This chapter emphasizes the aspects of gross morphology of chromosomes that are visible under the light microscope. In Chapter 3, aspects of fine structure will be discussed.

There are several stages at which chromosomes can be studied, and each stage has advantages and disadvantages. The stage of the cell cycle in which the chromosomes are most easily identified and distinguished is during mitotic metaphase when they are usually most condensed or coiled. In the past, methods for preparing mitotic metaphase chromosomes did not reveal many morphological characteristics that could be used to distinguish them within the complement. Only a few criteria could be employed to describe them. Due to the lack of simple and reproducible differential staining procedures for such ordinary metaphase chromosomes, cytologists turned their major attention to special chromosome types such as the giant salivary gland chromosomes of insects and some other organisms that exist in the prophase stage. Because of their polyteny—an increase in lateral multiplicity—they reveal much detail that usually cannot be studied in ordinary prophases. Other advantages of the study of prophase are (1) the possibility to distinguish between eu- and heterochromatin, (2) the visibility of chromomeres, and (3) the presence of nucleoli that are associated with specific chromosomes and that mark them as nucleolus organizer chromosomes. For these reasons many species have been subject to pachytene analysis. But there are disadvantages to the morphological study of the pachytene chromosomes of meiosis. Because of their considerable length, they are not usually all visible in squash preparations. The higher the n-number of chromosomes, the more difficult is a pachytene analysis.

However, not every organism can be analyzed in this manner. Those scientists who worked on the majority of species, including man, had to rely on the ordinary metaphase chromosome analysis. But a recent major breakthrough in cytogenetic technology has suddenly changed this situation (see Chapter 1). Several reliable methods are now available that reveal unique banding patterns in mitotic metaphase chromosomes.

In 1971 an ad hoc committee meeting on the Standardization of Human Chromosomes was held to revise the nomenclature system in light of new techniques and new findings (Paris Conference, 1971). This system of cytogenetic human nomenclature was again revised in 1978 (International System, 1978). The Paris Conference describes four different chromosome banding methods now known as
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C-banding, G-banding, Q-banding, and R-banding. In this chapter we will consider the different applications for studying the gross morphology of chromosomes.

2.1 Mitotic Metaphase Chromosomes

Because of the recentness of the discovery of banding patterns in mitotic metaphase chromosomes, the majority of metaphase chromosome analyses have been carried out with the aid of other methods. It is therefore important for the student of chromosome morphology to familiarize himself with earlier approaches. Mitotic metaphase chromosomes usually range in sizes from about 0.5 μm to 30 μm in length and from 0.2 μm to 3 μm in diameter. Plants and animals alike can have very small chromosomes, but on the average, plants have larger chromosomes than animals.

2.1.1 Total Length of Chromosomes

The morphology of a chromosome in mitotic metaphase is described by two major factors: its total length and the position of the centromere. In order to demonstrate these characteristics, cytologists construct idiograms of the karyotypes of species. The karyotype as described by Battaglia (1952) is the particular chromosome complement of an individual or a related group of individuals, as defined by chromosome size, morphology, and number. An idiogram is a diagrammatic representation of the gametic chromosome set (n) of a given species and is used to compare the karyotype of one species with those of other species. Figure 2.1 shows an idiogram of *Agropyron orientale* (Schulz-Schaeffer and Jurasits, 1962). There exist karyotypes with chromosomes essentially similar in size and others with chromosomes differing greatly in size. The average size of chromosomes is 6 μm. The longest chromosomes exist in the plant genus *Trillium* and are longer than 30 μm. The shortest chromosomes are less than 1 μm in length and occur in fungi, rushes, sedges, and in some animals. In many species we find two distinct sizes of chromosomes, large ones and small ones. Such karyotypes occur in the plant genera *Yucca* and *Haemanthus* (Fig. 2.2) and in birds and lizards. In polyploid plant species, groups of chromosomes in different size classes give clues of parental origin. For instance, in the grass genus *Bromus*, the North American octoploids

![Fig. 2.1. Idiogram of Agropyron orientale (2n = 28). The satellite chromosomes are placed at the beginning of the idiogram and are arranged according to the length of their satellites. The rest of the chromosomes are arranged according to the length of their short arms. One unit of the scale to the left of the idiogram equals 0.72 μm. (From Schulz-Schaeffer and Jurasits, 1962. Reprinted by permission of McClure Newspapers, Inc., Burlington, Vermont).](image-url)