

STUDY GUIDE AND REVIEW MANUAL OF

Human Embryology

SECOND EDITION

KEITH L. MOORE, M.Sc., Ph.D., F.I.A.C., F.R.S.M.

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PREFACE

This Study Guide and Review Manual is designed primarily for use with the author's textbooks: *The Developing Human: Clinically Oriented Embryology* and *Before We Are Born: Basic Embryology and Birth Defects*, published by the W.B. Saunders Company. However, it can be used with similar advantage by students with other textbooks of human embryology.

This book is designed as a *study guide* for beginning students and a *review manual* for advanced students preparing for National Board, Licensing, or Fellowship examinations. Because multiple-choice examinations are being used more and more, and are formidable even to the best prepared, commonly used types of these questions have been developed around each topic in embryology. These test questions are intended for those wishing to determine the state of their knowledge and to improve their skills with multiple-choice exams.

With increasing encroachment upon the time available for the formal study of embryology, there is a need for more independent study by students. To learn independently, stated objectives are required. At the beginning of each chapter in this book, there is a *list of objectives* indicating what students should be able to do when they have completed their study of these topics. The self-assessment questions in each chapter provide students with feedback as to their status in achieving the objectives, and afford them the opportunity to correct deficits that may exist in their knowledge. Encouraging students to use this study guide should not be regarded as "spoon feeding" because only those students who attempt the questions and study the notes and explanations accompanying the answers will be "nourished".

I am grateful to students from around the world who have written to me expressing their appreciation of this study guide and review manual of embryology. Their enthusiasm for it encouraged me to update it and to add more illustrations. I am also grateful to many colleagues, especially Drs. J.W.A. Duckworth, D.L. McRae, and C.G. Smith, Professors Emeritii, University of Toronto. I am also indebted to Dr. T.V.N. Persaud, Professor and Head of Anatomy in the University of Manitoba, for his many suggestions for improving this book. I am especially grateful to my wife Marion who typed the manuscript, did the graphic work, and was copy editor.

Keith L. Moore

Front cover: photograph of a 13-week fetus

Study Guide and Review Manual of Human Embryology

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USER'S GUIDE

This guide is designed to help you study, and later review, human embryology by providing learning objectives and various types of multiple-choice questions based on these objectives. The questions are not intended as a substitute for careful study, but they should enable you to detect areas of weakness and afford the opportunity to correct deficits in your knowledge.

Although answers to questions are explained and relevant notes are given, you should consult your textbook for a comprehensive review of difficult concepts and processes. Through discussion of weak areas with your colleagues and instructors, you can test your ability to do the things listed as learning objectives. To use this guide most effectively, the following steps are suggested:

1. *Read the objectives* listed at the beginning of the chapter you plan to study.
2. *Carefully study the appropriate chapter(s)* in your textbook, focusing on the topics included in the objectives.
3. *Answer the true and false questions.*
4. *Complete the sentences with missing words.* If your answers do not agree with the answer key, read the notes, explanations, and appropriate material in your textbook before proceeding.
5. *Write in the missing words in the various sentences.* This may be difficult because the correct words are not given with a number of distractors, as in the five-choice completion questions. If you are unable to complete some sentences, read the notes, explanations, and appropriate material in your textbook and try again.
6. *Attempt the series of self-assessment tests.* All questions are designed to be answered at the rate of about one per minute. As you complete each set of questions, check your answers. If any of your answers are wrong, read the notes and explanations and study the appropriate material and illustrations in your textbook before proceeding to the next set of questions.
7. If you get 80 per cent or more of the questions correct on the first trial, or during a subsequent review, you have performed very well and should have no difficulty answering similar questions based on the objectives given in this guide.

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INTRODUCTION

Terms and Concepts

OBJECTIVES

BE ABLE TO:

- * *Define the term development and the developmental periods⁺.*
- * *Explain why embryology forms a basis for medical and dental practice.*
- * *Use the various terms of position and direction and to illustrate the various planes of the body.*
- * *Explain the difference in meaning between the following terms: embryo and fetus; conception and conceptus; embryology and developmental anatomy; and embryology and teratology.*

TRUE AND FALSE STATEMENTS

DIRECTIONS: Indicate whether the following statements are true or false by circling the T or the F at the end of each statement.

1. Human development begins when an ovum is fertilized by a sperm. T or F
2. Development is a rapid process occurring during a relatively short period. T or F
3. Important developmental changes, in addition to growth occur during childhood. T or F
4. The term conceptus refers to all structures which develop from the inner cell mass. T or F
5. As a child becomes older, the rate of growth slows down. T or F
6. Puberty is the period during which primary sexual characteristics develop. T or F
7. Embryology is an essential basis for obstetrics and perinatology. T or F
8. Cranial and caudal are used to indicate the relative levels of structures in embryology. T or F

⁺Make no attempt to memorize the Timetables of Human Prenatal Development. Use them as you would a calendar to indicate important events.

INDICATE WHETHER STATEMENTS ARE TRUE OR FALSE

9. The hands are on the distal portions of the upper limbs. **T or F**
10. The knee is distal to the ankle. **T or F**
11. Sections parallel to the median plane, but not through it, are called sagittal sections. **T or F**
12. The anatomical position provides an unambiguous system of correlation for the embryo. **T or F**

-----ANSWERS, NOTES AND EXPLANATIONS-----

1. **T** The development of a human being begins with fertilization, the process by which a sperm from the male and an ovum from the female unite to form a zygote. As soon as fertilization is complete, the zygote divides into two blastomeres and human development has begun.
2. **F** Development is a gradual bringing to completion, both in structure and in function; in some cases it continues long after birth, e.g., the brain. While it is true that remarkable development occurs over a short period (first 8 weeks), development is not completed during the embryonic period. Some structures (e.g., the reproductive organs) appear long before the necessity or possibility of their functional activity.
3. **T** Development does not stop at birth or during infancy, but continues during childhood, adolescence, and into adulthood.
4. **F** The term conceptus refers to all structures which develop from the zygote, embryonic, and extraembryonic structures (i.e., the embryo that develops from the inner cell mass and the membranes which develop from the trophoblast).
5. **T** Just before puberty, however, growth accelerates rapidly; this is known as the adolescent or prepubertal growth spurt.
6. **F** Primary sexual characteristics (basic differences) develop during the embryonic and fetal periods and secondary sexual characteristics (e.g., mammary glands in female, growth of pubic hair) develop during puberty.
7. **T** Embryology, obstetrics, and perinatology are concerned with development of the embryo and fetus and with development of the fetal membranes connecting the fetus and the mother. This knowledge is essential for understanding the physiological relationship between the mother and the fetus.
8. **T** Cranial means toward the cranium, e.g., the heart is cranial or superior to the liver. Caudal means toward the tail, e.g., the pelvis is caudal or inferior to the abdomen. The term caudal is frequently used in embryos, instead of inferior and it is appropriate because embryos have tails.
9. **T** Structures like the hands that are at a distance from the source of attachment of structures (the upper limbs in this case) are distal.
10. **F** The knee is closer to the source of attachment of the lower limb than the ankle, thus the knee is proximal to the ankle.

11. **T** Longitudinal sections through the median plane are called median sections. They divide the body vertically into right and left halves. Sections parallel to the median plane are called sagittal sections.
12. **F** The term anatomical position is not used for embryos, but all descriptions of infants, children, and adults are based on this position. The position of embryos used for descriptive purposes is similar to that of typical four-legged animals.

MISSING WORDS

DIRECTIONS: Write in the missing word or words in the following sentences.

1. Human development is a continuous process of _____.
2. The most striking advances in development occur during the first _____ weeks.
3. The fetal period extends from the ninth week until _____.
4. The median plan is a _____ plane passing through the center of the body, dividing it into _____ and _____ halves.
5. A _____ plane is any plane passing through the body parallel to the median plane.
6. In the lower limb, the knee is _____ to the ankle and the ankle is _____ to the knee.

----- ANSWERS, NOTES AND EXPLANATIONS -----

1. growth and differentiation. Development is a continuous process of change and growth. Growth is an increase in size, whereas differentiation is an increase in complexity and organization. It is important to remember that important changes, in addition to growth, occur after birth, e.g., the teeth develop and erupt and secondary sexual characteristics appear.
2. eight. By the end of the eighth week, i.e., of the embryonic period, the beginnings of all major structures are present.
3. birth. As soon as the fetus is born, it is called a neonate or newborn infant and the neonatal period begins.
4. vertical; right; left. This plane passes lengthwise through the midline of the body from front to back.
5. sagittal. A sagittal plane is any plane passing through the body parallel to the median plane. The median plane divides the body vertically into right and left halves.
6. proximal; distal. To indicate distance from the source of attachment, structures are designated as proximal or distal. These terms are used particularly in the limbs, instead of superior and inferior.

FIVE-CHOICE COMPLETION QUESTIONS

DIRECTIONS: Each of the following questions or incomplete statements is followed by five suggested answers or completions. SELECT THE ONE BEST ANSWER in each case and then underline the appropriate letter at the lower right of each question.

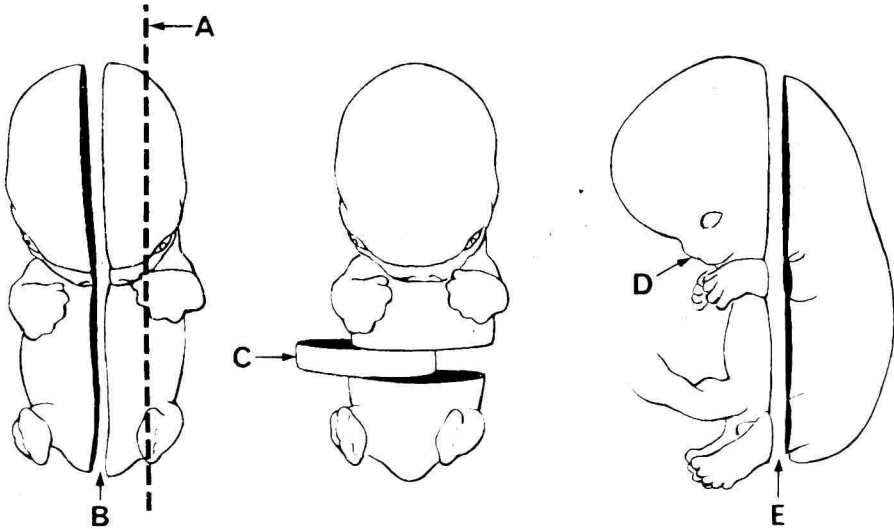
1. THE TERM CONCEPTUS INCLUDES ALL STRUCTURES WHICH DEVELOP FROM THE:
A. Chorion
B. Embryoblast
C. Zygote
D. Trophoblast
E. None of the above
A B C D E
2. SELECT THE BEST TERM DESCRIBING THE FOOT IN REFERENCE TO THE LEG:
A. Ventral
B. Posterior
C. Distal
D. Inferior
E. Proximal
A B C D E
3. A SECTION THROUGH AN EMBRYO DIVIDING IT INTO FRONT AND BACK PARTS IS A _____ SECTION.
A. Frontal
B. Sagittal
C. Cross
D. Oblique
E. None of the above
A B C D E
4. IN THE ADULT IT IS STATED THAT THE NECK IS SUPERIOR TO THE THORAX. THE CORRESPONDING TERM FOR AN EMBRYO IS:
A. Dorsal
B. Inferior
C. Caudal
D. Posterior
E. Cranial
A B C D E
5. THE PLANE OR SECTION DIVIDING A FETUS INTO RIGHT AND LEFT HALVES IS CALLED THE _____ PLANE OR SECTION.
A. Sagittal
B. Median
C. Coronal
D. Transverse
E. Frontal
A B C D E

ANSWERS, NOTES AND EXPLANATIONS

1. **C** The term conceptus is used when referring to the embryo (or fetus) and its membranes, i.e., the total products of conception which develop from the zygote. The conceptus (embryo and its membranes) expelled or removed during abortions is called an abortus.
2. **C** The foot is at the distal end of the leg. The term distal is commonly used in descriptions of a limb instead of the term inferior.
3. **A** A vertical section through the frontal (coronal) plane is known as a frontal (coronal) section. This is one of the major planes of the body.
4. **E** The neck of the embryo is cranial (cephalic) to the developing thorax; i.e., it is closer to the head. Cranial means toward the cranium and cephalic indicates towards the brain.
5. **B** The median plane is a vertical plane passing through the center of the body, dividing it into right and left halves. The median plane passes longitudinally through the embryo and intersects the surface of the front and back of the body at what are called the anteromedian and posteromedian lines.

FIVE-CHOICE ASSOCIATION QUESTIONS

DIRECTIONS: Each group of questions below consists of a numbered list of descriptive words or phrases accompanied by a diagram with certain parts indicated by letters, or by a list of lettered headings. For each numbered word or phrase, **SELECT THE LETTERED PART OR HEADING** that matches it correctly. Then insert the letter in the space to the right of the appropriate number. Sometimes more than one numbered word or phrase may be correctly matched to the same lettered part or heading.



1. ☐ Transverse plane
2. ☐ Rostral
3. ☐ Median plane

4. ☐ Frontal plane
5. ☐ Sagittal plane
6. ☐ Coronal plane

A. Median
B. Dorsal
C. Coronal

D. Caudal
E. Rostral

7. ☐ Posterior
8. ☐ Near to the nose
9. ☐ Frontal

10. ☐ Midsagittal
11. ☐ Nearer to the tail end
12. ☐ Lying in the middle

..... ANSWERS, NOTES AND EXPLANATIONS

1. **C** The transverse plane is any plane that is at right angles to both the median and frontal planes. Although the term transverse is often used synonymously with horizontal, you must understand that transverse implies that it is through the longitudinal axis of the structure. In the anatomical position, a transverse section through the hand is horizontal, but a transverse section through the foot in the anatomical position is coronal. Transverse sections are used very commonly in embryology; e.g., serial transverse sections of pig embryos are studied in the laboratory.
2. **D** The term rostral (toward the nose) is used to indicate the relationship of a structure to the nose; i.e., the eyes are rostral to the ears.

3. **B** The median plane is a vertical plane passing through the center of the body, dividing it into right and left halves. Median sections of embryos show, for example, the relationship of thoracic and abdominal structures.
4. **E** A frontal (coronal) plane is any vertical plane that intersects the median plane at a right angle. This kind of section is helpful in studying paired structures (e.g., the kidneys), and those that run longitudinally (e.g., the esophagus).
5. **A** A sagittal plane is any vertical plane passing through the body parallel to the median plane. A median section passes through the median plane. These sections are often used to show the course of structures that run through various regions of the body; e.g., the spinal cord runs through the neck, thorax, abdomen and pelvis.
6. **E** A frontal or coronal plane is any vertical plane that intersects the median plane at a right angle. It divides the body into front and back parts. Sections through the frontal plane are commonly used in studying embryos.
7. **B** Dorsal refers to structures near the back. In the adult, dorsal is equivalent to posterior. The term dorsal is used commonly in descriptions of embryos and in some descriptions of adults; e.g., we refer to the dorsum or dorsal part of the foot and the hand.
8. **E** Structures that are near the nose are rostral; e.g., a structure such as a nerve grows rostrally (toward the nose) or in a rostral direction.
9. **C** The term coronal is often used synonymously with frontal. Coronal refers to the circumstance that a coronal plane passes through the coronal suture of the skull.
10. **A** Midsagittal sections pass through the median plane; thus the terms midsagittal and median are used synonymously in reference to sections cut in the median plane, but the term median is preferable.
11. **D** Caudal is used in the description of structures nearer the tail end or rump. Embryos have tails until the seventh week. In descriptions of adult anatomy the term inferior is usually used.
12. **A** Median means lying in the middle and the term medial is used to indicate a structure nearer the median plane; i.e., the eye is medial to the ear.

THE BEGINNING OF DEVELOPMENT

The First Week

OBJECTIVES

BE ABLE TO:

- * *Describe spermatogenesis and oogenesis with special emphasis on the chromosomal changes occurring during maturation of the germ cells. Compare the sperm and the ovum with reference to: size; chromosome constitution; time of formation; transport; and viability.*
- * *Define the term nondisjunction and explain how this abnormal process leads to monosomy and trisomy. Describe the most common malformation syndrome.*
- * *Discuss the ovarian cycle (follicle development, ovulation, and corpus luteum formation) and the menstrual, or endometrial cycle, explaining how ovarian cyclic activity is intimately linked with cyclic changes in the endometrium.*
- * *Construct and label diagrams illustrating fertilization. Discuss capacitation, the acrosome reaction, sperm entry; changes occurring in the ovum, fusion of the pronuclei, and the results of fertilization.*
- * *Discuss cleavage of the zygote and implantation of the blastocyst, using labelled sketches. Define: morula, blastocyst, zona pellucida, trophoblast, inner cell mass, blastocyst cavity, embryonic pole, and hypoblast.*

TRUE AND FALSE STATEMENTS

DIRECTIONS: Indicate whether the following statements are true or false by circling the T or the F at the end of each statement.

1. Each human primary spermatocyte and primary oocyte normally contains 44 autosomes and two sex chromosomes. T or F
2. The normal haploid chromosome number of human secondary spermatocytes is 22 autosomes plus two different sex chromosomes. T or F
3. With respect to sex chromosome constitution, there are two kinds of normal sperms and ova. T or F
4. The undifferentiated male germ cells (spermatogonia) begin to increase in number at puberty, and continue to multiply during childhood. T or F

Oogonia do not proliferate after birth in humans and no primary oocytes form after birth. T or F

.....INDICATE WHETHER STATEMENTS ARE TRUE OR FALSE.....

6. Two sperms are derived from one primary spermatocyte. **T or F**
7. Each spermatid undergoes mitosis to form two sperms. **T or F**
8. At ovulation the nucleus of the secondary oocyte begins the second maturation division and progresses to metaphase where division is arrested. **T or F**
9. The polar bodies are small haploid, nonfunctional cells that subsequently degenerate. **T or F**
10. Progesterone prepares the endometrium for implantation of a blastocyst. **T or F**

.....ANSWERS, NOTES AND EXPLANATIONS.....

1. **T** These germ cells contain the diploid number (46) of chromosomes. Primary spermatocytes contain 44 autosomes plus an X and a Y chromosome, and primary oocytes contain 44 autosomes and two X chromosomes.
2. **F** The normal haploid chromosome number of human secondary spermatocytes is 23, consisting of 22 autosomes and one sex chromosome (X or Y). Two secondary spermatocytes result from the meiotic division of a primary spermatocyte. This is called the first meiotic or reduction division; it assures that the sperms that subsequently form will contain only the haploid number of chromosomes.
3. **F** There are two kinds of normal sperms (X and Y), but there is only one kind of normal ovum (X). If nondisjunction occurs, germ cells may not contain a sex chromosome, or they may contain more than one. Nondisjunction is the failure of two members of a chromosome pair to disjoin during anaphase of cell division, so that both pass to the same daughter cell.
4. **T** The spermatogonia multiply by ordinary cell division or mitosis. This process normally begins at puberty (the beginning of sexual maturity, usually between the ages of 13 and 16) and continues until old age. Follicle stimulating hormone (FSH) stimulates spermatogenesis in the seminiferous tubules.
5. **T** All oogonia form and are believed to enlarge and develop into larger cells called primary oocytes before birth. About two million are present in the ovaries, but many of these regress during childhood leaving 10 to 30 thousand by the age of 25 or so.
6. **F** Two secondary spermatocytes are derived from one primary spermatocyte during the first maturation (meiotic) division. Two spermatids result from the second maturation (meiotic) division of each secondary spermatocyte. Therefore, four sperms are derived from one primary spermatocyte, as a result of the two maturation or meiotic divisions.
7. **F** Spermatids do not divide; they are gradually transformed into sperms during the process of differentiation called spermiogenesis. During maturation the sperms undergo marked physiochemical changes which involve a concentration of chromatin and a loss of fluid from the cytoplasm.
8. **T** If fertilization occurs, the second maturation (meiotic) division of the secondary oocyte is completed and the second polar body is extruded. If fertilization does not occur, the second maturation division is not completed

and the oocyte soon degenerates.

9. **T** These small cells receive very little cytoplasm, but they normally have 23 chromosomes. They dispose of 23 chromosomes produced during meiosis assuring that the ovum that subsequently forms will contain only the haploid number of chromosomes. In this sense, polar bodies have a functional activity.
10. **T** Progesterone produced by the corpus luteum, probably in association with estrogens secreted by the ovarian follicles, induces the endometrial glands to swell, become tortuous and secrete profusely, and the connective tissue to become grossly edematous. Progesterone brings about the secretory phase of the menstrual cycle; these changes are designed to make the endometrium nutritive for the blastocyst.

MISSING WORDS

DIRECTIONS: Write in the missing word or words in the following sentences.

1. As a result of the abnormal process known as _____, some germ cells have 24 chromosomes and others only 22.
2. The usual site of fertilization is in the _____ part of the _____.
3. The gonadotropic hormones are _____ and _____; they are produced by the _____ lobe of the _____.
4. Ovulation is the process involving rupture of a mature _____ and release of its _____.
5. If the ovum is not fertilized, the corpus luteum begins to degenerate about _____ days after ovulation and is called a _____ of _____.
6. The human ovum remains viable for about _____ to _____ hours.
7. Once within the cytoplasm of the ovum, the sperm rapidly loses its _____ and its _____ enlarges to form the _____.
8. As the zygote passes down the _____, it undergoes rapid _____ divisions; this succession of divisions is known as _____.
9. At three days the _____, a solid ball of 16 or so cells called _____, leaves the uterine tube and enters the _____.
10. About the fifth day after fertilization, the membrane around the blastocyst, called the _____, degenerates and disappears. The _____ of the blastocyst then attaches to the _____ epithelium.

..... ANSWERS, NOTES AND EXPLANATIONS

1. nondisjunction. During maturation of germ cells, homologous chromosomes sometimes fail to separate and go to opposite poles of the cell. Both chromosomes then go to one germ cell, giving it 24 chromosomes. The other germ cell receives 22, one less than the haploid number. It is estimated

that about one of 200 unborn infants has chromosomal abnormalities which occurred during meiosis. These abnormalities cause congenital malformation e.g., the Down syndrome or trisomy 21.

2. ampullar; uterine tube. Fertilization of the ovum ordinarily occurs in the ampulla of the uterine tube within 24 hours after ovulation. The ampulla is the wide part of the tube between the isthmus and the infundibulum; it is the longest and widest part of the tube.
3. FSH; LH; anterior; pituitary gland. The production of gonadotropins by the pituitary is regulated by releasing factors produced by nerve cells in the hypothalamus. These hormones exert little or no direct action on the uterus or vagina, but act on the follicles and corpus luteum in the ovaries.
4. ovarian follicle; secondary oocyte. Ovulation is induced by FSH and LH. It should be noted that the secondary oocyte released at ovulation is not a mature oocyte. It matures only if a sperm contacts the oocyte and causes completion of the second meiotic division. It is then a mature ovum.
5. nine; corpus luteum; menstruation. As the corpus luteum degenerates, its progesterone production decreases and menstruation results. If the secondary oocyte is fertilized, degeneration of the corpus luteum is prevented by human chorionic gonadotropin (HCG) secreted by the syncytiotrophoblast. This hormone is important in the maintenance of the corpus luteum, and is the basis for pregnancy tests.
6. 12; 24. The human ovum (secondary oocyte) dies within 12 to 24 hours in vitro. It may remain viable for up to 24 hours in vivo, but it is generally believed that the human oocyte is capable of being fertilized for only a short period after ovulation (probably not longer than 12 hours in most cases).
7. tail; head; male pronucleus. The cell membrane of the sperm does not enter the oocyte. The tail, consisting of the middle piece, principal piece and end piece, degenerates and is apparently absorbed by the cytoplasm of the ovum. The main contribution of the sperm to zygote formation is the nucleus with its 23 chromosomes. Its sex chromosome content (X or Y) determines the sex of the embryo that develops from the zygote.
8. uterine tube; mitotic; cleavage. Cleavage consists of a succession of mitotic divisions of a diploid cell called a zygote. This results in the production of a progressively larger number of increasingly smaller diploid cells called blastomeres.
9. morula; blastomeres; uterus. Some factors (e.g., chronic inflammation of the uterine tube) may delay or prevent transport of the morula into the uterus. Implantation then takes place in the uterine tube; this is called an ectopic (extrauterine) pregnancy; over 90 per cent of ectopic pregnancies occur in the uterine tube.
0. zona pellucida; trophoblast; endometrial. As the blastocyst expands, the zona pellucida disappears. It must degenerate before implantation of the blastocyst can begin. The trophoblast cells then attach to the endometrial epithelium. Note that both the trophoblast and the maternal tissues are involved in implantation. It seems certain that the blastocyst exerts an influence, possibly both chemical and physical, on the endometrium. For implantation to occur, the endometrium must be in a receptive state, i.e., in the secretory phase of the menstrual cycle.