in *Arabidopsis* and Other Angiosperms

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**Abstract** Stamen development is a critical process governing male fertility in flowering plants and is tightly regulated by genetic and hormonal networks. The ABC model of floral organ identity, extended to include D and E functions, explains stamen specification through the combined activity of B-, C-, and E-class MADS-box genes such as *APETALA3*, *PISTILLATA*, and *AGAMOUS*. In *Arabidopsis thaliana*, anther development proceeds through fourteen stages involving coordinated cell division, differentiation, and tissue organization. Early developmental events are controlled by receptor-like kinases including CIKs, BAM1/2, and RPK2, which regulate archesporial cell fate and parietal layer formation. Additional regulators such as SPL/NZZ, EMS1 – TPD1 signaling, and MAP kinases contribute to microsporogenesis and tapetum function. Hormonal pathways involving jasmonates, gibberellins, and auxins further coordinate pollen maturation and anther dehiscence. Comparative studies in other angiosperms reveal both conserved and species-specific regulatory mechanisms.

**Keywords** Stamen development; ABC model; MADS-box genes; *Arabidopsis thaliana*; Anther development; Microsporogenesis; Tapetum; Hormonal regulation

## 1 Introduction

Flowering plants (angiosperms) possess highly specialized reproductive structures, with the flower representing one of the most complex organs in plant development. A typical hermaphroditic flower is organized into concentric whorls consisting of sepals, petals, stamens, and carpels, each arising from a determinate floral meristem. Among these, the stamen constitutes the male reproductive organ and plays a central role in pollen production and successful fertilization. Structurally, a stamen comprises a filament that supports the anther, where pollen grains are formed within specialized compartments known as microsporangia. Proper development of stamens is therefore essential for plant fertility and reproductive success.

The genetic basis of floral organ identity has been extensively explained by the ABC model, later expanded into the ABCDE model, which describes how combinations of MADS-box transcription factors specify distinct floral organs (Schwarz-Sommer et al., 1990). In this framework, stamens are specified by the combined action of B-, C-, and E-class genes, including *APETALA3* (*AP3*), *PISTILLATA* (*PI*), and *AGAMOUS* (*AG*) (Bowman et al., 1991; Pelaz et al., 2000; Ng and Yanofsky, 2001; Becker and Theissen, 2003). These genes regulate downstream targets that control organ identity as well as the initiation and differentiation of reproductive tissues (Shore and Sharrocks, 1995; Riechmann and Meyerowitz, 1997). Mutations in these regulatory genes often result in homeotic transformations, highlighting their fundamental role in floral patterning (Bowman et al., 1989; 1991; Coen and Meyerowitz, 1991; Pelaz et al., 2000; Pinyopich et al., 2003; Alvarez-Buylla et al., 2010).

The model plant *Arabidopsis thaliana* has provided critical insights into the molecular and cellular mechanisms underlying stamen and anther development (Ma, 2005; Bowman, 2012). Anther ontogeny in *Arabidopsis* is divided into fourteen distinct stages characterized by precise patterns of cell division, differentiation, and tissue organization (Owen and Makaroff, 1995; Sanders et al., 1999). Early developmental events involve the specification of archesporial cells and their differentiation into sporogenous and somatic cell lineages. This process is tightly regulated by receptor-like kinases such as CLAVATA3 INSENSITIVE RECEPTOR KINASEs (CIKs), BARELY