raymond f. gasser

ATLAS OF HUMAN EMBRYOS

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raymond f. gasser Ph.D.
PROFESSOR OF ANATOMY
LOUISIANA STATE UNIVERSITY MEDICAL CENTER
ASSOCIATE DEAN
LOUISIANA STATE UNIVERSITY SCHOOL OF MEDICINE
NEW ORLEANS, LOUISIANA

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dedicated to the dignity of human life;
my teachers and students;
Rusty, Ray, Jr. and Chris

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preface

The most important and yet most difficult part of gross anatomy is the understanding and remembering of adult anatomic relations. This task is made easier if one is aware of early prenatal conditions when the body is more simply arranged. The most logical and meaningful way to formulate concepts and principles of adult anatomy is to become familiar first with the embryonic form. This knowledge will better enable one to relate and store the voluminous details of adult anatomy.

This atlas was assembled with the hope that it will help students obtain a firm foundation on which to organize and understand adult human anatomy. It may also serve investigators as a reference for the arrangement of *normal* human embryos during the period when most birth defects occur.

Since the foundations of the definitive body plan are established during the embryonic period, only this portion of development is included. This atlas is divided into eight chapters covering the first eight weeks of prenatal life. The age of each specimen is based on the publications of Iffy *et al.* (Acta Anat 66: 178–186, 1967) and/or O'Rahilly (Anat Anz 130: 556–559, 1972). The important events in each week are presented in outline form and, when possible, organized according to the body systems. Sincere efforts were made to use *Nomina Embryologica* (1970) and *Nomina Anatomica* (1966) terminology. The many micrographs are of representative levels through almost technically perfect specimens. Photographic retouching was used minimally. A bar giving the magnification accompanies most illustrations thus allowing for an appreciation of the actual size of the developing organs. Every effort was made to orient accurately each micrographic section, not only in the embryo itself but also in most of its systems. The level of each section is indicated on drawings taken from wax or graphic reconstructions. A legend points out important features in each section.

After the third week, one embryo illustrates the level of development for each week. Studying the sections in series enables one to follow the morphogenesis of the systems and, at the same time, to become aware of the very important relations one system has to another during the perion of organogenesis. An appreciation of the shifts that viscera undergo before they come to rest in their adult position can be attained by comparing the position of each viscus at different stages of development. This information helps explain many definitive anatomical facts (e.g., nerve patterns) and gives meaning to the possible locations of various pathological developments (e.g., thyroglossal cysts).

acknowledgments

This book is the result of the assistance and goodwill of many enthusiastic and talented people. With one exception, all of the specimens are from the Carnegie Collection when it was housed at the Carnegie Institution of Washington, Department of Embryology, Baltimore, Maryland. Several dedicated embryologists spent many years producing this outstanding collection of human embryos. The references in each chapter recognize those whose specimens were used. I wish to thank Dr. James Ebert for making the collection and the facilities in Baltimore available. The assistance given by Drs. Ronan O'Rahilly and Bent Böving is also appreciated. The idea for the atlas was a result of the guidance, encouragement and example of my friend and teacher, the late Dr. Tryphena Humphrey. The work began with her 18 mm embryo that is part of the Hooker-Humphrey Collection at the University of Alabama Medical Center, Department of Anatomy, Birmingham, Alabama.

Fortunately I was able to secure the services of Don Alvarado, whose exceptional artistic ability is so evident in each of his drawings. The many quality micrographs were made through the talented photographic efforts of Charles Falk, Dick Grill, Gene Miscenich and Elizabeth Candelario. Varia Adams did a superb job with the necessary retouching. I will forever be grateful to my technician, Cathy Chase, who performed a dozen different tasks including trimming the micrographs and placing the leader lines; she never complained when my inconsistencies caused her additional work. The efficiency and patience of the typist Eunice Schwartz are appreciated; she somehow managed to decipher my handwriting. My thanks are extended to Drs. Elizabeth Crosby and Jerry Brown for their valuable assistance with the identification of structures in the brain sections, and to Dr. Marjorie Fox for reviewing the cardiovascular system. I am indebted to Dr. Melvin Hess for the necessary travel funds and the proper environment in which to work. Most necessary was the generosity of the Edward G. Schlieder Educational Foundation without whose financial support the atlas could never have been assembled. I wish to thank the people at Harper and Row for the professional and friendly manner in which they handled its printing and publishing. Finally, I hope that the many hours spent at night and weekends on this endeavor are justified—they were taken primarily from my wife and children.

ATLAS OF HUMAN EMBRYOS

contents

1

the first week of life

conception to implantation period

I. CONCEPTION (FERTILIZATION)

Fig. 1–1

1. *Conception* is the process whereby one *male gamete* (*sperm*) fuses with one *female gamete* (*ovum*) resulting in a new cell called the *zygote.* Since each gamete contains 23 chromosomes (1*n*), the diploid number (2*n*) of 23 pairs is restored in the embryo. The sex of the new individual is determined at the moment of conception by the type of sex chromosome in the male gamete. The zygote contains genetic information from both parents.
2. Conception occurs in the infundibular region of the uterine tube. The ovum is surrounded by a thick layer of glycoprotein called the *zona pellucida.* Sperm become firmly attached to the zona pellucida. After one sperm enters the ovum, permeability of the zona pellucida changes preventing other sperm from entering.
3. One *male* and one *female pronucleus* is formed within the one-cell zygote. The second *meiotic division* of the ovum is completed resulting in the production of a second *polar body.* Duplication of the inherited information (DNA) that resides in each pronucleus produces the 4*n* amount in the cell.
4. The spindle of the first *mitotic division* forms. Each paternal and maternal chromosome splits longitudinally with each half moving in a random fashion to opposite poles of the cell.
5. The one-cell zygote separates into two cells (Fig. 1–2), each containing a nucleus with the identical amount (2*n*) of inherited information (DNA). Cleavage begins with the formation of the two-cell zygote (schizolig).

II. CLEAVAGE

Figs. 1–1, 1–2, 1–3*A*

1. *Cleavage* is defined as a rapid succession of mitotic divisions resulting in the production of a progressively larger number of increasingly smaller cells called *blastomeres.*
2. Cleavage occurs in the zygote as it makes its way through the uterine tube to the uterine cavity. No true growth occurs since there is no increase in protoplasmic volume but only an increase in the number of cells.
3. The mass of cells reaches the uterine cavity when it is composed of approximately 16 cells. It has the appearance of a mulberry and is referred to as a *morula.* The cells in the center of the mass are called collectively the *inner cell mass* and will give rise to the *embryo proper.* The surrounding cells at the surface are called collectively the *outer cell mass* and will give rise to the *extraembryonic membranes.*

III. BLASTOCYST FORMATION

Figs. 1–1, 1–3*B*

1. The physical appearance of the morula changes when it enters the uterine cavity. Fluid collects between the inner and outer cell masses causing the inner cell mass to lie in an eccentric position. A cavity is thus formed called the *blastocoele.* The entire mass of cells is then referred to as a *unilaminar blastocyst.*
2. The zona pellucida disappears as the blastocoele enlarges. Cells of the outer cell mass flatten and collectively form the

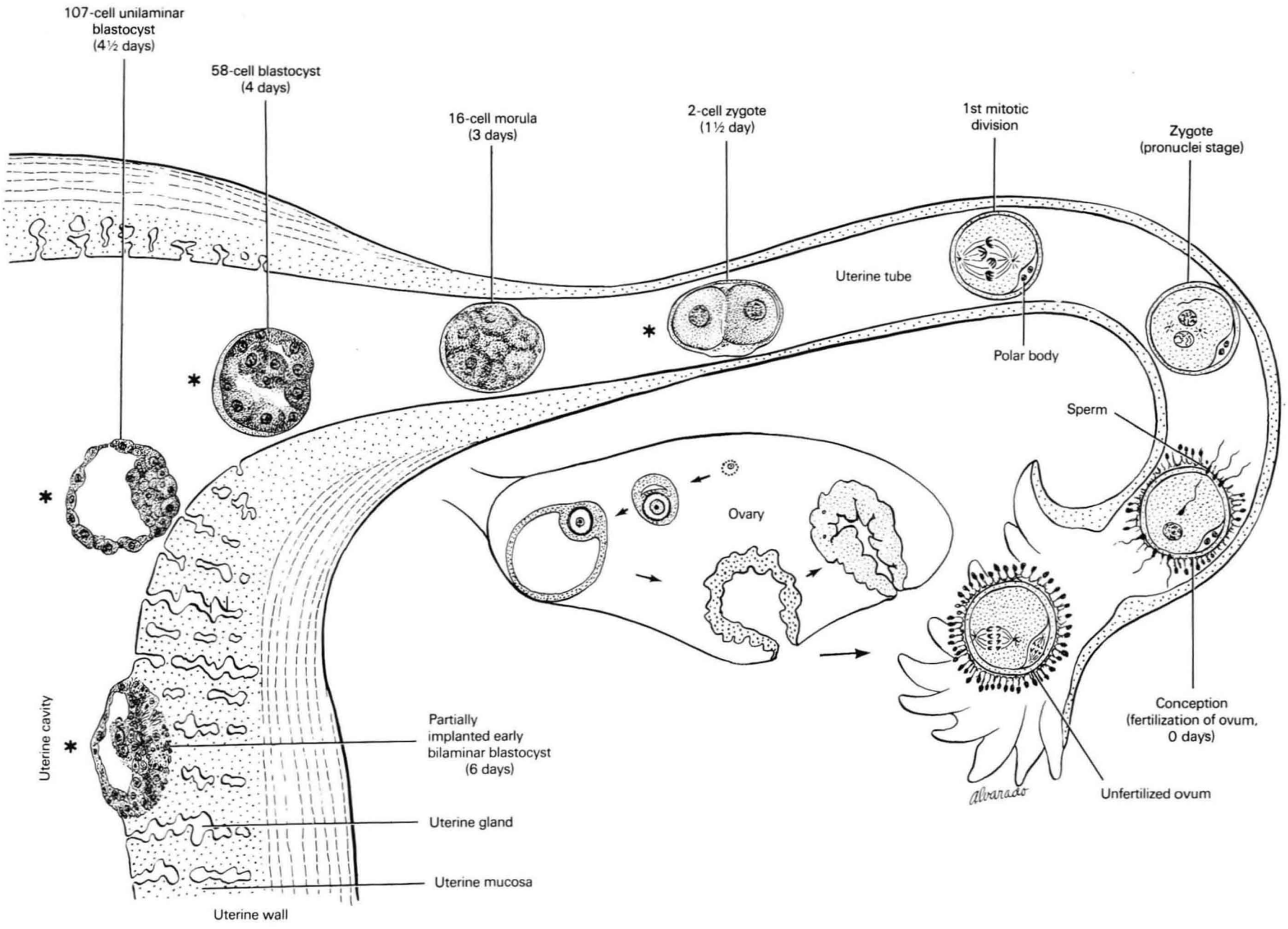

FIG. 1–1
The stages of development during the first week and the general location of each in the uterine tube or uterus. Specimens so marked (*) are illustrated elsewhere.

trophoblast. The inner cell mass becomes the *embryoblast* which lies at the *embryonic pole* of the blastocyst.

IV. IMPLANTATION

Figs.1–1, 1–4

1. *Implantation* is defined as the process whereby the blastocyst attaches to and erodes through the epithelial lining of the uterus (*endometrial epithelium*). The erosion of the epithelium is accomplished by the trophoblast, which allows the blastocyst to subsequently invade and embed in the underlying tissue (*endometrial stroma*).
2. Attachment occurs at the embryonic pole, probably around 6 days. Attachment usually occurs between the surface openings of the *uterine glands.*
3. The trophoblastic cells in contact with the endometrial stroma lose their cell boundaries and form a syncytium. This layer of trophoblastic cells is called the *syncytial trophoblast* (syncytiotrophoblast). Trophoblastic cells adjacent to the blastocoele retain distinct boundaries and form a thin, single layer of cells called the *cellular trophoblast* (cytotrophoblast). Small cells known as *extraembryonic mesoblasts* begin to differentiate *in situ* on the inner surface of the cellular trophoblast. The *amniotic cavity* begins as a cleft between the embryoblast and cellular trophoblast.
4. With the appearance of the amniotic cavity the embryoblast becomes the *embryonic disc.* The embryonic disc consists of two layers, the *epiblast* and *endoderm.* The epiblast is a thick layer of potential ectoderm and mesoderm. The endodermal cells border the blastocoele. Because of the two-layered embryonic disc the entire mass of cells is called a *bilaminar blastocyst.*

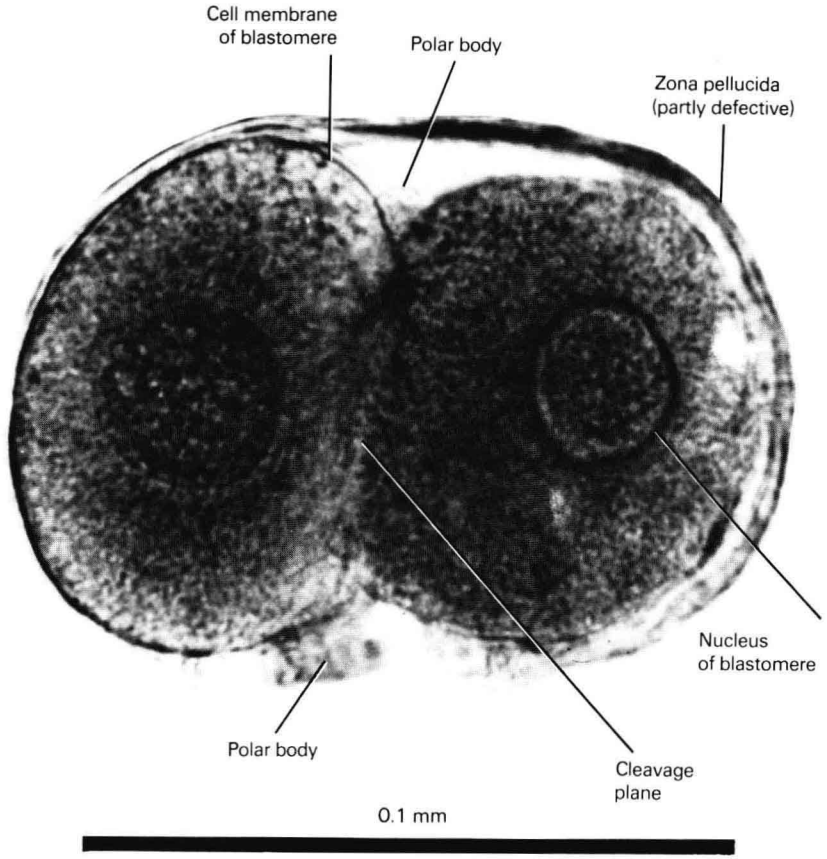

FIG. 1–2
The 2-cell zygote (schizolig)
Stage 2
Age 36 hours (1.5 days)
Carnegie collection 8698
Reference
Hertig AT, Rock J, Adams EC, Mulligan WJ: On the preimplantation stages of the human ovum: a description of four normal and four abnormal specimens ranging from the second to the fifth day of development. Contrib Embryol Carnegie Instn 35: 199–220, 1954

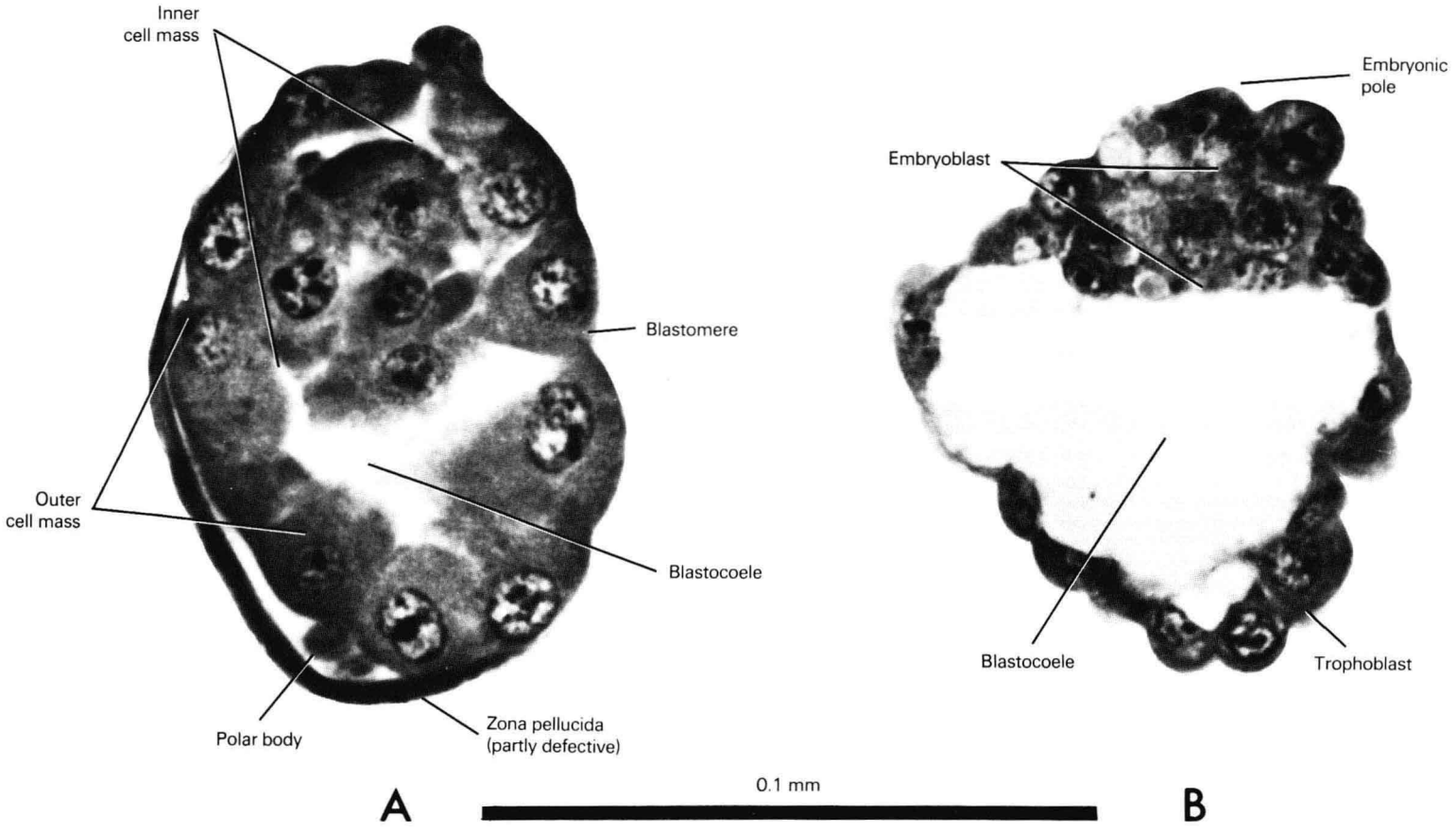

FIG. 1–3
***A.* The 58-cell blastocyst**
Stage 3
Age 96 hours (4 days)
Carnegie collection 8794
Reference
Hertig AT, Rock J. Adams EC, Mulligan WJ: On the preimplantation stages of the human ovum: a description of four normal and four abnormal specimens ranging from the second to the fifth day of development. Contrib Embryol Carnegie Instn 35:119–220, 1954

***B.* The 107-cell (unilaminar) blastocyst**
Stage 3
Age 108 hours (4.5 days)
Carnegie collection 8663
Reference
Hertig AT, Rock J, Adams EC, Mulligan WJ: On the preimplantation stages of the human ovum: a description of four normal and four abnormal specimens ranging from the second to the fifth day of development. Contrib Embryol Carnegie Instn 35:199–220, 1954

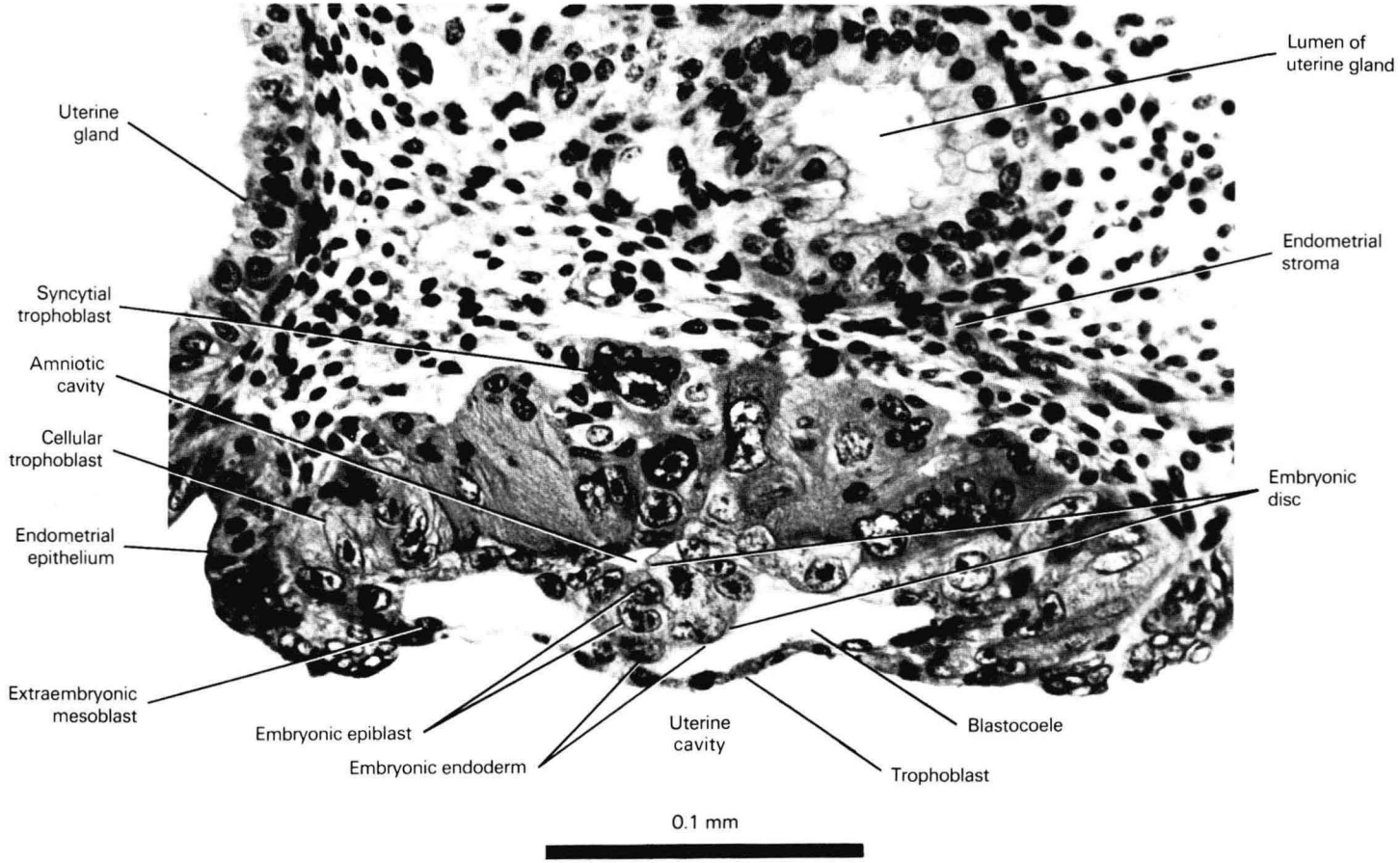

FIG. 1–4
The partially implanted (bilaminar) blastocyst with the adjacent uterine wall
Stage 5
Age 7 days
Carnegie collection 8020
Reference
Hertig AT, Rock J: Two human ova of the pre-villous stage, having a developmental age of about seven and nine days respectively. Contrib Embryol Carnegie Instn 31:65–84, 1945

II

the second week of life

bilaminar and early trilaminar period

I. EMBRYO PROPER

Figs. 2–1 to 2–6

1. The blastocyst becomes firmly embedded in the endometrium (uterine mucosa). It establishes a relationship with the maternal blood vessels whereby it receives food and eliminates waste products. Both the embryo proper and the extraembryonic membranes grow rapidly. A *fibrous coagulum* forms at the site of penetration of the endometrium and is soon covered over entirely by epithelial cells completing the implantation process.
2. Early in the second week the embryo appears as a *bilaminar* or two-layered disc with an upper layer called the *epiblast* and a lower layer called the *endoderm.* The epiblast is thick and composed of regularly arranged columnar cells. It is continuous at its periphery with the amnion (see below). The endoderm is thin and made up of irregularly arranged, polyhedral cells. It is continuous at its periphery with the yolk sac (see below).
3. By the end of the second week the *primitive streak* becomes evident in the epiblast near the caudal end of the embryonic disc. It is produced by the epiblast and begins as a clump of cells in the midline between the epiblast and the endoderm. This clump of cells represents the first appearance of embryonic *mesoderm.* After the primitive streak produces embryonic mesoderm, the epiblast layer is referred to as *ectoderm.*

II. EXTRAEMBRYONIC MEMBRANES

Figs. 2–1 to 2–6

A. TROPHOBLAST

1. As the trophoblast invades deeply into the endometrium, the maternal capillaries in the vicinity become congested with blood cells and dilate to form *sinusoids.* The *syncytial trophoblast* erodes the wall of the sinusoids and becomes continuous with their endothelial lining.
2. Spaces called *lacunae* develop in the syncytial trophoblast by fusion of intracytoplasmic vacuoles. The lacunae join together to form an intercommunicating network that becomes continuous with the maternal blood vessels. Maternal blood begins to flow through the lacunar network, establishing the early *uteroplacental circulation.*
3. The *cellular trophoblast* is located on the inner or embryo side of the syncytial trophoblast. Cells called *extraembryonic mesoblasts* form along the inner surface of the cellular trophoblast. Their origin is controversial.

B. CHORION

1. By the end of the second week the extraembryonic mesoblasts fuse with the overlying trophoblast to form a membrane called the *chorion.* The chorion encloses the embryo proper and all of the other extraembryonic membranes.

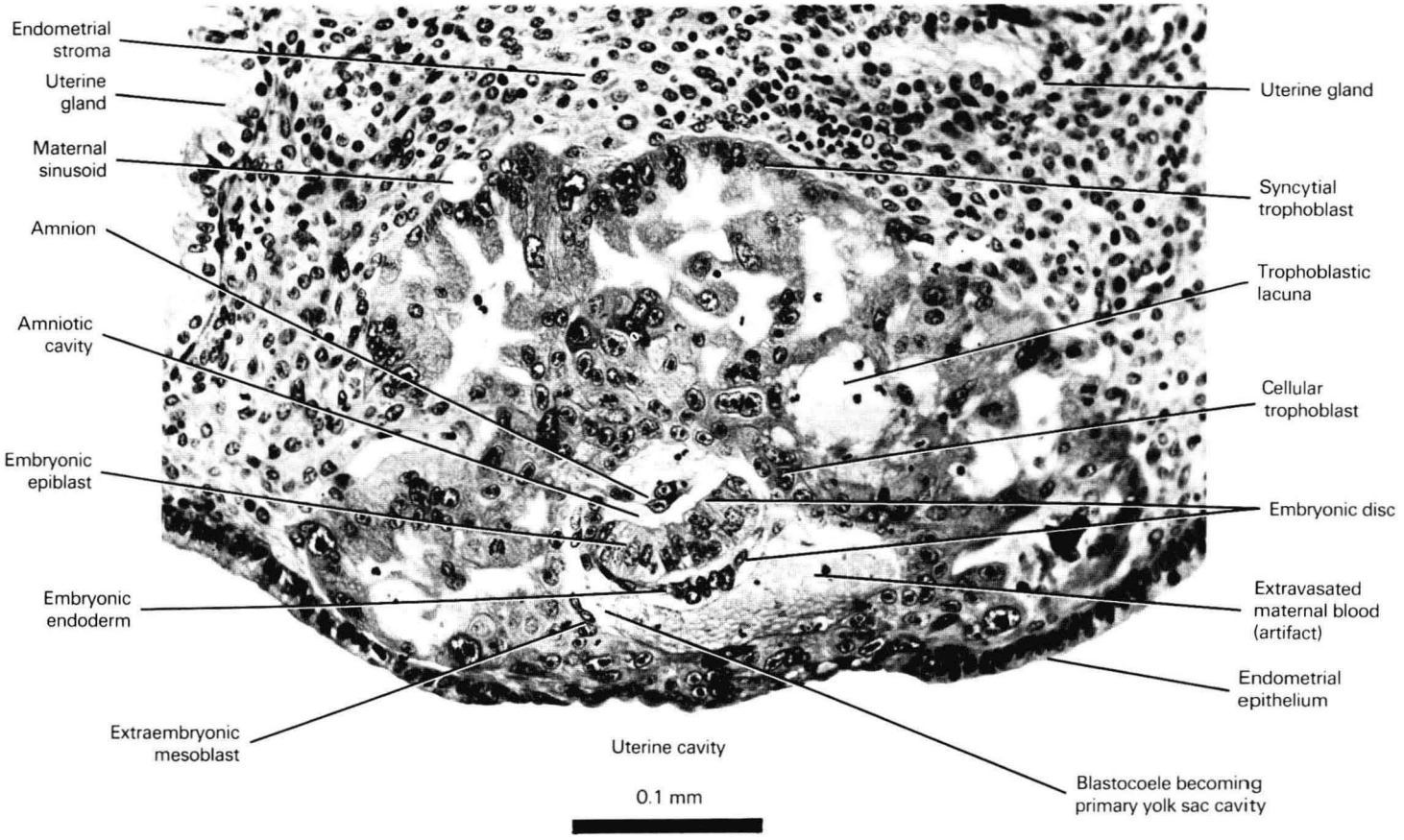

FIG. 2–1
The 9-day previllous embryo (bilaminar blastocyst)
Stage 5
Age 9 days
Carnegie collection 8004
Reference
Hertig AT, Rock J: Two human ova of the pre-villous stage, having a developmental age of about seven and nine days respectively. Contrib Embryol Carnegie Instn 31:65–84, 1945

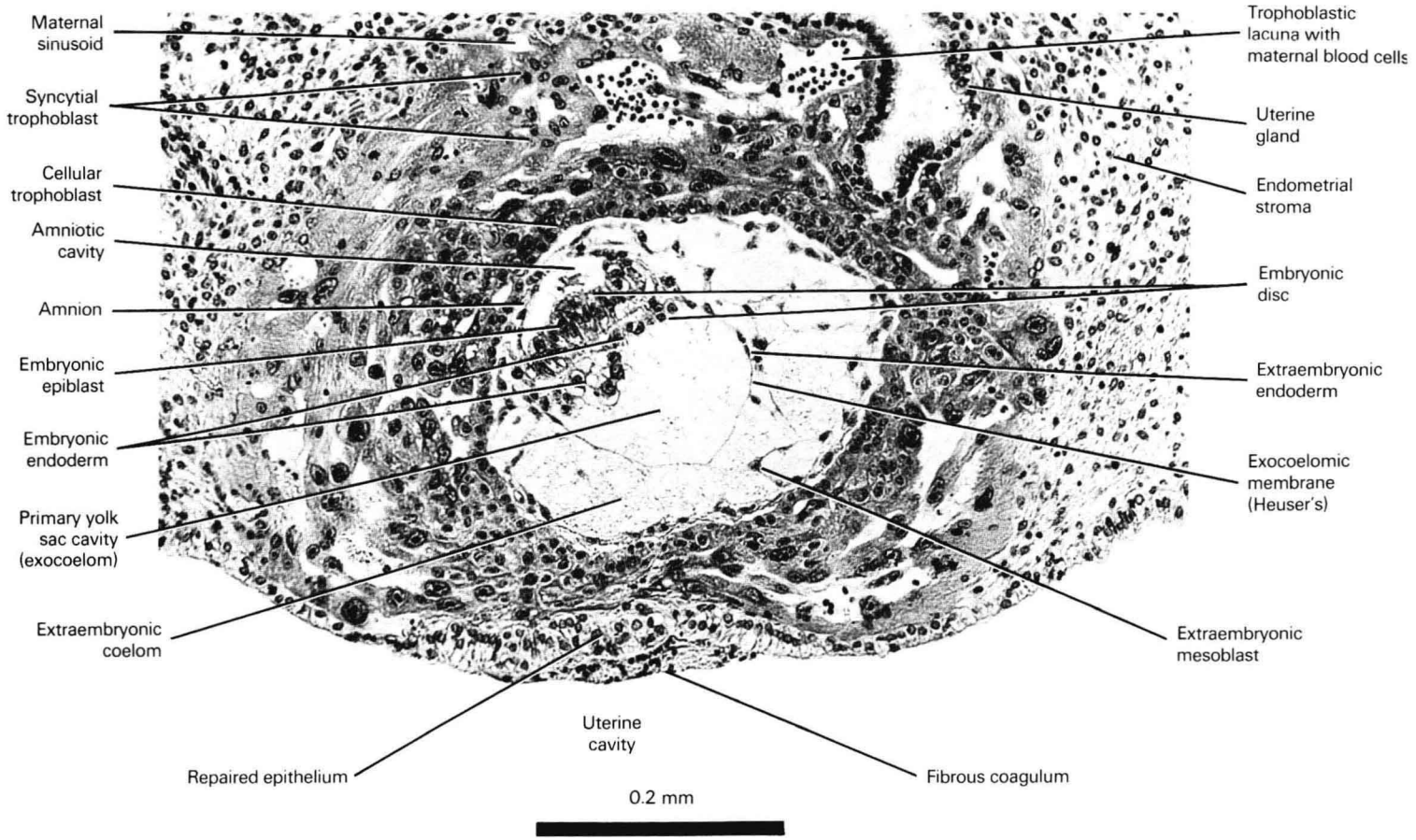

FIG. 2–2
The 11-day previllous embryo (late bilaminar blastocyst)
Stage 5
Age 11 days
Carnegie collection 7699
Reference
Hertig AT, Rock J: Two human ova of the pre-villous stage, having an ovulation age of about eleven and twelve days respectively. Contrib Embryol Carnegie Instn 29:127–156, 1941