ORAL DEVELOPMENT AND HISTOLOGY

Editor
James K. Avery

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Preface

Dentistry as a profession continues to undergo changes including improvements in clinical treatment. As our knowledge has increased and our techniques have improved, there have resulted a greater appreciation of the biology of oral tissues and refinements in the materials to replace tooth structure. Each of the basic biologic sciences has contributed to this information gain, and this book provides descriptions of most of our recent gains in the area of microscopic anatomy of oral tissues. Most importantly, this information is presented for ready assimilation by the first-year professionals, whether a dental hygiene or a dental student. Text and illustrations (diagrams and light and electron microscopic illustrations) are arranged side by side for easy review.

This book is divided into twenty-seven subject areas and chapters, more than are found in most texts on oral histology. Each chapter represents an area of need in today's dental curriculum as we, the authors, percieve it. Each chapter is relatively short and is written in an engaging manner. Such features as introductory comments, objectives, an outline of the chapter subject matter, a summary, a self-evaluation review, and suggested readings further aid in the understanding and assimilation of the information.

Although there is some overlap between chapters, each is a complete unit. This is done to allow instructors to include or exclude material to fit the needs of their course design. Some chapters such as those on the histology of tooth movement or extraction site healing provide direct clinical correlations, whereas others provide only discussions of these correlations at the end of the chapter.

This book is divided into seven sections by subject area. Section I provides a description of prenatal development, concentrating on those aspects resulting in craniofacial anomalies. Chapter 5, written by an orthodontist and basic scientist, introduces the student to the basic information important to pediatric dentistry and orthodontics. Chapter 6 on the aging of oral tissues is included because of the increase in life-span and the dentist's and dental hygienist's subsequent increasing responsibility to the elderly.

Section II contains information relevant to tooth development, eruption of teeth, and the closely allied subject of shedding of teeth. It follows closely the section on jaw development and covers the life-span of primary teeth from their inception to their loss by exfoliation. Included in this section is information on the effects of vitamins and parathyroid hormone on tooth development. This chapter acts as a reminder that teeth are not impervious to uptake or deficiencies of various substances. It also serves as a reminder of the extensive research so capably reviewed by Dr. Henry M. Leicester in *Biochemistry of the Teeth* (C. V. Mosby, St. Louis, 1949). Information is included on the uptake of sodium fluoride and tetracycline, examples of compounds whose effects future dental practitioners are likely to see.

Section III provides information on the structure of teeth. In Chapter 23, a comparison is made between the primary and the permanent dentition. This chapter is a response to numeorus student questions over the years concerning the differences between the two dentitions. This section also provides a detailed description of the pain pathways in teeth and the possible mechanisms of pain transmission through dentin.

Section IV on the soft tissues includes the traditional description of the histology of the oral mucosa and its innervation. Also included are chapters on the dentally relevant paranasal sinuses and nasal mucosa and on that oropharyngeal area usually overlooked in oral histology texts, the tonsils. We also provide in this section a chapter on the histology of taste and olfaction; we believe that today's dentist needs to understand the structure and function of the oral cavity, residing tastebuds, and their relationship to the olfactory organs.

Section V concerns the periodontium and includes a traditional description of the supporting structures of the teeth. Wound healing is discussed in Chapter 22, with an extraction site used as the example. Chapter 23 provides a description of the histologic changes in the periodontium after various types of orthodontic tooth movement. (This chapter is also a response to numerous student questions on the subject.) The final chapter in this section provides a description of the histologic changes after tooth transplantation and the placement of the endosseous implant. Both of these subjects provide insights into possible future clinical experience.

Section VI contains information of the production of

saliva and the formation of pellicle, plaque, initial caries, and calculus on the tooth's surface. Included is an indepth discussion on the development, structure, and function of the salivary glands and the characteristics of saliva and oral bacteria and their action in tooth decay.

Section VII provides a functional and clinical description of the temporomandibular joint from its inception, into its prenatal development, and through its growth during childhood and adulthood and into old age.

We hope this book serves you well as an introduction to the microscopic anatomy and development of oral tissues. We welcome your comments, suggestions, and criticisms to enable us to improve this text as a teaching resource.

James K. Avery, Editor

Acknowledgments

Oral Development and Histology is the result of a group effort by members of the Oral Histology Laboratory at the University of Michigan to meet the instructional needs of the dental hygiene and dental student. The inception of this book began more than fifteen years ago with a series of slide tapes for class use. Dr. Donald Strachan inspired the development of some thirty subject capsules which evolved into an atlas distributed to students. Updated copies were published binannually, and we were assisted in these early efforts by Educational Resource Department staff members Ruth Ashley, Philip Kovacs, and James Schultz.

Many dental students contributed to our class book: some by their efforts in oral histology; others with medical illustrations and photographic or histologic assistance; and still others by review or editing of the texts. This enthusiastic group could be found most weekends and evenings working in the oral histology laboratories.

Several individuals made specific contributions to the book while they were students. We are grateful to Dr. Norman Wilhelmsen who, under the guidance of Dr. James MacNamara, carried out the studies on tooth movement described in Chapter 23. Drs. John Gregg and David Johnsen studied root formation and tooth eruption, contributing information to Chapters 8 and 10. Dr. Carla Koziol (now Evans) through her research on facial growth contributed to Chapters 2 and 3, and Dr. Jim Jackson through his research on vitamins and hormones contributed to Chapter 9. Dr. Arthur Tomara provided information for Chapter 20. And Dr. Thomas Simmons' research on oxytalan fibers provided information for Chapter 21.

Dr. Jeff Clark, while a dental student, used his artistic talents to illustrate the class text. His fine work, which bears his name, can be seen in the early chapters of the present book. A second artist, Alayne Spencer-Evans, who is pursuing studies in dentistry, is responsible for the majority of the illustrations throughout this text. She listened to the needs expressed by each of the contributing authors and responded most capably. In addition, she researched topics and prepared background information to assure accuracy. The students and faculty reviewing the text compliment her on the clarity, quality, and integrity of her work.

Photographs of earlier editions of the class text were provided by multitalented dental students Steve Olsen, Gary Bilyk, and Thomas Simmons. Having previously created yearbooks, they found it no challenge to photograph and print the necessary detail the illustrators demanded. More recently, John Virey and Warren Wheeler have provided high-quality photographs for this book. The authors are especially grateful to Mr. Wheeler who collaborated with Alayne Spencer-Evans to provide photographs for each chapter. We are grateful to Dr. Soo D. Lee and Charles C. Cox for the many fine electron micrographs they researched and provided for the book and to the staff and the students in oral histology who sectioned and stained the tissues for photography. Especially helpful were Messrs. John and Jim Baker.

During the biannual updating of the class texts which shaped the present book, we received editiorial assistance from Neal Van Poperin, John Baker, Donna Adamczak, George Keevil, Lisa Smith, and Matthew Turchi. Dr. Thomas Green of our Educational Resources Department advised us on numerous questions. We are grateful to Julie Myers for final reviews and Linda Suspeck who did much of the indexing.

All of the authors join me in praising the unsung heroines who typed the manuscript and made the many changes and the final corrections. They were Millie Wadsworth, Carol Lewicki, Constance Lopatin, and Carol Gerlach. We can never express adequately our appreciation for their efforts in evolving this text.

Several faculty members, in addition to writing chapters, have made special contributions to this text. Dr. Sol Bernick made yearly visits to Ann Arbor and inspired staff and students with his demonstrations in the celloidin technique. He has provided many of the fine photomicrographs seen throughout this book. Dr. Nagat ElNesr, Professor at the University of Alexandria, Egypt, spent a sabbatical year with us and researched the literature on numerous subjects. She has contributed to chapters on facial growth, root development, eruption of teeth, structural aspects of teeth, and the periodon-

tium. Charles C. Cox, a person who can always be relied upon to get the job done no matter how large or small, assisted with more deadlines than I can mention in preparing various versions of the text. He has inspired dental students and staff members alike, and working with him has been a gratifying experience. And Dr. Daniel Chiego's suggestions have contributed to improvements in the neuroscience and cell biology discussed in the text.

All of the authors are indebted to Dr. William J. Dougherty of the Medical University of South Carolina. As a scientific consultant for Williams & Wilkins and at our invitation, he proofread the majority of the manuscript. With his knowledge as a scientist and contributor to the literature on oral tissues, he was able to provide insights into improvements to the text.

Other staff and faculty have also made contributions. In addition to Dr. Strachan, Drs. Don and Ron Heys and Mark Fitzgerald of the Oral Histology Group have assisted with their ideas and reviews. Again, thanks to Jonathan Pine, Vicki Vaughn, and Anne Seitz of Williams & Wilkins for their continued support. A special thanks to Bill Cady for his patience and wisdom in editorial assistance. It has been a most enjoyable experience working with all these individuals.

The single most important person who has always supported and encouraged me since the earliest thought of this book is my wife Dody. She has put up with my absence at home, as well as my grumbling presence, with a degree of understanding I don't deserve.

For the benefit of the students, thank you all.

J. K. A.

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CHAPTERS 1–6

1

General Human Development

Introduction

In this chapter, some of the important developmental events that occur between conception and birth of the human being are discussed. Such subjects as implantation, development of the embryonic disc, yolk sac, neural and blood-vascular systems, and organs are included. Changes that occur at birth are described briefly. Information on the role of genetic and environmental influences are also considered. The most critical period for facial development is during the second month and early in the third month after conception, when the most important events in oral-palatal development occur. More changes in structure occur in this short period of prenatal development than occur in all the years after birth.

Objectives

After reading this chapter you should be able to describe these events including the various systems of the body and structures that comprise each system. You should also be able to discuss the hereditary and environmental causes of congenital malformations.

Origin of Human Embryo

Human prenatal development begins with processes involved in the ovarian cycle and fertilization (Fig. 1.1). As the ovum develops, the uterine wall thickens, and ducts and capillaries proliferate within its inner surface (endometrium). The uterus is, thus, preparing for the arrival of a fertilized ovum (uterine changes) Fig. 1.1). Blood levels of the hormones estrogen and progesterone fluctuate cyclically; both function in uterine wall development (Fig. 1.1). Progesterone acts also to aid in degeneration of the empty ovarian follicle which is then termed the *corpus luteum*. The average menstrual cycle is 28 days, although this varies with the individual. If the cycle is defined from the first day of menstrual flow, ovulation will occur about 14 days later. By this time, a follicle ruptures on the surface of the ovary, releasing a mature ovum (ovarian changes) (Fig. 1.1).

Fertilization occurs in the distal one third of the

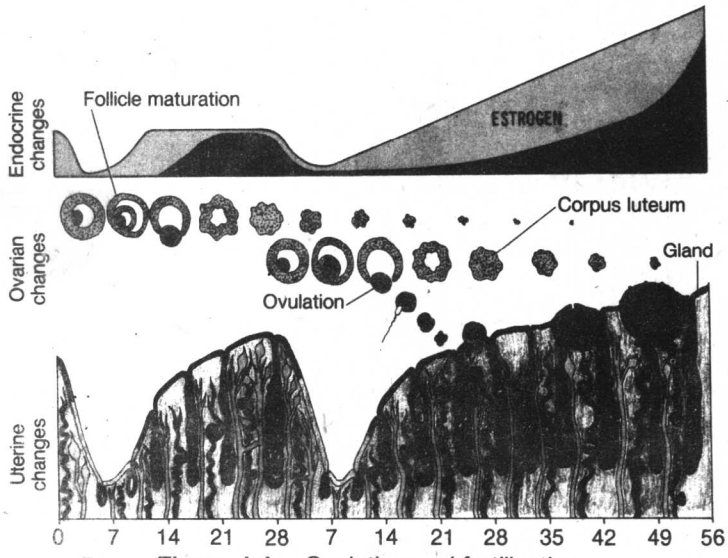

Figure 1.1. Ovulation and fertilization.

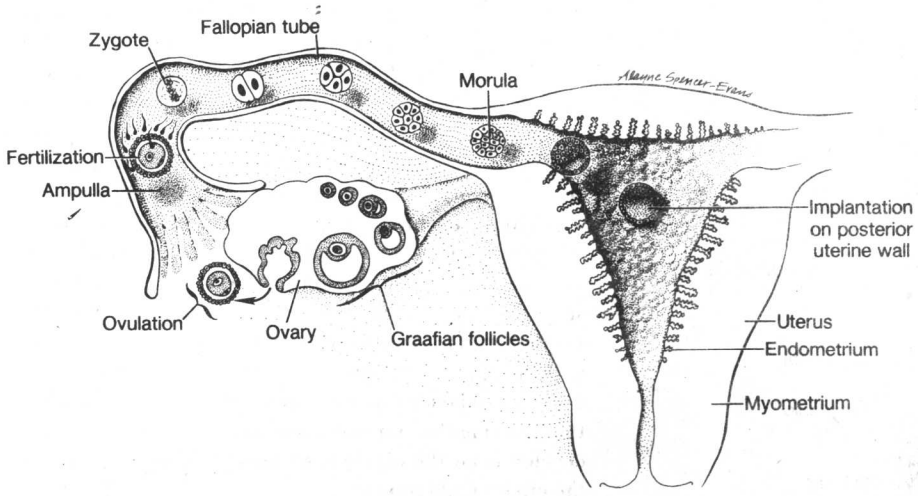

Figure 1.2. Site of fertilization.

Fallopian tubes (Fig. 1.2). It begins with the deposition of some 200 million spermatozoa in the vagina during coitus. The mobile spermatozoa move 1.5 to 3 mm per minute toward and into the uterus and Fallopian tubes to the point of fertilization where 300 to 500 spermatozoa surround the ovum. Generally, only one spermatozoa penetrates the surface of the ovum (termed *zona pellucida*) which then develops a fertilization membrane. This prevents other spermatozoa from penetrating the surface of the ovum. Fusion of the female and male pronuclei (each with 23 chromosomes) culminates the fertilization process. The fertilized ovum, termed a zygote, undergoes cleavage or division as it moves toward the uterine cavity (Fig. 1.2). By 4 days, when the zygote reaches the uterus, it is a many-celled mass called a *morula* (Fig. 1.3). As the cell mass divides, it enlarges and gains a fluid-filled inner cavity termed the blastocele. The blastocele separates the cells into two parts: 1) an outer cell layer, the trophoblast, and 2) an inner cell mass, the embryoblast. This is called the blastocyst stage (Fig. 1.4) and occurs at 4½ days after conception and shortly before implantation.

On the sixth day, implantation takes place. The trophoblast at the embryonic pole attaches to the sticky endometrial surface on the posterior wall of the body of the uterus (Fig. 1.2). The wall has developed increased vascularity to receive the cell mass. The surface cells of the trophoblast produce enzymes that digest the uterine endometrial cells, which allows a deeper penetration of the cell mass (Fig. 1.4).

Early human development can be described as the *proliferative period.* It extends from fertilization until the end of the second or third week. It is a period of rapid production of cells. From 2 or 3 to 8 weeks, the human is called an embryo; this is the period of development of an embryo from the cells of the inner cell mass. During the second week, the cells of the inner

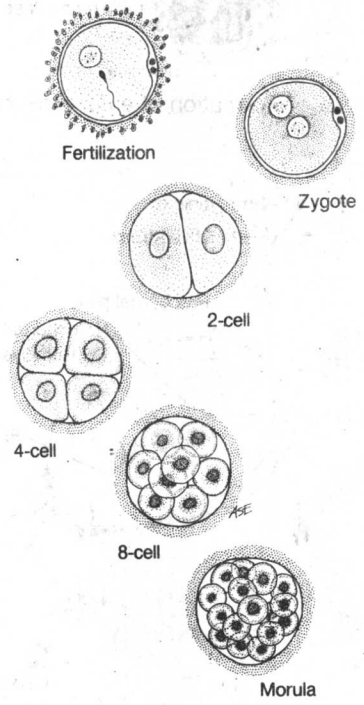

Figure 1.3. Cleavage stages.

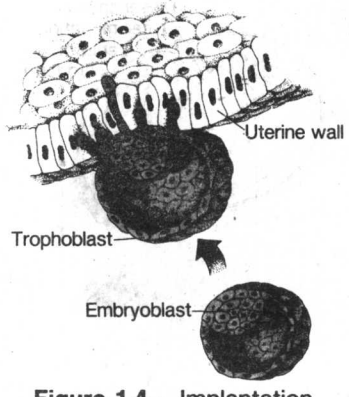

Figure 1.4. Implantation.

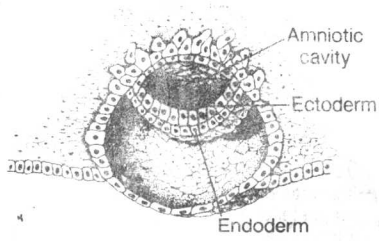

Figure 1.5. Differentiation of ectoderm and endoderm.

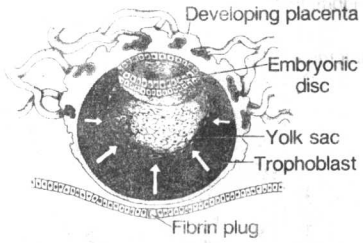

Figure 1.6. Formation of embryonic disc.

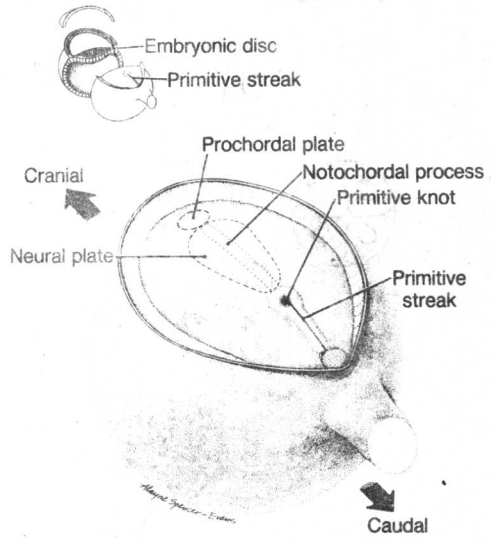

Figure 1.7. Primitive knot and streak on embryonic disc.

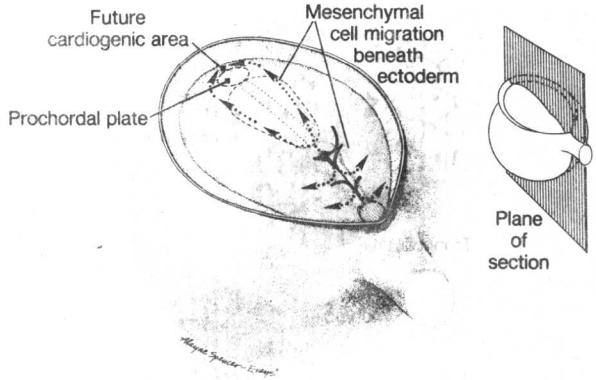

Figure 1.8. Formation of mesoderm.

mass of the growing blastocyst differentiate into two cell types (Fig. 1.5): 1) columnar-shaped ectodermal cells and 2) cuboidal-shaped endodermal cells adjacent to the blastocele. The amniotic cavity appears between the ectodermal cells and the overlying trophoblast (Fig. 1.5). Later in the developmental process the amnion expands, filling the entire extraembryonic coelom and eventually extending from the umbilical cord to the inner wall of the placenta, to which it adheres. Thus, in its final form, the amnion is a free membrane enclosing a fluid-filled space around the embryo. Again, cells grow from the trophoblast and the embryonic disc, to form a primitive yolk sac (Fig. 1.6). During the second week, the blastocyst becomes embedded in the endometrium, and fibrin plugs the endometrial implantation site. The placenta will develop from the highly vascularized tissue surrounding the enlarging blastocyst.

On Day 15, a groove, called the primitive streak, appears on the surface in the midline of the dorsal aspect of the ectoderm of the embryonic disc. By Day 16, a primitive knot of cells (Hensen's node) appears at the cephalic end of the primitive streak. This knot gives rise to the cells that form the notochordal process (Fig. 1.7) which grows cranially in the midline to define the primitive axis of the embryo. Cells from the primitive streak and notochordal process migrate laterally between the ectodermal and endodermal layers of the embryonic shield. These cells form the third germ layer which is called the mesodermal layer (Fig. 1.8). By the end of the third week, the mesoderm migrates in a lateral direction between the ectoderm and the endoderm, except at the anterior prochordal plate and posterior cloacal membrane. The anterior plate forms the future oropharyngeal membrane (Fig. 1.9). Finally, mesodermal cells of the embryonic disc migrate peripherally to join the extraembryonic mesoderm on the amnion and yolk sac. Anteriorly, mesodermal cells pass on either side of the prochordal plate to meet each other in front of this area (Fig. 1.8.).

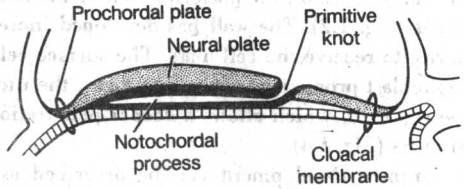

Figure 1.9. Sagittal view of notochord.

Ectodermal cells will give rise to the nervous system, the epidermis and its appendages (hair, nails, and sebaceous and sweat glands), the epithelium lining the oral cavity, nasal cavities and sinuses, a part of the intraoral glands, and the enamel of the teeth. Endodermal cells will form the epithelial lining of the gastrointestinal tract and all associated organs. The mesoderm will give rise to the muscles and all the structures derived from connective tissue, e.g., bone, cartilage, blood, dentin, pulp, cementum, and the periodontal ligament (Fig. 1.10).

The embryonic disc will soon become altered by bends and folds necessary for the further development of the human body.

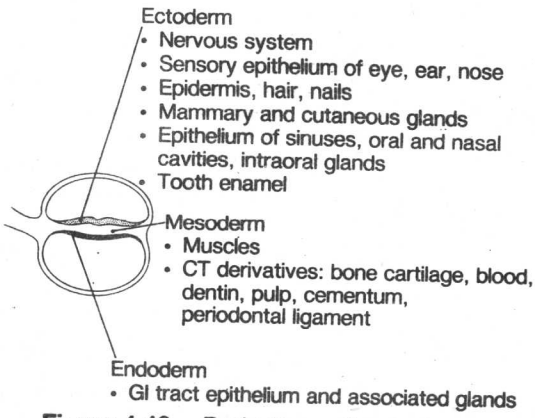

Figure 1.10. Derivatives of germ layers.

Development of Nervous System

On Day 18, the developing notochord and adjacent mesenchyme affect (induce) the overlying ectoderm to form the neural plate (Figs. 1.11 and 1.12). Induction is the net influence exerted by cells or their products on adjacent cells or tissues. It usually occurs for a limited time during early development and results in a thickening of the ectoderm dorsal to the notochord (Fig. 1.7). The neural plate then bends along its central axis to form a groove, and the raised margins along both sides of this groove form neural folds. The neural folds gradually approach each other in the midline where they fuse (Fig. 1.11). Fusion of these folds to form the neural tube begins in the central body region and proceeds in cephalic and caudal directions. The folds remain temporarily open at the cranial and caudal ends forming the anterior and posterior neuropores (Fig. 1.11). The neuropores close during the fourth week, and the central nervous system is established. At the time of neural tube closure, a unique population of cells separate from the crest of the folds. They are known as the "neural crest cells" (Fig. 1.12). These cells undergo extensive migration beneath the surface ectoderm, especially in the head and neck region (Fig. 1.13) and give rise to a variety of different cells that form components of many tissues.

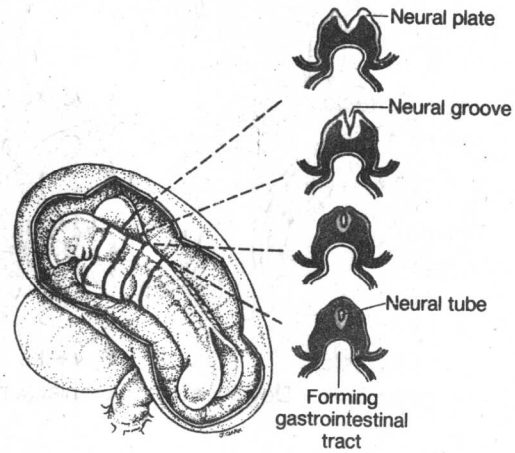

Figure 1.11. Development of neural tube.

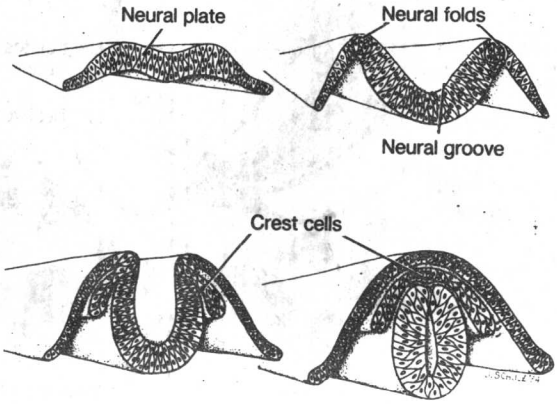

Figure 1.12. Development of neural crest.

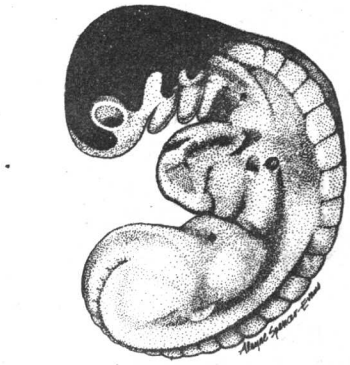

Figure 1.13. Neural crest migration.