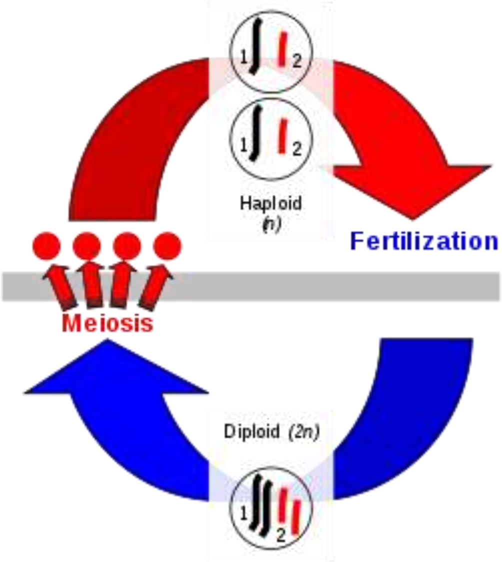
Topic: ABC model of flower development.



In the first stage of sexual reproduction, "meiosis", the number of chromosomes is reduced from a diploid number (2n) to a haploid number (n). During "fertilization", haploid gametes come together to form a diploid zygote, and the original number of chromosomes is restored.

The ABC model of flower development in angiosperm demonstrates the presence of three classes of genes that regulate the development of floral organs. The genes are referred to as class A genes, class B genes and class C gene. These genes and the interaction between them induce the development of floral organs.

In the following essay the basic concept of ABC model will be discussed in brief. The analysis of ABC model is based on the use of molecular genetics and formulated on the observation that mutants induce right floral organs to develop in wrong whorls.

In the flower of angiosperms there are usually four concentric whorls of organs, i.e. sepal, petal, stamen and carpel that are formed in whorl 1, whorl 2, whorl 3 and whorl 4 respectively, the whorl 1 being on the peripheral side.

In the whorl 1 class A genes when expressed induce the development of sepals. The interaction between class A and class B genes induce the development of petals in the whorl 2. Stamens are formed in the whorl 3 as a result of interaction between class B and class C genes.

In the whorl 4 class C gene induces the formation of carpel. So the summary of ABC model is: class A genes together and class C gene alone are responsible for the development of sepals and carpel respectively. The class B genes and class A genes function cooperatively to determine the development of petals. The class B genes and class C gene act together to induce the development of stamens (Fig. 30.12).

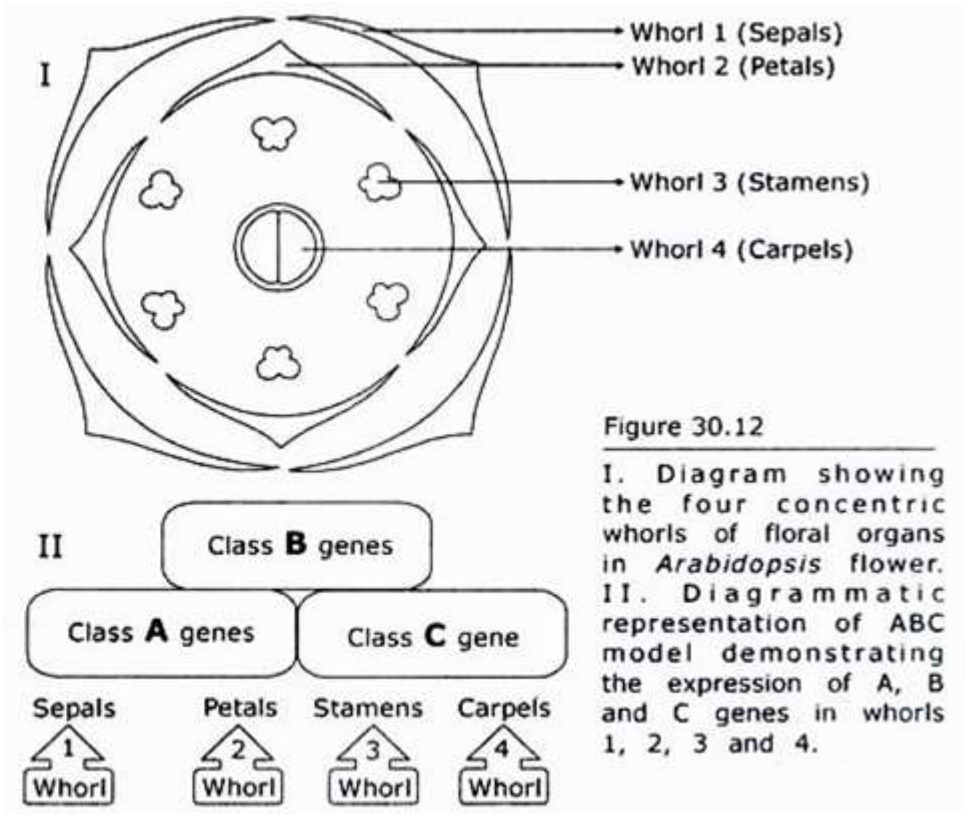


Figure 30.12

I. Diagram showing the four concentric whorls of floral organs in *Arabidopsis* flower. II. Diagrammatic representation of ABC model demonstrating the expression of A, B and C genes in whorls 1, 2, 3 and 4.

Coen et al. (1991) formulated the ABC model. While analyzing the mutations affecting flower structure. Coen et al. identified the class ABC genes that direct flower development. They also formulated the molecular models of how floral meristem and organ identity may be specified. They have shown that the distantly related angiosperm plants use homologous mechanisms in pattern formation of floral organs. Ex. Arabidopsis thaliana and Antirrhinum majus.

The following two have led to formulate ABC model:

(1) The discovery of homeotic mutants (homeotic genes identify specific floral organs and help the organ to develop in respective whorl. The homeotic mutant has inappropriate expression—that is, it induces right organ to develop in wrong whorl. As for example — petals emerge in the whorl where normally stamens develop).

(2) The observation that each of the genes that induce the formation of an organ in a flower has an effect on two groups of floral organs, i.e. sepal and petals or petals and stamens.

Class A, B and C genes are homeotic genes. They determine the identity of different floral organs and induce the organs to develop in their respective whorls.

The homeotic mutants have defects in floral organ development and induce the right organs to develop in wrong whorls/place, i.e. one floral organ develops in the whorl, which is the normal position of another floral organs. Petals, for example, develop in the whorl where stamens are normally to be formed.

In each whorl of a flower there is one or more homeotic genes and their cooperative functions determine the organ to be formed in that whorl. For example, the activity of class A genes is restricted to whorls 1 and 2. The class B genes have function in whorls 2 and 3. The class C gene functions in whorls 3 and 4.

Another way of describing the function of class A, B and C genes is that—in whorl 1, the class A gene-function alone determines the formation of sepals; in whorl 2, class A and B gene-functions both determine the formation of petals; in whorl 3, class B and C gene-functions both determine the emergence of stamens and in whorl 4, class C gene-function alone determines the carpel formation.

In *Arabidopsis* there are two genes in class A, two genes in class B and one gene in class C (Table 30.1). The most characteristic feature of these homeotic genes is in the identification of floral organs and in the determinacy of position / whorl of their emergence in a floral meristem. The two genes of class A and the two genes of class B act cooperatively.

The function of class A genes is confined to whorls 1 and 2. Similarly the function of class C gene is restricted in whorls 3 and 4. This can be interpreted in another way. In the whorls 1 and 2 the function of class A genes prevents class C gene from functioning in the same whorls. Similarly the function of class C gene prevents class A genes from functioning in the whorls 3 and 4.

Any mutation in class A genes with defects in floral organ development will invite class C gene to express in whorls 1 and 2. The class C gene, in class A mutants, will express in whorls 1 and 2 in addition to the normal whorls 3 and 4.

Similarly any mutation in class C gene with defects in floral organ development will lead to the encroachment of the function of class A genes. The class A genes will express in the whorls 3 and 4 in addition to the normal whorls 1 and 2.

Class	*Arabidopsis*
Class A	*APETALA 1 (AP1), APETALA 2 (AP2)*
Class B	*APETALA 3 (AP3), PISTILLATA (P1)*
Class C	*AGAMOUS (AG)*

Table 30.1

Illustrating Homeotic genes in *Arabidopsis*.

The following three examples of homeotic mutant genes will illustrate the above discussion (Fig. 30.13):

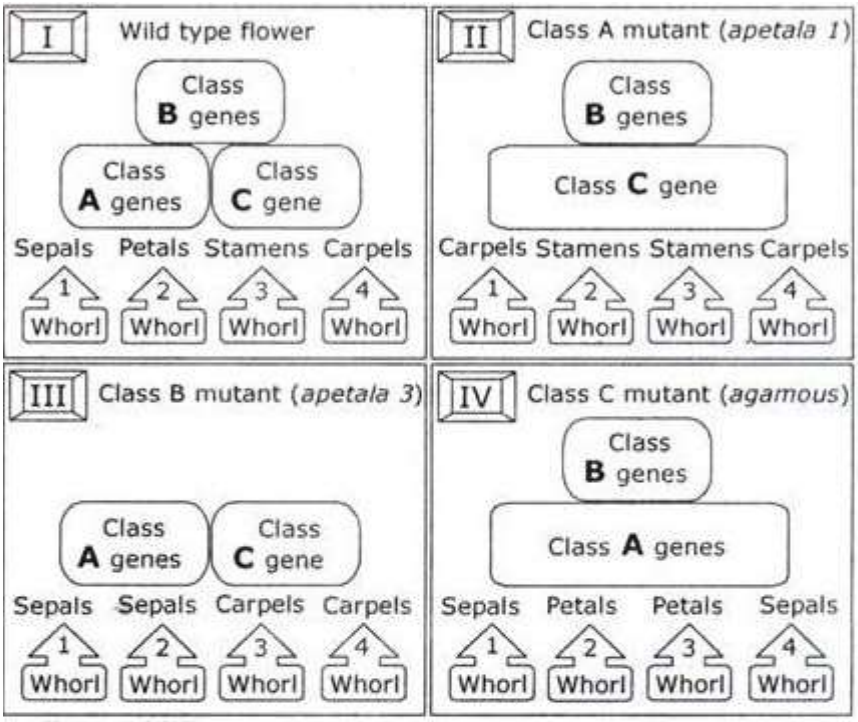


Figure 30.13

Diagrammatic illustrations of the floral organs formed in wild type and homeotic mutants of *Arabidopsis* flower. I. Wild type flower. The individual and cooperative expressions of class A, B and C genes are in the formation of sepals, petals, stamens and carpels in whorls of 1, 2, 3 and 4 respectively. II. Class A mutant, *apetala 1*. This homeotic mutant contains loss-of-function A genes. Class C gene expresses alone in whorl 1 in addition to whorl 4. Class C gene and class B genes together express in whorls 2 and 3. As a result stamens are formed in both whorls 2 and 3. III. Class B mutant, *apetala 3*. This homeotic mutant contains loss-of-function B genes. Class A genes express in whorls 1 and 2. As a result sepals are formed in both whorls 1 and 2. Class C gene expresses in whorls 3 and 4. So carpels are formed in both whorls 3 and 4. IV. Class C mutant, *agamous*. This homeotic mutant contains loss-of-function C gene. Class A genes express in whorls 3 and 4 in addition to whorls 1 and 2. As a result petals and sepals are formed in whorls 3 and 4 respectively. In whorl 3 class A and class B genes together form petals. In whorls 1 and 4 the sole group of class A genes expresses and so sepals are formed.

(1) The flower of Arabidopsis with class A mutants, such as apetala 1(ap 1) shows the following pattern of floral organs (Fig. 3.13.II): whorl 1 shows bract-like structure with carpelloid characteristics; whorl 2 shows stamens; whorl 3 shows stamens and whorl 4 shows carpel.

The pattern of floral organ formation in whorls 1 and 2 is changed. In ap 1 mutants the activity of two genes of class A is lost. So the class C gene expressed in whorls 1 and 2 in addition to whorls 3 and 4. As a result carpelloid organ developed in whorl 1 and stamens formed in whorl 2. In the whorls 3 and 4 stamens and carpel respectively are formed similar to wild type (Fig. 30.13.I).

(2) Example: Flower of *Arabidopsis* with class B mutant, such as apetala 3 (ap 3): The flower shows sepals only both in whorls 1 and 2, while the whorls 3 and 4 show carpel only (Fig. 30.13III). Class B mutant contains loss-of-function genes and as a result class A genes express in whorls 1 and 2; and class C gene alone expresses in whorls 3 and 4. In ap 3 mutants in whorl 2, sepals are formed instead of petals and in whorl 3, carpel is formed instead of stamens.

(3) In *Arabidopsis* the class C gene contains the sole gene agamous (ag). *Arabidopsis* flower with agamous (ag) mutant consists of many sepals and petals. The reproductive organs – stamens and carpel are not formed in the whorls 3 and 4. Class C gene with ag mutant contains loss-of-function gene. As a result class A genes express in whorls 3 and 4 in addition to 1 and 2. In ag mutant sepals and petals are formed in whorls 3 and 4 instead of stamens and carpel. The literature of Howell provides the scan electron micrograph of flower phenotypes of the floral homeotic mutants of class A, B and C genes.

In Arabidopsis it was observed that in all the mutants one homeotic gene remains functional in each whorl. The flower with class ABC triple mutant shows sepals in each whorl. In ABC triple mutant, the genes required for floral organ formation become nonfunctional. As a result sepals or leaves are formed in each whorl, as homeotic mutants specify no floral organs. This observation led Botanists to regard ‘flowers as modified leaves’ on the basis of molecular genetics.

The important feature of ABC model is that it can predict the type of floral organ to be induced to develop in any whorl. Krizek et al. (1996) was successful to induce any one of the four different floral parts in whorl 1 of *Arabidopsis* flower. This became possible by genetic manipulations of right combination of homeotic selector genes.
The ABC model appears to be simple, but a completely different picture is obtained when it is analyzed on the basis of molecular genetics and in molecular terms.

The analysis includes the structure of different classes of homeotic genes, the homeotic mutants, the co-operative function between homeotic genes, mutual exclusion in the expression of class A and C genes in the same whorl, the identification of floral homeotic genes and their isolation by cloning, the production of MADS box protein by homeotic mutants, the study of genes that mediate the interaction between floral meristem and floral organ development, presence or absence of different classes of transcription factors etc., the details of which can be obtained in the literatures on molecular genetics.

Arabidopsis thaliana belongs to the family Brassicaceae and has become the model organism for understanding the genetics and molecular biology of flowering plants like mice and *Drosophila* in animal researches due to following reasons:

(i) It has five chromosomes (n = 5) and so this small-size-genome is advantageous in gene mapping and sequencing.

(ii) The size of plant is small and so can be cultivated in a small space and requires modest indoor facilities.

(iii) It has rapid life cycle and takes about six weeks from germination to mature seeds.
(iv) An individual plant produces several thousand seeds.

(v) 'The *Arabidopsis* genome is among the smallest in higher plants, with a haploid size of about 100 megabases (mb) of DNA. With a small genome size it was expected that there would be fewer problems with gene duplication'— Howell.

(vi) It is easily transformable with T-DNA mediated transformation.

In 2004 ABCE model has been formulated. The characterization of sepallata 1, 2, 3 triple mutants in *Arabidopsis* has led to the above formulation. It is regarded that the class E genes have important role in the development of floral organs.

References:

1.https://www.biologydiscussion.com/flower/development/abc-model-of-flower-development-plants/69453.

2.https://en.wikipedia.org/wiki/Sexual_reproduction

(All the above mentioned information including the figures are collected from the above references and will be solely used for teaching and learning purposes).