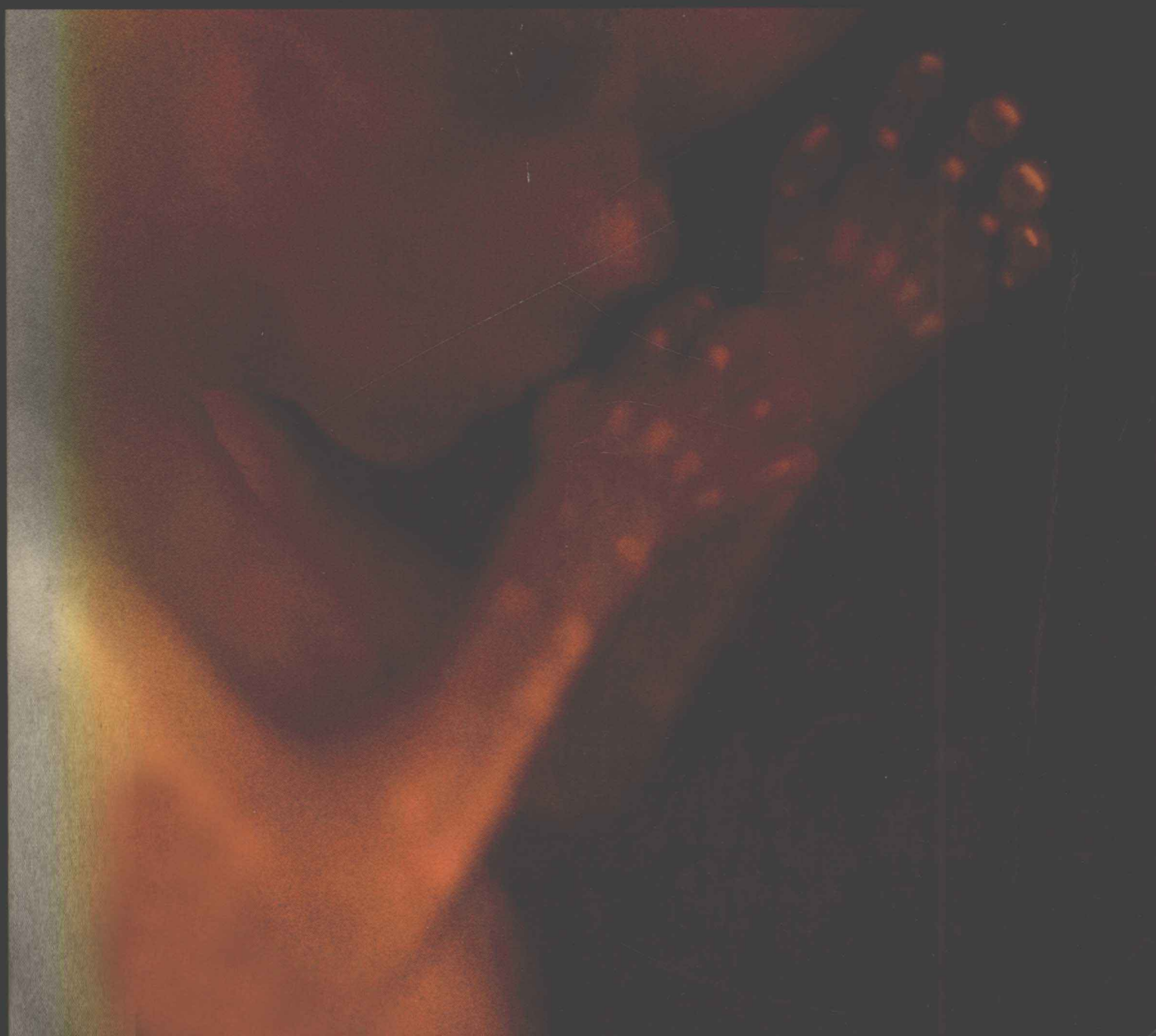
TRENT D. STEPHENS

ATLAS OF HUMAN EMBRYOLOGY



Atlas of Human Embryology

Trent D. Stephens, Ph.D.
Senior Fellow, Central Laboratory for Human Embryology,
Department of Pediatrics

and

Senior Fellow, Department of Biological Structure
University of Washington
Seattle, Washington 98195

Macmillan Publishing Co., Inc.
New York
Collier Macmillan Publishers
London

Preface

The students whom I have taught during the past few years have expressed some disappointment concerning the content of descriptive embryology laboratories. The problem primarily consists of two major points: (1) little or no human material is included, and (2) few if any embryos are examined beyond the 10-mm stage. The standard explanation is that the 10-mm pig and 10-mm human are remarkably similar in structure. While this statement is somewhat justified, no embryos are examined beyond 10-mm because there are considerable differences from that stage forward. I believe that the students' complaints are legitimate since the majority of those who take embryology are planning or involved in a career in the medical sciences.

I have found, in my experience, that the *Atlas of Descriptive Embryology* by Willis W. Mathews is the best student embryology atlas available. This *Atlas of Human Embryology* has been developed not to replace such an atlas, as the understanding of early developmental stages of other animals is important to our complete knowledge of development, but to expand and complement it by the addition of human embryos and at later stages.

The 11.5-mm human embryo was selected as a major point of emphasis because the 10–11-mm human can be compared with the 10-mm pig and this links the development of humans to that of other animals. The other major stage of emphasis is the 32-mm human embryo, selected because this embryo is at the end of the embryonic period and has many recognizable "adult" structures. Other stages were chosen to fill in the gaps.

This book is thus prepared with the hope that it will provide embryology students and medical students with a relatively inexpensive source of knowledge of human development to expand on the foundation they have obtained from the study of other animals.

Trent D. Stephens

Acknowledgments

I wish to especially thank Dr. Thomas H. Shepard for his help, support, and encouragement during the preparation of this book. I am grateful to him for the use of the sectioned material which comprises this work. The Central Laboratory for Human Embryology and other facilities of its kind are extremely valuable in helping to expand our knowledge of ourselves. I am grateful to all those associated with this laboratory. This research was supported in part by NIH Grant No. HD00836.

I wish to thank Dr. Ronan O'Rahilly, Director of the Carnegie Embryological Collection, for permission to reproduce the first four figures of this book from Figures 4, 8, 43, and 56 in *Developmental Stages in Human Embryos. Part A: Embryos of the First Three Weeks (Stages 1 to 9).* Carnegie Inst. of Wash., Pub. 631, Washington, D.C.

I am grateful to all of my former students who have stimulated the development of this book; and to George and Barbara Brownfield and Mary Fenucan for technical advice and manuscript preparation. Figure 37 was photographed by Paul Macapa.

Introduction

Human embryos, as well as several other animal species, have been grouped into a series of developmental stages to facilitate comparison of developmental states and gestational ages between embryos. Streeter (1951, *Developmental Horizons in Human Embryos*, Carnegie Inst. of Washington Pub.) devised 23 developmental horizons to classify human embryos from fertilization to the approximate end of the embryonic period (60 days). In recent years the term "developmental horizon" has been replaced by most investigators with the term "developmental stage" and the Roman numerals introduced by Streeter have been replaced by Arabic.

These developmental stages will be referred to throughout the text. Unfortunately, the human developmental stages do not correspond to similar developmental stages of other animals, but comparisons can be made. The following chart describes the major features of the 23 developmental stages of human embryos including gestational age and crown-rump length.

Human Developmental Stages*

Stage	*Length (mm)*	*Age (Days)***	*Somite Pairs*	*Characteristics*
1	0.1	0–1		Fertilized uncleaved zygote
2	0.1–0.2	2–3		segmentation = two cells to morula
3	0.1–0.2	4–5		Unimplanted, free-floating blastocyst
4	0.2–0.3	6–7		Implantation
5	0.3–0.5	8–11		Progression into endometrium
6	0.2–0.5***	12–14		Embryonic disc, Villi, and yolk sac appear
7	0.3–0.7	15–16		Primitive streak appears
8	0.5–2.0	17–18		Neural folds elevate
9	1.5–3.0	19–20	1–3	Head fold appears
10	2.0–3.0	21–23	4–12	Neural fold fusion begins, heart begins to beat
11	2.5–3.0	23–25	13–20	Two branchial arches, foregut, hindgut, optic evagination
12	3.0–4.0	21–29	21–29	Arm buds appear, neural tube closed, optic cup
13	4–5	28–30	40 (complete no.)	Leg buds appear, heart chambers, lung buds, metanephric bud
14	6–7	30–32		Lens invagination, septum primum, gonadal ridge
15	7–8	32–34		Lens vesicle closed, external ears becoming recognizable
16	9–10	35–36		Eye pigment appears, hand plate, hypophysis, liver
17	11–14	37–40		Finger rays, foot plate, ear defined, somites less apparent superficially
18	14–16	40–42		Eyelid, finger rays notched, toe rays, nerve plexuses
19	17–20	42–44		Head more erect, limbs extend forward, muscles developing, duodenum closed
20	21–23	45–46		Fingers, scalp plexus present, optic nerve, septum secundum
21	22–24	46–48		Hands meet over heart region, corpus striatum, thalamus, heart valves
22	25–27	48–50		Fingers overlap those of opposite hand, duodenum reopened
23	28–30	50–52		Head erect and rounded, scalp plexus reaching head vertex, ossification begins

*From Streeter GL (1959): *Developmental Horizons in Human Embryos.* Carnegie Institution of Washington, Washington, D.C.; O'Rahilly R. (1973): *Developmental Stages in Human Embryos. Part A: Embroys of the First Three Weeks (Stages 1 to 9).* Carnegie Institution of Washington, Pub. 631, Washington, D.C.

**Gestational age in days established from Iffy L, Shepard TH, Jakobovits A, Lemire RJ, and Kerner P (1967): The rate of growth in young human embryos of Streeter's horizon XIII to XXIII. *Acta Anat.* 66:178–186.

***Stage six refers to embryonic disc only, stage 5 refers to overall size. Stages thereafter refer to crown-rump length.

Table of Contents

18.0-mm Human Embryo (Stage 19), Introduction Transverse Section

32.0-mm Human Embryo (Stage 23 +), Introduction Transverse Section

Early Human Embryos

Early Human Embryos

The first four figures* were chosen to represent some of the early stages of human embryology.

Figure 1, a two-celled embryo, is representative of stage 2. During this stage several cell divisions occur taking the embryo from two to perhaps twenty cells.

Figure 2, a 107-celled blastocyst, is characteristic of stage 3 and is 4–5 days old. This stage has developed a blastocoele but has not yet begun to implant.

Figure 3 is an embryo 15 days (2 weeks) old and is at developmental stage 7. It consists of an embryonic disc measuring 0.3–0.7 mm in diameter. The embryo has implanted into the endometrial lining of the uterus and has developed villi, a yolk sac, and an amnion. The embryo at this stage is bilaminar and is developing a primitive streak.

Figure 4 is an embryo 17 days (2.5 weeks) old and is at developmental stage 8. The embryo at this stage is trilaminar, has a well-defined primitive streak and Henson's node, and has the beginning of neural folds.

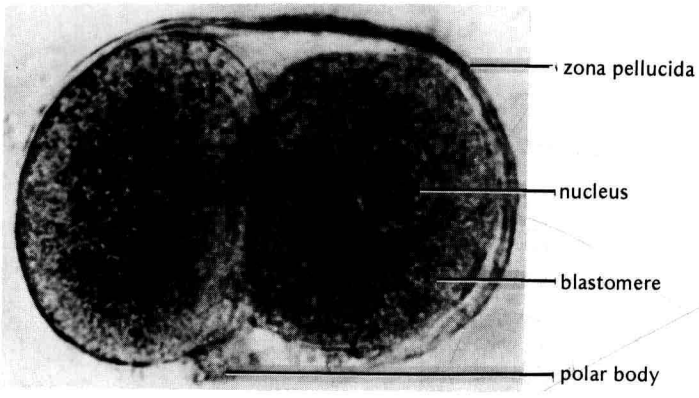


Figure 1 Human embryo after first sell division, two-celled embryo

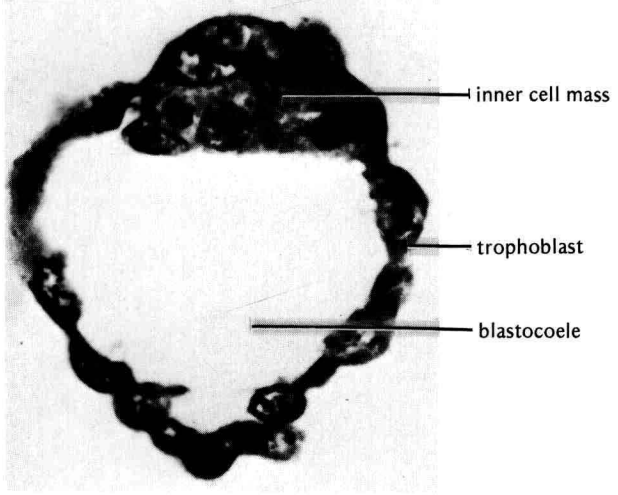


Figure 2 Human embryo at the blastocyst stage

*Reproduced by permission from O'Rahilly R. (1973): *Developmental Stages in Human Embryos. Part A: Embryos of First Three Weeks (Stages 1 to 9)*. Carnegie Institution of Washington. Publication 631. Figures 4, 8, 43, and 56.

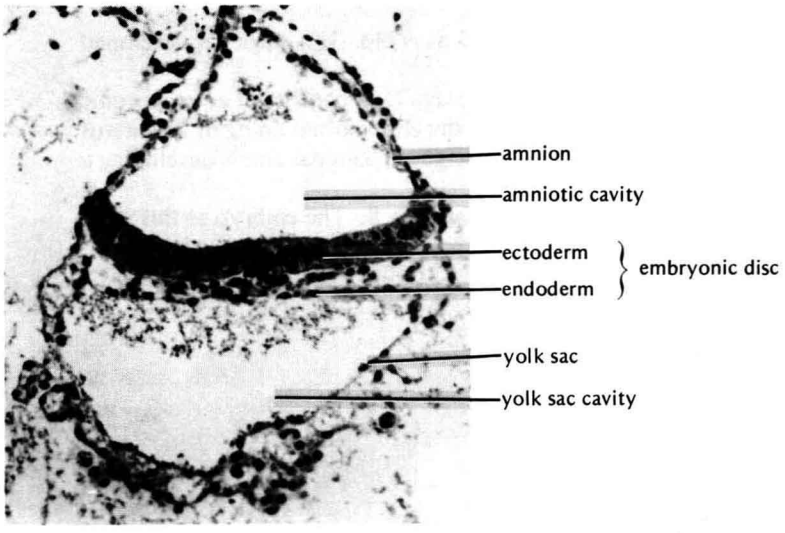


Figure 3 Human embryo at embryonic disc stage

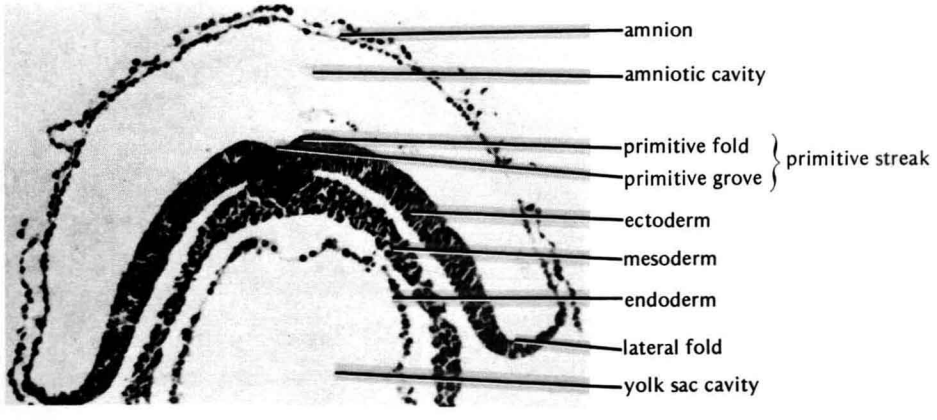


Figure 4 Human embryo at primitive streak stage

6.5-mm Human Embryo

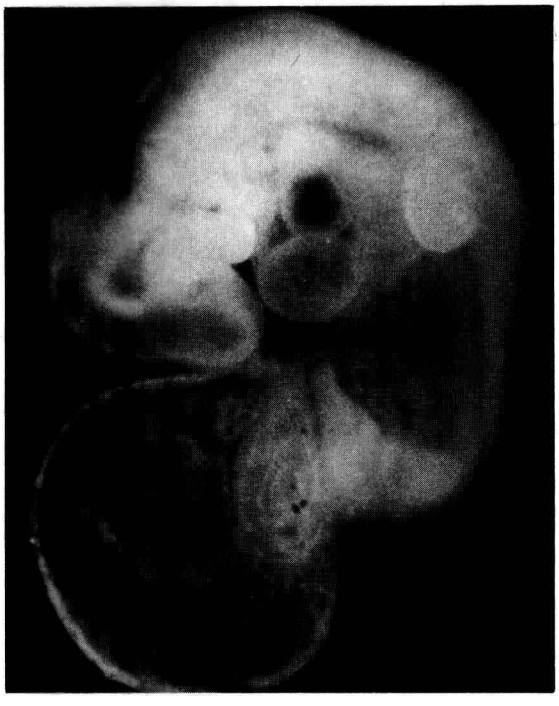


Figure 5 6.5-mm human embryo

6.5-mm Human Embryo

The specimen chosen to represent this stage is H-1099, a male. The embryo was preserved in Lillies fixative, sectioned at 10μ, and stained with PAS. The 6.5-mm human embryo is approximately 32 days (4 weeks) old and is at developmental stage 14.

Following is a list of some of the changes which have occurred since stage 8. The neural folds have elevated and closed into a tube. All 40 somites have appeared. The limb buds have appeared. Three branchial arches are present. The optic cup has evaginated from the brain and the lens vesicle is invaginating. Otic and olfactory placodes have appeared and the former has become a vesicle. The heart has fused in the midline, begun to beat, and has become divided into four primitive chambers. The foregut and hindgut have developed; the stomatodeum has ruptured; and the primordia of the thyroid, liver, pancreas, and lungs can be seen associated with the developing gastrointestinal tube. The mesonephros has developed and the metanephros is appearing.

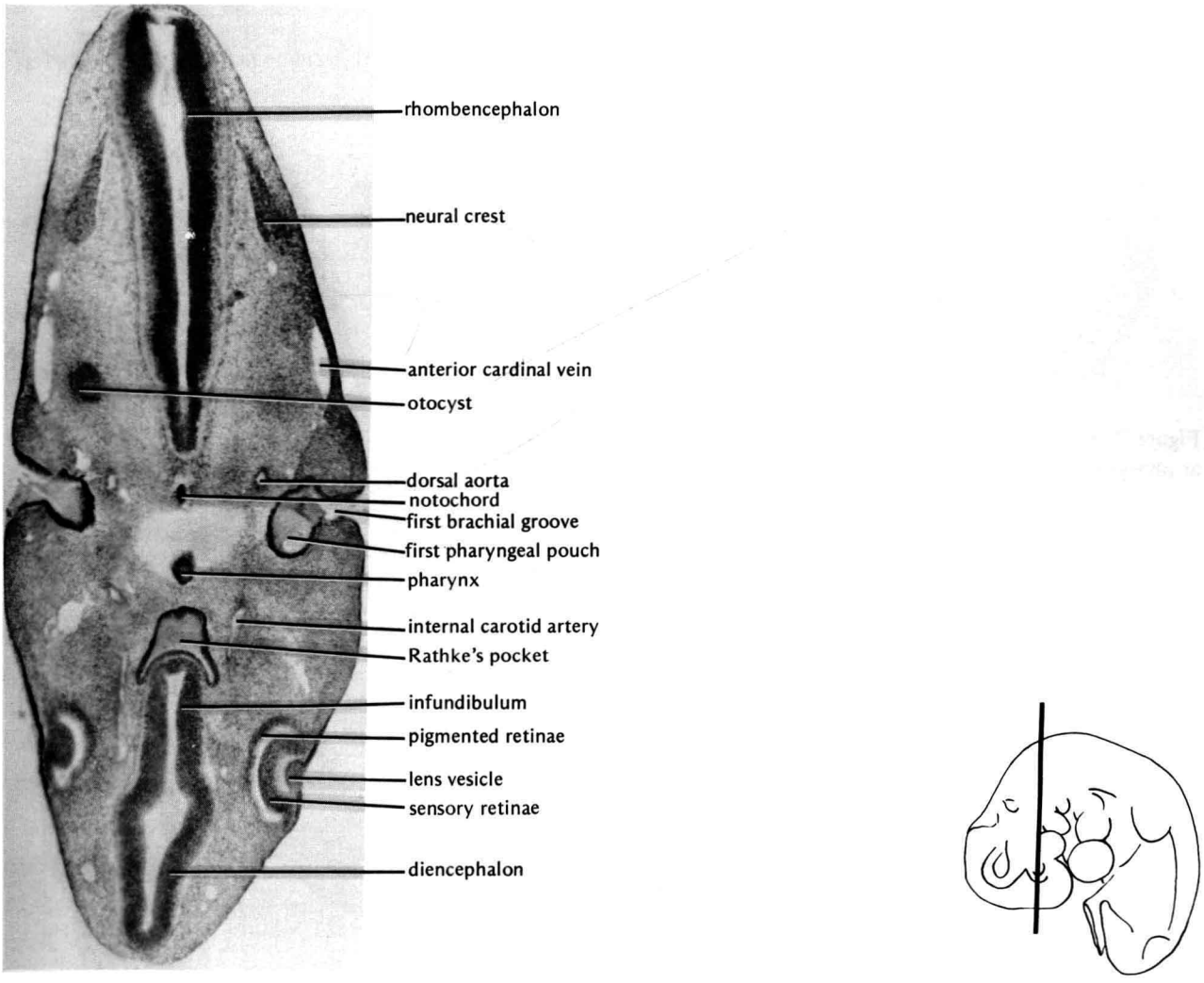


Figure 6 6.5-mm human embryo, transverse section at brain level

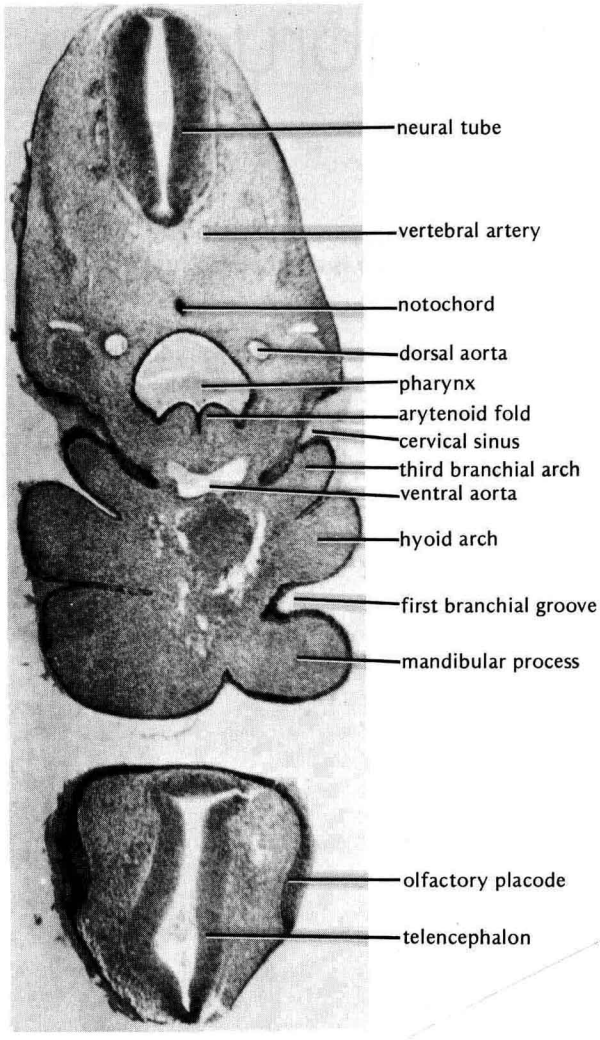
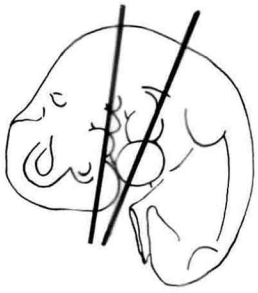


Figure 7 6.5-mm human embryo, transverse section at pharynx level



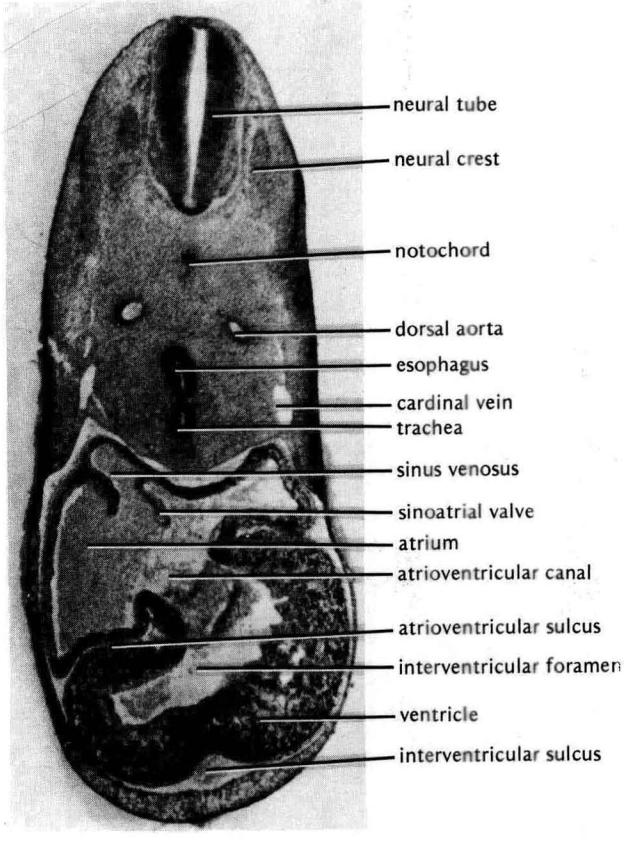


Figure 8 6.5-mm human embryo, transverse section at heart level