Biological Aspects of Reconstructive Surgery

Desmond A. Kernahan
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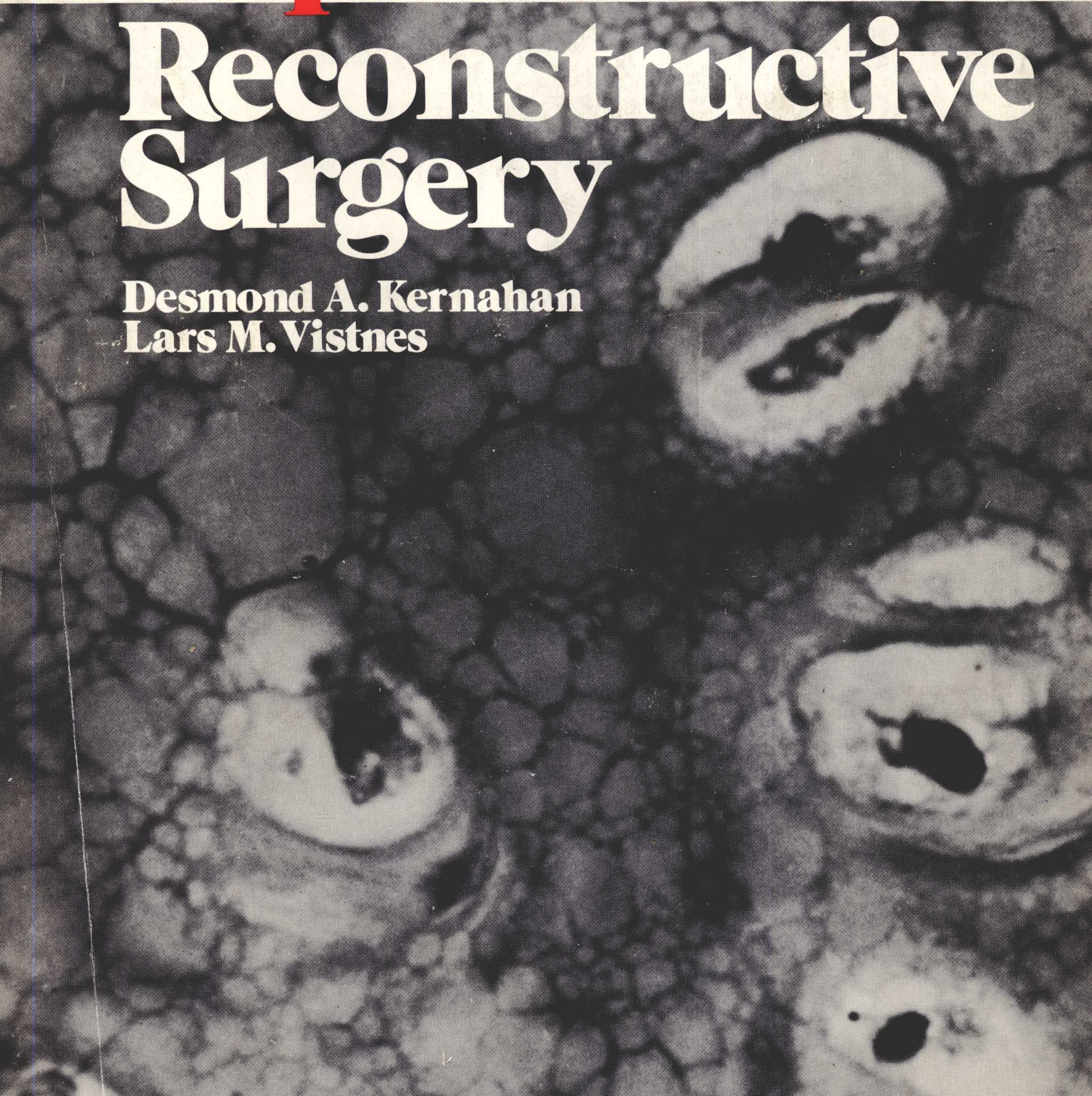

Biological Aspects of Reconstructive Surgery

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Preface

The extent and application of plastic surgery have expanded rapidly in the last twenty-five years, and the concept of repair *as opposed to* ablation *has extended into most fields of surgical endeavor. Although the development of plastic surgery was in large part pragmatic and technical—trial and too often error being the way in which the frontiers were advanced—there has been a steady increase in our knowledge of why and how our successes and failures occur. Particular instances are in our understanding of the circulatory patterns of skin flaps, the vascularization of skin grafts, and the behavior of healing tendons, to mention only a few. Much of this information still is gained only by searching for and reading the original papers. This is time-consuming for all, and often confusing for those still in training. Standard texts of pathology and surgical physiology, oriented as they are to the wider audience, do not always present in sufficient detail concepts of particular interest to the plastic surgeon.*

Biological Aspects of Reconstructive Surgery *brings together in one place this body of information: the basic science foundation on which reconstructive surgery builds. We have in general excluded subjects, such as hand anatomy and skin pathology, that are distinct entities covered in standard texts. Our contributing authors have concentrated on the fundamental biological processes and their impact on the practice of plastic surgery.*

The conception of this book occurred when the editors were associates in the practice of plastic surgery, and the contributors largely reflect the institutions with which we have been associated. Other authors were chosen by virtue of their personal contributions in particular spheres of interest. Like most outstanding professionals, they are busy and often overcommitted. We thank them both for the quality of their contributions and for the way in which they found time to produce them.

It is a particular pleasure to thank Mr. Fred Belliveau, General Manager of the Medical Division of Little, Brown and Company, for his enthusiasm, support, and guidance in bringing the project to completion. We also thank Mr. Robert M. Davis for his many helpful suggestions and editorial supervision.

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I

The Predetermined Aspects

INTRODUCTION

A person's genetic and embryological constitution determines his body form. Therefore, and because the sciences of genetics and embryology have advanced significantly in the past decade and a half, Part I of this book is devoted to these disciplines.

The plastic surgeon must have a good working knowledge of genetics and embryology because he frequently treats congenitally deformed children and counsels their families. Knowing the embryological background of a lesion is often the key to successful treatment. Informed advice to parents enables them to plan their family wisely and prevent future tragedies.

The material in Chapters 1 and 2 will help the surgeon to advise a family on why a deformity occurred and provide suitable counseling when confronted with an inherited or de novo developmental anomaly. At the same time, these chapters are a current concise review of pertinent topics in two difficult and diffuse basic sciences.

1

The Embryological Basis of Congenital Defects

Keith L. Moore

EARLY HUMAN DEVELOPMENT

Development begins at fertilization when a sperm unites with an ovum to form a single cell called a *zygote* (Fig. 1-1). Fertilization restores the diploid number of 46 chromosomes and initiates preparations for the first division of the zygote. Mutant genes or abnormal numbers of chromosomes from the ovum or the sperm, or both, can cause congenital malformations (see Chapter 2).

The process of cleavage consists in repeated mitotic divisions of the zygote into cells called *blastomeres* (Fig. 1-2). By the third day a solid ball of 16 or so blastomeres, called a *morula* (Fig. 1-2D), has formed. The morula enters the uterus from the uterine tube, and fluid passes into the morula from the uterine cavity. As the fluid collects, a blastocyst cavity forms, converting the morula into a blastocyst (Fig. 1-2E). The embryo-forming cells making up the inner cell mass are surrounded by a peripheral layer of trophoblastic cells. The membranous zona pellucida degenerates as the blastocyst forms on the fourth and fifth days. The trophoblast adheres to the endometrial epithelium, and implantation of the blastocyst begins; implantation ends during the second week (Fig. 1-3).

Differentiation of cells in the inner cell mass into an embryo begins at the end of the first week. The cells facing the blastocyst cavity become cuboid and form a single layer of endoderm; the remaining cells become columnar during the second week and form a thick layer known as the *ectoderm.* The amniotic cavity appears between the ectoderm and the trophoblast. By the end of the second week, the developing embryo consists of a bilaminar embryonic disk which is continuous peripherally with the amnion and the yolk sac (Fig. 1-3E).

The third week is a period of rapid embryonic development. The primitive streak appears as a midline thickening of the embryonic ectoderm, and cells from it spread laterally between the ectoderm and the endoderm of the embryonic disk to form mesoderm, the third germ layer of the embryo. From the thickened end of the primitive streak, called the ***primitive knot***, cells extend cranially to form the notochordal process, the primordium of the notochord. To-

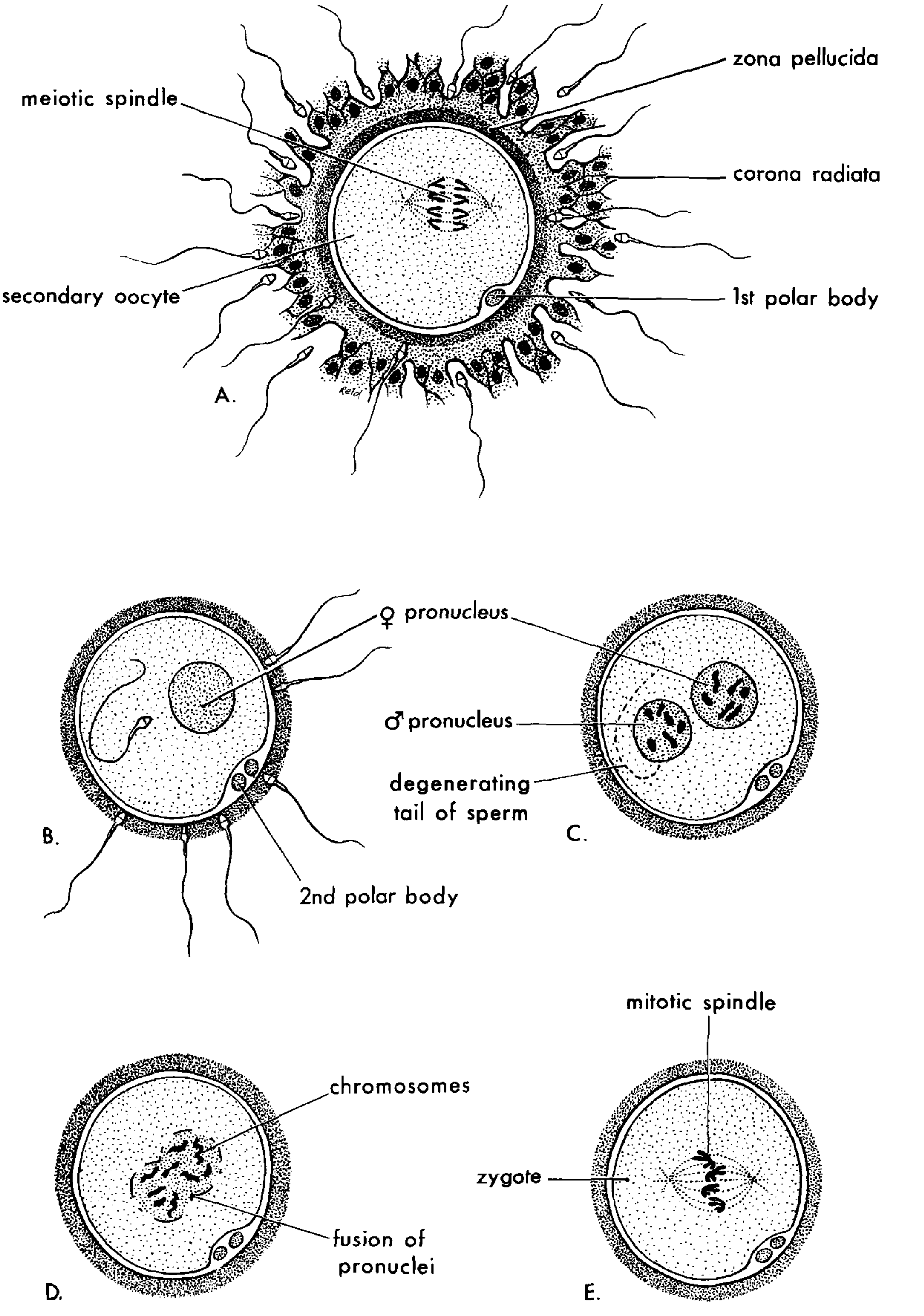

FIGURE 1-1. *Fertilization. A. Secondary oocyte about to be fertilized (only four of the 23 chromosome pairs are shown). B. The corona radiata has disappeared, and the sperm has passed through the zona pellucida into the ovum. The second maturation division has occurred. C. The sperm head has enlarged to form the male pronucleus. D. The pronuclei are fusing. E. The chromosomes of the zygote are arranged on a mitotic spindle in preparation for the first cleavage. (From K. L. Moore,* The Developing Human *[2nd ed.]. Philadelphia: Saunders, 1977.)*

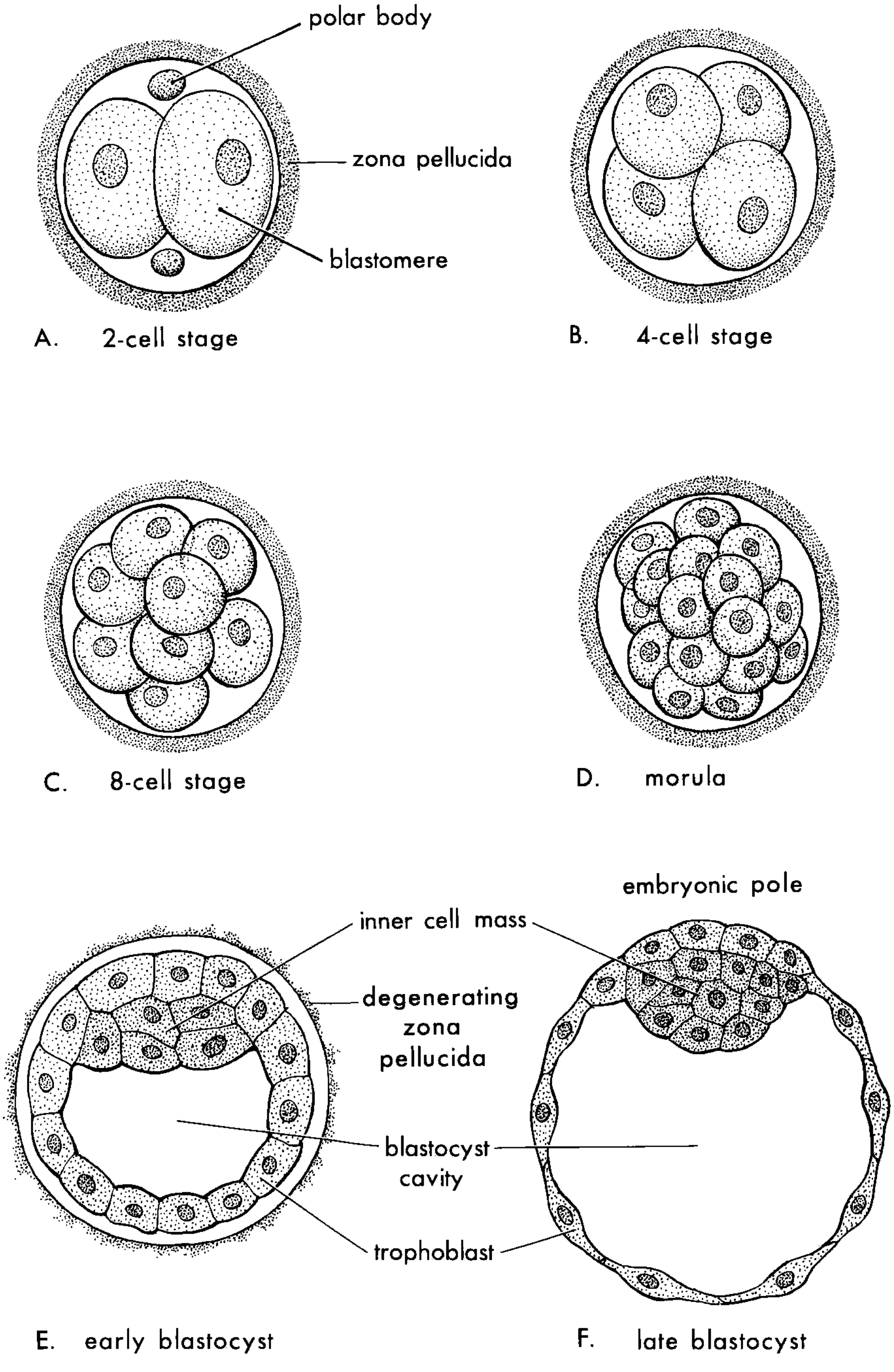

FIGURE 1-2. *Cleavage of the zygote and formation of the blastocyst. E and F are sections of blastocysts showing the inner cell mass (primordium of the embryo). (From K. L. Moore,* The Developing Human *[2nd ed.]. Philadelphia: Saunders, 1977.)*

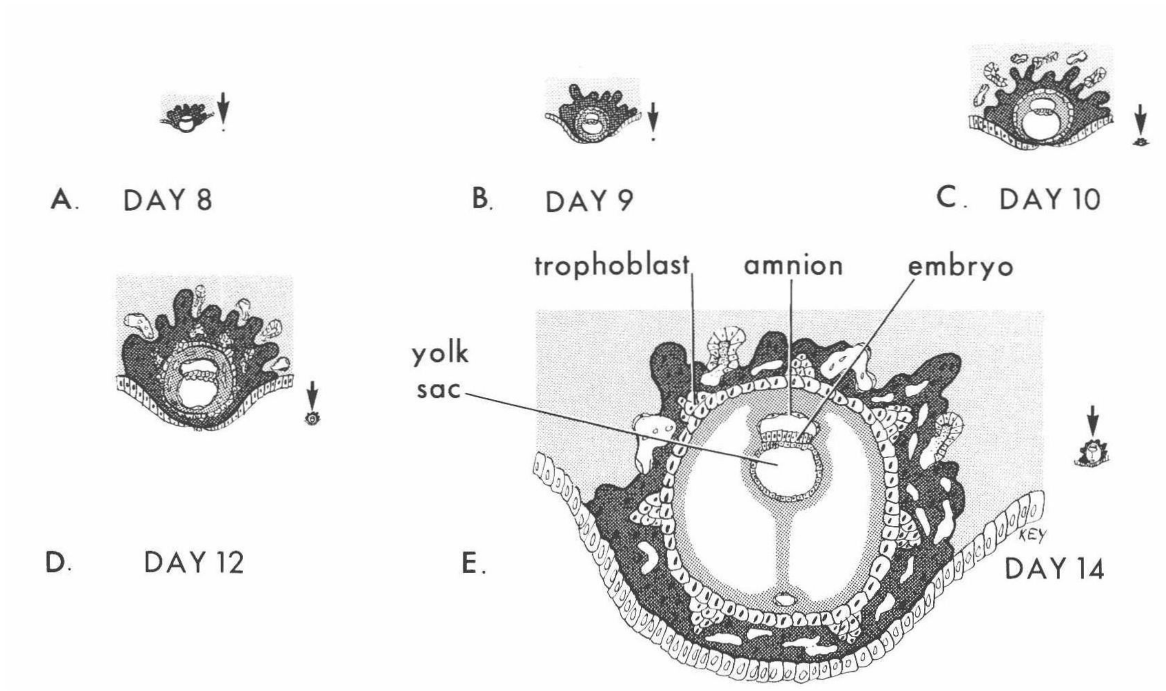

FIGURE 1-3. *Sections of human blastocysts during the second week, illustrating the implantation, the rapid expansion of the trophoblast, and the relatively minute size of the embryo (×25); the sketches indicated by the arrows show the actual size of the blastocysts. (From K. L. Moore,* The Developing Human *[2nd ed.]. Philadelphia: Saunders, 1977.)*

ward the end of the third week, formation of the nervous and cardiovascular systems begins.

THE EMBRYONIC PERIOD AND TERATOGENESIS

Rapid growth and differentiation of the embryo continue throughout the embryonic period. By the end of the eighth week all the main systems of the body have formed and all major features of external body form have appeared. Exposure of an embryo to environmental teratogens (substances known to cause congenital malformations) may result in abnormal development and congenital malformations. Despite rapid advances in knowledge concerning congenital malformations in the last decade, much is still to be learned about the etiology of birth defects. It is estimated that about 10 percent of malformations are caused by environmental factors and another 10 percent by genetic and chromosomal factors. Probably many of the remaining abnormalities result from a complex interaction of genetic and environmental factors. For a review of the causes of human malformations, see Moore [9] and Persaud and Moore [11].

FOURTH WEEK. Initially the embryo is almost straight, but longitudinal and lateral folding resulting from rapid growth of the embryo, especially of the brain and spinal cord, produces a somewhat cylindrical embryo. The main external features of four-week embryos are shown in Figure 1-4.

FIFTH WEEK (FIG. 1-5). Growth of the head is extensive and results mainly from rapid development of the brain. Other external changes are minor compared with those occurring during the fourth week. The limbs, especially the arm buds, show considerable regional differentiation.

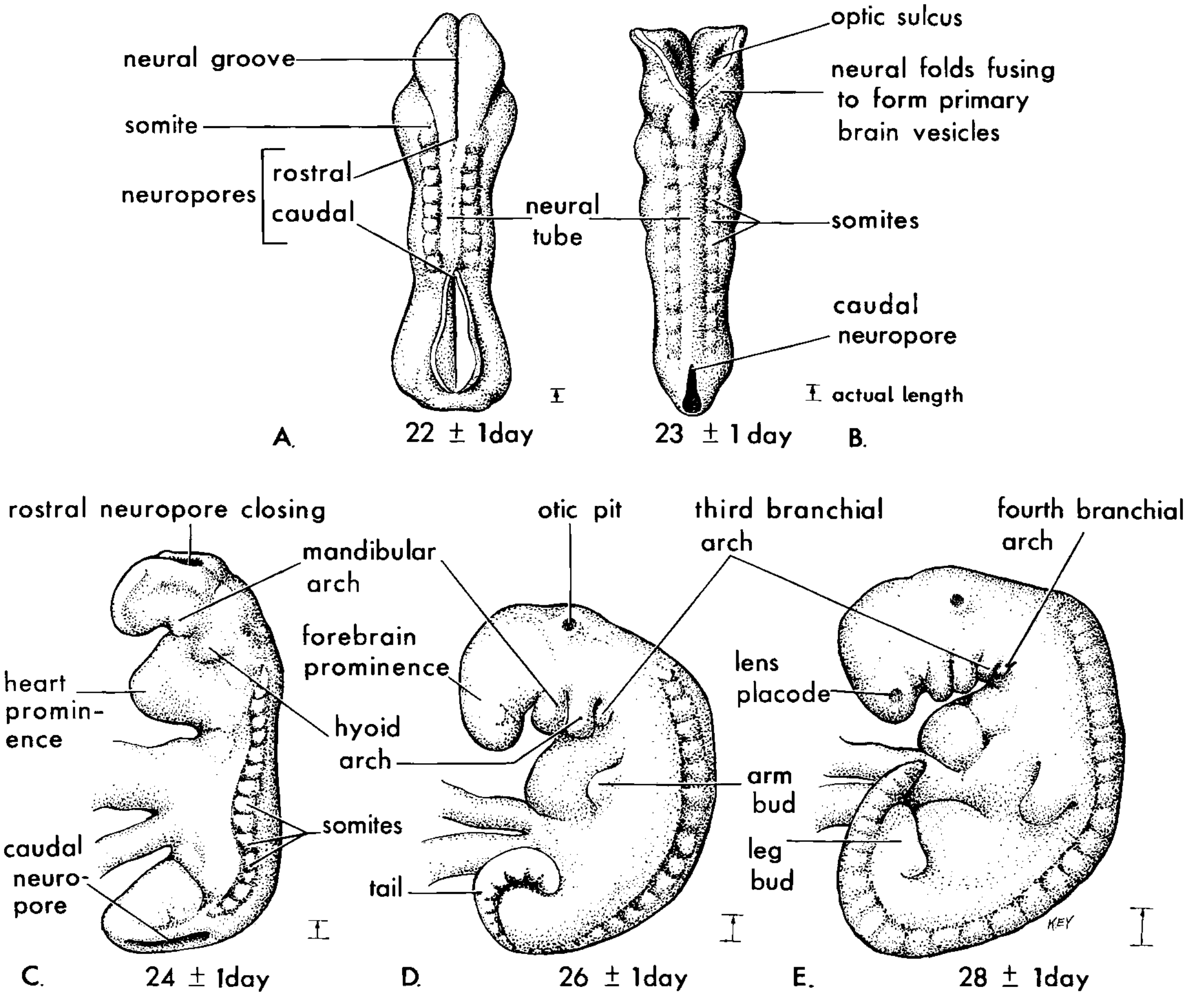

FIGURE 1-4. *Four week embryos. A and B. Dorsal views. C, D, and E. Lateral views. (From K. L. Moore,* The Developing Human *[2nd ed.]. Philadelphia: Saunders, 1977.)*

SIXTH AND SEVENTH WEEKS (FIG. 1-6). The cervical flexure of the brain causes the head to bend over the chest. The intestines enter the umbilical cord, and short webbed fingers are present. The somites are no longer recognizable; the tail is still present but much shorter.

EIGHTH WEEK (FIG. 1-7). The embryo now has unquestionably human characteristics (Fig. 1-7B). By the end of the week, the head is more rounded and the digits are clearly defined. The beginnings of all major external and internal structures are now formed.

THE FETAL PERIOD

From the ninth week until birth the developing human is referred to as a *fetus*. Changes that take place during this period (Fig. 1-8) are not so dramatic as those in the embryonic period but these changes are very important. The fetus is far less vulnerable to the teratogenic or deforming effects of drugs, viruses, and radiation, but these agents may interfere with normal functional develop-