In theories about how the forms of organisms are regulated, the concepts of polarity and axis of polarity occupy a central position. Their great importance in terms of determining the plane of division in the cell has been described in the previous chapter. In higher plants (cormophytes) the basic root/shoot polarity is, as a rule, already determined at the first division of the zygote in the embryo sac (see Fig. 19.4). This division is asymmetrical, producing two unequal daughter cells from a mother cell (Fig. 7.1). This type of cell division plays a decisive role in the development of higher organisms. Usually, the first division of a germ cell (zygote or spore) is such an asymmetrical division. For example, the first division of a germinating *Equisetum* spore (see Fig. 6.1) produces a small rhizoid cell and a larger prothallus cell, from which the prothallus is produced by further divisions.

The polar characteristics of organs and organisms are the result of cell polarity. The polarity of organs, and with it also cell polarity, is generally very stable. A classic example of such stability was described by Vöchting, who showed that under favourable conditions a section of a defoliated current-year’s willow twig will regenerate shoots at the morphological apical end and roots at the morphological basal end of the twig, independent of the orientation of the section with respect to gravity (Fig. 7.2). If the willow twig is cut into several pieces or ringed in the middle, each part shows polar regeneration, with shoots produced at the apical end and roots at the basal end of each segment. Vöchting could exclude “external forces” as determinants of the ability of the cut ends to regenerate with such qualitative differences. He therefore had to postulate an internal cause, which he called polarity (to be more precise organ polarity). The organ polarity is not limited to shoot axes. Roots also show comparable polar regeneration.

At the physiological level, the polarity of auxin transport is a characteristic phenomenon (Fig. 7.3). It can be assumed that there is a positive feedback
Fig. 7.2 Organ polarity during regeneration of a willow twig (Salix sp.) in darkness. Left A segment of willow twig in its normal orientation, suspended in moist air. Right A similar segment in the reverse position with respect to gravity. The morphological basal end (root pole) regenerates roots, whilst the morphological apical end (shoot pole) regenerates shoots. The gravitropic orientation of the regenerated organs is, however, always normal relative to gravity. (After Pfeffer 1904)

Significance of Cell Polarity

How is it possible to explain asymmetrical cell division giving unequal daughter cells (see Fig. 7.1)? Division of the nucleus is symmetrical, namely a typical mitosis, with equal products. It can be assumed that each daughter cell contains enough plastome and chondrome to remain omnipotent. However, the cytoplasm with the organelles must be differentially distributed to both daughter cells. Consequently, the daughter nuclei are in different environments, and through this differential gene expression occurs. As a result, the daughter cells form different cell phenotypes.

The basis for each asymmetrical division is thus the polarity of the mother cell (Fig. 7.1, left). The term cell polarity is an attempt to express that the cytoplasm does not possess the same characteristics throughout the cell. The characteristics change from one pole of the cell to the opposite pole, that is along an axis of polarity. If the polarity of the cell is fixed then we talk of structural polarity. This control between the polarity of the tissue (of the cells) and the polar flux of auxin through the tissue: The background (weak) polarity permits a polar auxin flux which amplifies the polarity. This positive feedback mechanism guarantees that polarity will be achieved in the intact structure, and also, at the same time, permits regeneration in case of damage to the structure and if the original auxin flux no longer functions (see p. 388).

A prerequisite for the explanation of organ polarity is an understanding of cell polarity.