THE PLANE AND SYMMETRY OF CELL DIVISION

The plane (direction) and symmetry of cell division are immensely important in determining plant form.

Asymmetrical cell division, in which one daughter cell receives more cytoplasm than the other during mitosis, is fairly common in plant cells and usually signals a key event in development

PLANT DEVELOPMENT

PLANT DEVELOPMENT INVOLVES COMMITMENTS

Commitment	the process whereby a cell becomes firmly committed to just one of the several developmental pathways that are open to it before expressing the phenotype of the differentiated cell type.
Commitment" or "determination"	is a general term that includes setting up of polarities and pattern formation

Inherent in the concept of polarity is the presence of poles, typically two, with an axis running between them, thus apical-basal polarity, or in and out (radial) polarity

Commitment occurs in steps, and choices at each step are limited to a few options

Plant development is hierarchical and involves a series of progressive commitments.

Commitment during Embryogenesis

Illustrated by the first division of the zygote setting out the apical and basal cells, which give rise to the embryo proper and suspensor, respectively

Suspensor	– structure that connects endosperm to an embryo. It pushes the embryo towards the endosperm in order to draw its nutrition.

At the tissue level, the protoderm is separated from the central cells, followed by the separation of the central cells into ground meristem and procambium, and later, in roots, separation of the ground meristem into cortex and endodermis and of procambium into pericycle and vascular tissues.

Protoderm cells normally will form epidermis, epidermal hairs, guard cells, and elaborate cuticle, but will not form xylem or phloem cells

PLANT DEVELOPMENT (cont)

In contrast, procambial cells will normally form vascular tissues, pericycle, and vascular cambium and will not suddenly form glandular epidermal hairs or elaborate cutin.

Vascular cambium, when established, is committed to giving rise to derivatives by specific planes of cell division, and the derivatives in turn are committed to forming xylem or phloem cells.

GENE ACTIVITY

Gene activity involves at least three types of genes:

a. Housekeeping genes	that encode proteins required for general housekeeping, such as enzymes involved in respiration, sugar uptake, or synthesis of proteins or synthesis/replication of nucleotides and polynucleotides

b. Genes that are expressed in a cell- and tissue specific manner and which encode proteins that are specific for the channelized route or the designated function.

c. Regulatory genes	that specify pattern or that regulate the expression of cell/tissue specificity

Mechanism of Differentiation

The functions are performed efficiently and to the benefit of the whole organism, but at the price that the specialized cells, tissues, and organs have only limited parts of their genome open for transcription.

■ Typical leaf mesophyll cell, which is specialized for photosynthesis, may have 40-50 well differentiated chloroplasts.

In contrast, a root parenchyma cell storing starch, will have no chloroplasts, no chlorophyll and associated proteins, and no RUBISCO. Instead, it would have amyloplasts (starch-storing plastids) and large amounts of ADP glucose pyrophosphorylase

The root and mesophyll cells have the same genomic DNA, but they are specialized for different functions because different genes are expressed in the two types of cells.

Differential gene expression is used in a broad sense to include all gene-directed activity, not only gene transcription, but also posttranscriptional and posttranslational modifications, as well as gene silencing.

Differential gene activity is the basis for the phenomenon known as epigenesis, the unfolding of the developmental program of an organism

CELL DIFFERENTIATION

a process where cells become biochemically and structurally specialized to carry out specific functions

■occurs through cell determination, a series of molecular events in which activities of certain genes are altered in ways that cause a cell to progressively commit to a particular differentiation pathway

ORIENTATION OF CELL EXPANSION

he orientation of the cellulose microfibrils affects the direction of cell expansion

PREPROPHASE BAND

Preprophase band	the microtubules in the cytoplasm which becomes concentrated into a ring.
	disappears predicts the future plane of cell division.

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Arabidopsis thaliana

A weed of the mustard family (Brassicaceae Family)

Plant model system for genetic studies

The first plant to have its entire genome sequenced

Arabidopsis has about 26,700 protein-encoding genes

Shoot vs Leaf Determination

Shoot vs Leaf Determination

Young leaves can be excised from the shoot apex and placed in a culture medium, and they develop and form a complete leaf.

In many ferns, leaf development occurs over a long period

n one experiment, primordia P1 through P10 were excised and cultured.

Results clearly showed that younger primordia were undetermined and produced shoots, both stem and leaves, whereas older primordia were progressively more committed (or determined) to produce leaves only

Shoot Meristem Identity

Plant homeobox genes are required for cell fate determination, as well as pattern definition and specification of organ/tissue boundaries.

KNOX (for knotted-like homeobox)	family of genes, named after the maize KNOTTEDI (KNl) gene
	is further divided into two classes, I and II. Class I KNOX genes
	are expressed in shoot meristems and are downregulated in primordia of lateral organs.

For instance, the KNl gene in maize and its ortholog STM gene in Arabidopsis are first expressed in the globular-heart stage embryo in cells of the presumptive shoot apex, but not in cotyledons (scutellum in maize).

Subsequently, they are expressed in both vegetative and floral shoot meristems of the adult plant, but are not expressed in cells on the periphery, which are the founder cells of lateral organs, such as leaves or petals.

Floral Meristem and Organ Identity

Floral meristems express other regulatory genes that distinguish them from vegetative shoot meristems

In dicots, many of these genes belong to the MADS-box gene family.

LEAFY {LEY), a non-MADS-box gene, and APETALAI {API), a MADS-box gene, in Arabidopsis encode transcription factors that act as primary determinants of floral meristem identity.

API also specifies an organ, the sepals whorl in Arabidopsis flower.

Loss-of-function mutations in these genes (e.g., lfy, apl) lead to a partial conversion of presumptive floral sites into shoots.

EXTERNAL OR INTERNAL PERTURBATIONS

EXTERNAL OR INTERNAL PERTURBATIONS MAY CAUSE A REVERSAL OF ESTABLISHED COMMITMENTS

The extent of reversal, whether partial, i.e., going back a few steps, or complete, going back to the zygotic stage, seems to be a function of the extent of perturbation. Two terms, dedifferentiation and redifferentiation, are used to denote a reversal of established patterns and differentiation along new lines.

EXTERNAL OR INTERNAL PERTURBATIONS (cont)

Dedifferentiation -	means a programmed change in the metabolic machinery of a cell, shutting down of genes that were being transcribed in connection with the established function of the cell, and adjustment to new conditions.
Redifferentiation	Induction of new sets of genes and their transcription

MORPHOGENESIS

morphogenesis	The development of form, in which differentiated cells in specific locations become spatially organized into recognizable structures
pattern formation	The development of specific structures in specific locations
	a series of steps requiring signalling between cells, changes in the shapes and metabolism of certain cells and precise cell interactions

Many developmental biologists postulate that pattern formation is determined by positional information in the form of signals that continuously indicate to each cell its location within a developing structure. According to this hypothesis, each cell within a developing organ responds to positional information from neighboring cells by differentiating into a particular cell type, oriented in a particular way

POLARITY IN SHOOT AND ROOT CUTTINGS

Plants typically have an axis, with a root end and a shoot end.

Adventitious roots form within the root end of a stem cutting, and adventitious shoots arise from the shoot end of a root cutting.

Morphogenesis in plants is often under the control of homeotic genes, master regulatory genes that mediate many of the major events in an individual's development.

Over expression of KNOTTED-J gene in tomato plants results in leaves that are "supercompound" (right) compared with normal leaves

■The morphological changes that arise from these transitions in shoot apical meristem activity are called phase changes

GENETIC CONTROL OF FLOWER DEVELOPMENT

Flower formation involves a phase change from vegetative growth to reproductive growth.

When plants recognize an opportunity to flower, signals are transmitted through florigen.

The first genetic change involves the switch from the vegetative to the floral state.

The second genetic event follows the commitment of the plant to form flowers.

ABC MODEL OF FLOWER DEVELOPMENT

In the simple ABC model of floral development, three gene activities (termed A, B, and C-functions) interact to determine the developmental identities of the organ primordia within the floral meristem

A mutation in a plant organ identity gene can cause abnormal floral development