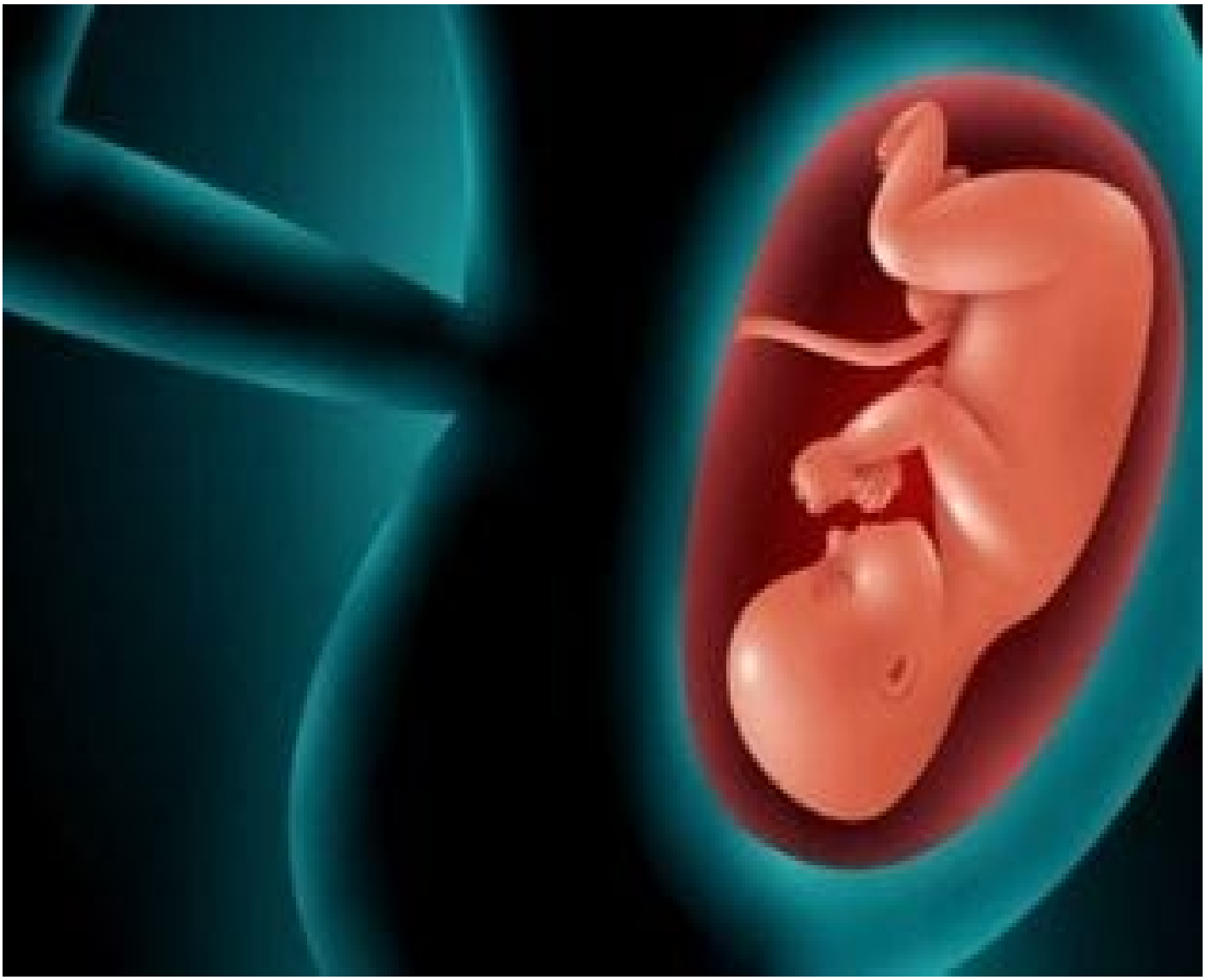
EMBRYOLOGY

STUDY GUIDE

Edited by associate professor L. I. Kyptenko



Ministry of Education and Science of Ukraine

Ministry of Health of Ukraine

Sumy State University

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Recommended by the Academic Council of Sumy State University

Sumy

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2024

UDC 611.013(075.8)

К 99

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Recommended for publication

by the Academic Council of Sumy State University

as a study guide

(minutes № 15 of 24.06.2024)

К 99 **Embryology** : study guide / L. I. Kyptenko, A. O. Ponyrko, T. P. Teslyk, V. Y. Illiashenko ; edited by associate professor L. I. Kyptenko – Sumy : Sumy State University, 2024. – 119 p.

UDC 611.013(075.8)

CONTENTS

INTRODUCTION

The course of The Human Histology is one of the most difficult subjects in The Medical Education System. Students have to understand and learn the features of the structure of histological structures in a short time. The process of studying of The Human Histology is known to be saturated with a significant amount of factual material, not easy, but extremely necessary for further study of medical disciplines.

The expediency of creating a Study Guide that contains basic information about the development and structure of ehe embryo is primarily due to the urgent need to help medical students form the necessary system of knowledge in the relevant sections of The Histology, which are traditionally characterized by complexity of understanding and a significant amount of data that require a concise and, at the same time, thorough explanation.

The study of the development and microscopic structure of germ cells, fertilization, gastrulation and implantation forms the basis of the future doctor's professional knowledge. Diagnosis and treatment of various diseases is based on a deep understanding of the mechanisms of functioning and structural organization of the embryo. This is facilitated by the development of new medical fields.

The Study Guide «Embryology» is written, in our opinion, in a form convenient for students, which will allow them to prepare for the class in a relatively short time. The theoretical material is illustrated with diagrams, drawings, electron micrographs and photographs of histological specimens with appropriate labels. The basis of Study Guide is the material of textbooks, manuals, and atlases of the national and foreign authors.

The structure of The Study Guide «Embryology» is based on the experience of previous editions and, as a rule, on feedback from the student audience. Several provisions and forms of presentation of the material, as well as the control unit are based on the methodological developments of the histology course of the Department of Morphology of the Academic and Research Medical Institute of Sumy State University.

The Study Guide is designed to help during extracurricular activities, as well as to organize students' independent work during practical classes. At the end of The Study Guide there is a list of references on the topics, which will certainly broaden the horizons of future doctors. A special block of illustrative tasks is used to develop the skills of morphological diagnosis of structures, as well as interpretation of their functional state, molecular organization, and regulatory features. In essence, this section of the manual is a «simulator» that makes it possible to develop students' practical skills, which is of fundamental importance in the training of a future doctor.

The authors have tried to present the material for the benefit of future professionals. We will be grateful for all the suggestions and comments and will take them into account in the next editions. We hope that this Study Guide «Embryology» will help students not only in preparing for practical classes in Histology but will also be interesting and useful at the further stages of studying of The Medicine and The Dentistry.

The Team of authors

SEX CELLS. FERTILIZATION

Embryogenesis is the process of development of an organism from fertilization till birth or way out from ovular membranes.

Embryology is the science studying both general regularities of embryogenesis and peculiarities processes of individual development of an organism.

Tasks of medical embryology

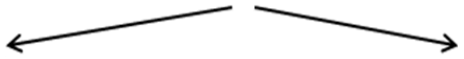
They are:

1) to study mechanisms of embryo development;

2) to understand the defects in embryo development;

3) purposeful influence on embryo development.

Main stages of human embryogenesis



Early:

1. Fertilization.
2. Cleavage.
3. Gastrulation (early, late).
4. Formation of axial complex of organs.
5. Formation of embryo body.

Late:

1. Histogenesis.
2. Organogenesis.

FIMALE SEX CELL

Ovum is known as an egg cell which is the largest cell in the human body. It is one of the cells apart from sperm from which a new life is formed. An ovum is produced from the ovaries of women and is then released into the fallopian tubes.

Main features:

1. Ovum is much larger than somatic cells. It is a cell of about 130–140 micrometres and somatic cells are only 10–20 mcm.

2. It has much cytoplasm (to provide the embryo with the initial cytoplasm mass).

3. In cytoplasm all the necessary organelles but centrosome (cell centre) are not present. So, it can't divide.

4. It has haploid set of chromosomes: 22 autosomes and 1 sex – X chromosome.

5. Presence of nutrients as yolk granules. Yolk is the compound of protein and lipids. The egg cells are divided into following types according to yolk amount:

A) **Alecithal** (without yolk).

They don't contain nutrient reserve. They are typical for inverterbrates which conduct a parasitic way of life (echinoccus, tapeworm, helminthes);

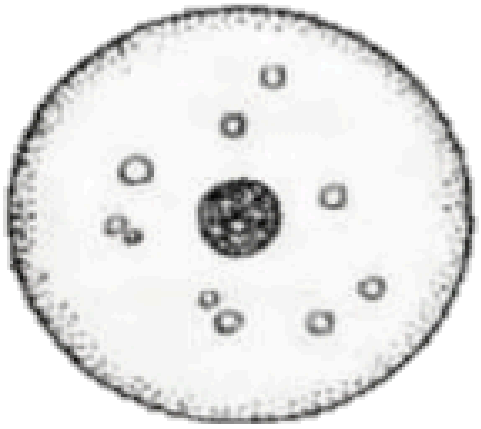


Figure 1 – *Alecithal type of egg cell*

B) **Isolecithal** (little yolk).

Yolk granules are distributed evenly through the cytoplasm.

a) *Primary isolecithal* typical for animals, which aquire early the ability for original feeding – lancet.

b) *Secondary isolecithal*, typical for animals with antenatal development – mammals, humans;

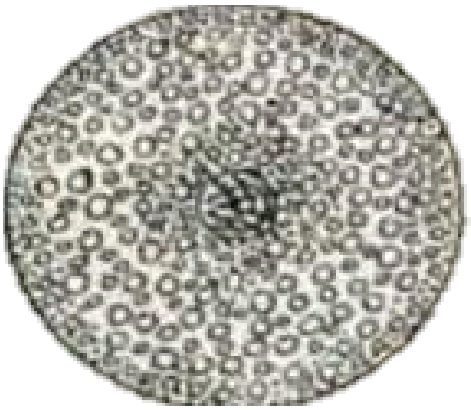


Figure 2 – *Isolecithal type of egg cell*

C) **Telolecithal** (contain a large amount of yolk).

a) *Moderately telolecithal*. Yolk is distributed on one pole – amphibian (a frog).

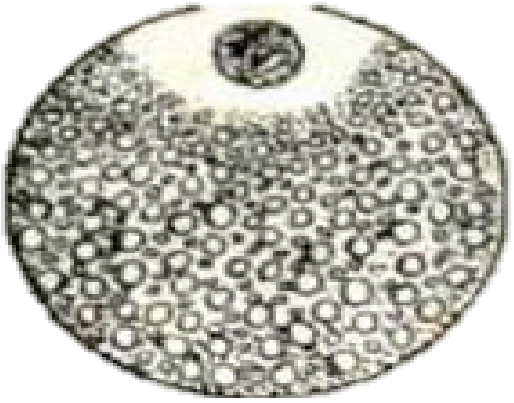


Figure 3 – *Telolecithal type of egg cell*

b) *Centrolecithal*. Yolk is in the centre and nucleus on the periphery – insects.

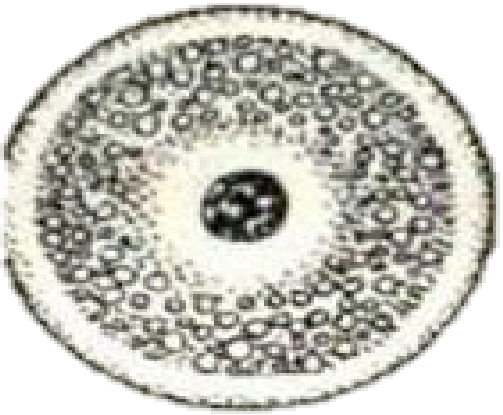


Figure 4 – *Centrolecithal type of egg cell*

c) *Sharply telolecithal*. There is much yolk, it is distributed through almost the whole cell – birds, reptile.

6. Presence of cortical granules, which are spread along the periphery of cytoplasm and consist of proteoglycans and glycoproteins.

7. An egg cell is covered with ovolemma and has external layers.

a) Primary, which is the product of cortical granules – *zone pellucida*. It is composed of glycoproteins and its functions are:

– protection from mechanical injuries;

– barrier, which allows the spermatozoon of only its own species pass through this layer.

b) Secondary – granular zone or *corona radiata*, consists of follicular cells. Its functions are:

– defensive;

– trophic.

8. Egg cells are immobile.

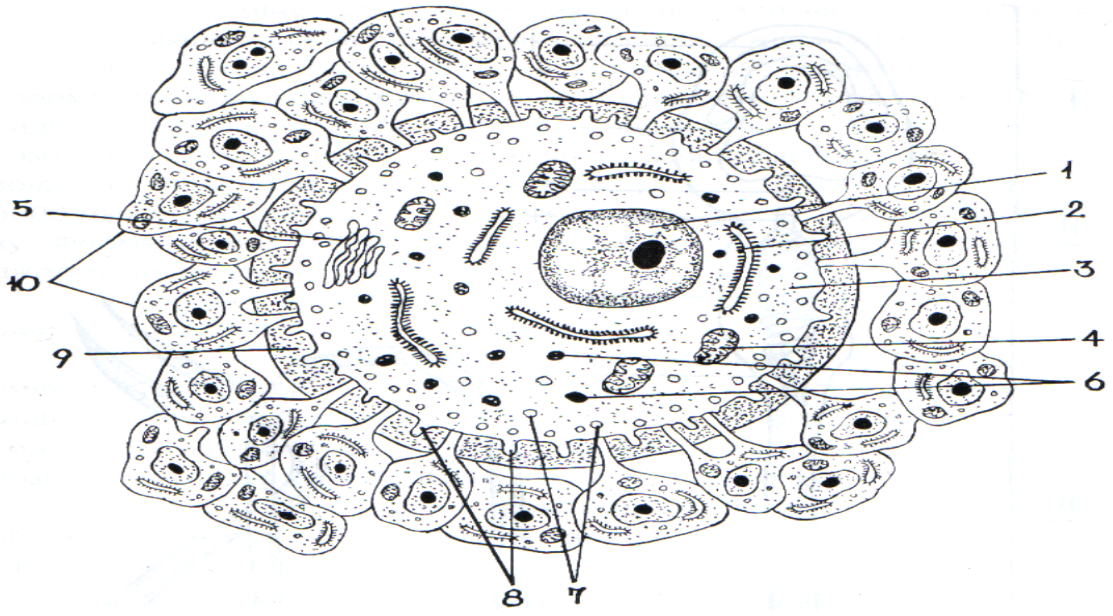


Figure 5 – *Egg cell*

1 – nucleus; 2 – granular endoplasmic reticulum; 3 – cytoplasm; 4 – mitochondria; 5 – Golgi bodies; 6 – yolk granules; 7 – cortical granules; 8 – microvilluses; 9 – zone pellucida; 10 – corona radiata.

Function of Ovum

- The following are the functions of ovum:
- Ovum is an essential part of the process of fertilization.
- Its major function is to transfer the set of chromosomes contributed by the female gamete.
- The process of fertilization is a significant process of life in which a male and female gametes fuses together to form a zygote which is a diploid cell. The site of fertilization is fallopian tube.
- Fallopian tubes are a muscular hollow organ which are of average between 10 and 14 cm in length.
- Production of ovum takes place from ovaries which relases it into oviducts for further processes.
- The largest and most active cell in early embryo is ovum.
- Oocyte undergoes meiosis and become capable for fertilization by becoming mature ovum.
- Ovum along with the sperm cell determines the child's characteristics.
- It is also responsible for providing nutrition to the growing embryo.

The egg cell or ovum is the female reproductive cell, or gamete, in most anisogamous organisms (organisms that reproduce sexually with a larger, female gamete and a smaller, male one). The term is used when the female gamete is not capable of movement (non–motile).

An oocyte is an immature egg (an immature ovum). Oocytes develop to maturity from within a follicle. These follicles are found in the outside layer of the ovaries. During each reproductive cycle, several follicles begin to develop.

Typically, only one oocyte each cycle will become a mature egg and be ovulated from its follicle. This process is known as ovulation. When released from the Graafian follicle and into the oviduct, the ovum will consist of three structures: oocyte, zona pellucida and corona radiata.

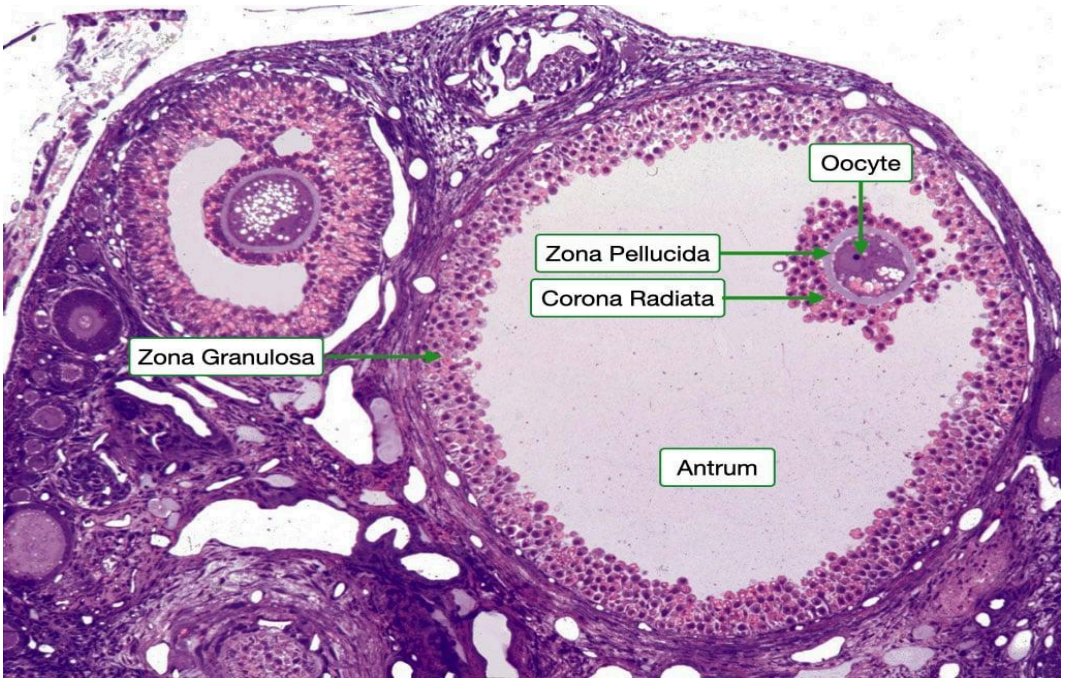


Figure 6 – Graafian follicle with oocyte.

A woman is born with all the oocytes she will ever have. This number decreases naturally with age. Age also reduces the quality and genetic stability of the oocytes. This is why it's harder to get pregnant after 35.

The fully mature ovum is visible to the human eye, measuring 0.1 mm. It is about the size of the period at the end of this sentence.

Medications known as fertility drugs can stimulate the ovaries to release multiple oocytes during a menstrual cycle. be used to stimulate the ovaries to produce multiple oocytes rather than and ovulating as mature eggs. This is the cause for the higher risk of multiple pregnancies when taking fertility drugs. For every ovum ovulated, there is a possibility it can become fertilized by a sperm cell. These fertilized ova can become embryos (and, eventually, if all goes well, babies.)

MALE SEX CELL

The sperm is the smallest cell in the male body. A microscope is needed to see sperm. The site of production of sperms is in the testis of the male present in the scrotum.

Main features:

1. The concentration of spermatozoon number is 300 million in ejaculate (one portion). A single ejaculate normally contains approximately 50 to 100 million spermatozoa per milliliter. A man whose sperm count is less than 20 million spermatozoa per milliliter is considered sterile.

2. It has a specific form – filament.

3. They are mobile.

4. They are very small; the length about 60 micrometers.

A spermatozoon consists of the *head*, *neck* and *tail*.

In the head there is a nucleus with haploid set of chromosomes: 22 autosomes and 1 sex chromosome. It may be X or Y. So, spermatozoons are divided into two types: 1) (22a + Y) give rise to male organism; 2) (22a + X) give rise to female organism.

The acrosome is located over the nucleus in the head. It has originated from Golgi apparatus. Acrosome contains hydrolythic enzymes: tripsin and hyaluronidase, which are capable to dissolve the ovum membranes at the moment of fertilization.

A thin cytoplasm layer, covering the nucleus and acrosome of the head, continues to the neck. Spermatozoa initially contains 2 centrioles (proximal, distal) and at fertilisation only a single (proximal) is present, which in most mammalian species is contributed to reconstitute the zygotic centrosome. Note that in rodents (rat, mice) both centrioles are lost and only a maternal centrosomal inheritance occurs.

- distal centriole – (perpendicular to membrane) required as the basal body generating the microtubule axoneme and is then lost (disintegration).
- proximal centriole – required after fertilisation for decondensing spermatozoa nucleus allowing development into the male pronucleus.

The axoneme beginning from distal centriole is the principal part of the tail. It is the movement apparatus.

The tail segment of a spermatozoon consists of the first part, the main part and the end part. In the first part there are mitochondria, which are located coil – like

around the axoneme. They provide the spermatozoon with energy to move. The main part of the tail contains the axoneme and is covered a narrow layer of cytoplasm which disappears in the end part. The axoneme is composed of two central microtubules and 9 doublet of peripheral ones. The movement speed of spermatozoon is 50 micrometer per second.

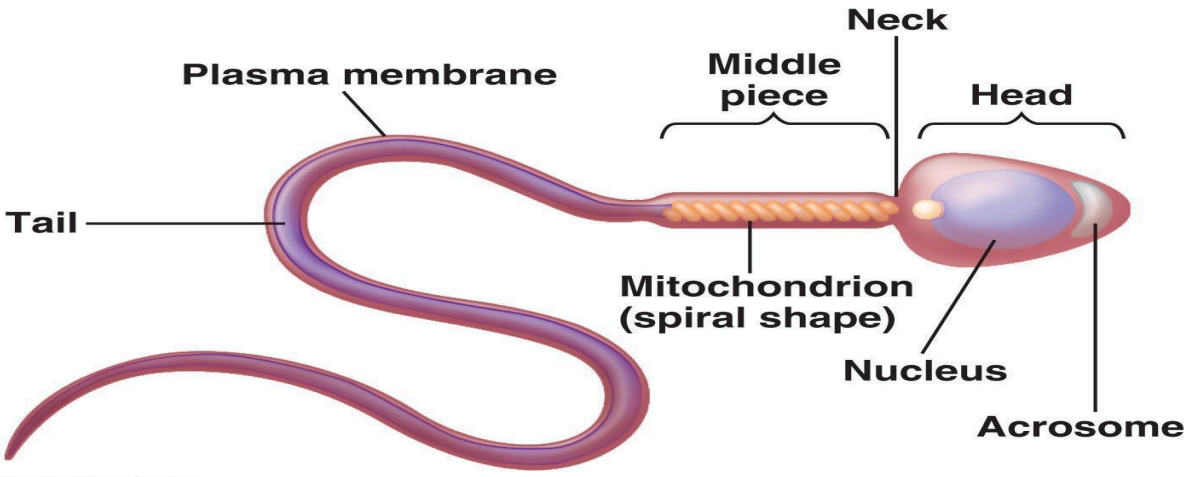


Figure 7 – *Spermatozoon*

Spermatozoon preserve the ability to fertilization in the female sex organs for two days. Off all organelles spematozoons contain only acrosome, mitochondria and 2 centrioles (centrosome).

Spermatozoon functions:

1. It transmits genetic information during fertilization.

2. It starts up the programme of further development in the zygota.

3. It determines the sex of new individual (X – carrying sperm will produce a female embryo, Y – carrying sperm will produce a male embryo).

Some sperm have two heads or two tails and if the testes are too warm they may die or spermatogenesis may not occur.

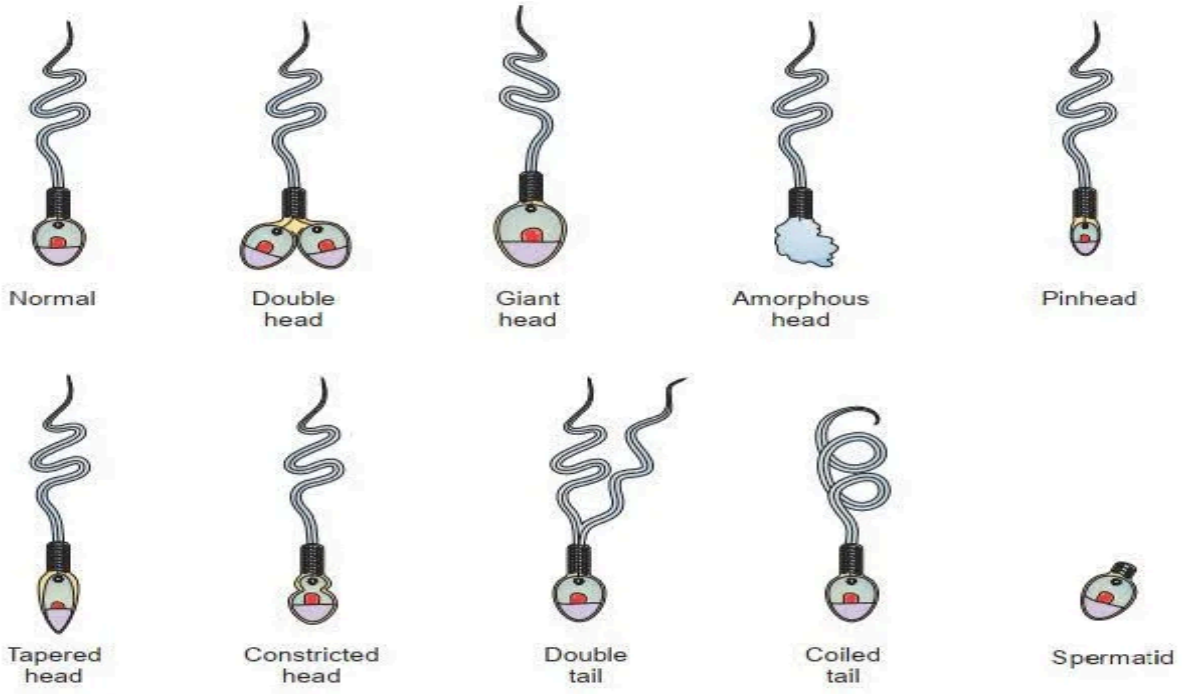


Figure 8 – Abnormalities of sperm and tails (Source: Urinalysis and BodyFluids)

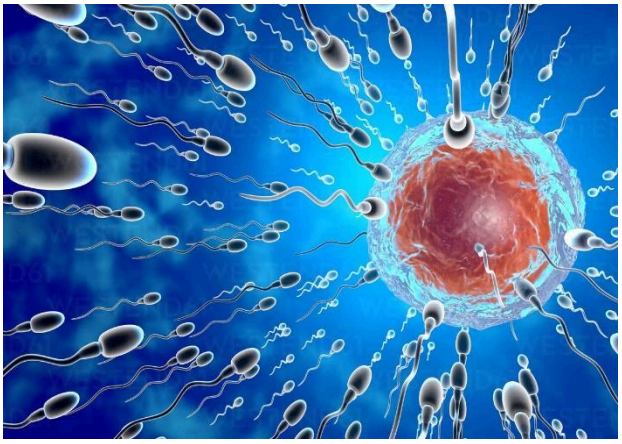
Sperm swim at a rate of about 3mm (0.12 inches) per minute. That's an average, it's different for every guy. Some sperm cells are "better" swimmers than others. Why? They need to wave their tales more than 1000 times just to swim 1.25 cm or a half an inch. Why some are better than others is still a mystery to many fertility specialists.

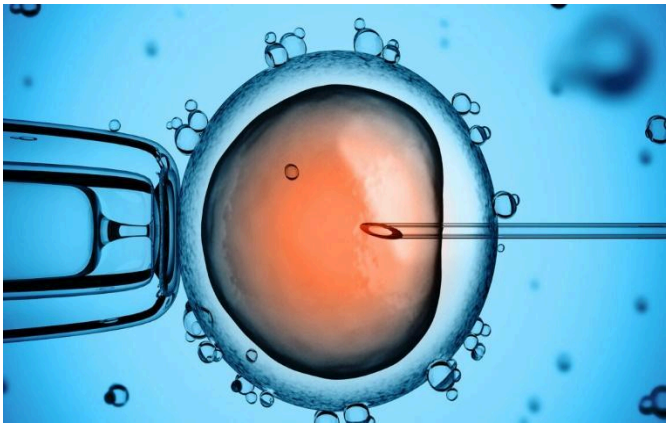
Sperm cells are made in the testes where it takes about 72 days for one sperm to grow. Sperm production requires a temperature which is three to five degrees below body temperature. Sperms can survive up to 3 to 5 days inside the female's body. Sperms are produced daily in millions of numbers.

The ultimate goal of a sperm is to fertilize the egg cell.

However, the journey of the sperm to get to the egg is not an easy one. To reach the egg cell, the sperm has to go through a long and difficult journey that can take from thirty minutes to several hours.

For this reason, fertilization needs a large number of motile spermatozoa for at least one of them to be able to overcome all barriers. Firstly for the sperm to get to the egg, and then to fertilize the egg.*





**Note:* The current stem cell research suggests that both the sperm and ovum can be made artificially for infertile couples. Stem cells are cells that are capable of forming any of the cells of the body. Scientists are working on skin cells to convert them into reproductive cells. Sperms have been made from skin cells by reversing them to become stem cells. But ovum is much more difficult to make.

In approximately nine months, a single cell – a fertilized egg – develops into a fully formed infant consisting of trillions of cells with myriad specialized functions. The dramatic changes of fertilization, embryonic development, and fetal development are followed by remarkable adaptations of the newborn to life outside the womb.

An offspring's normal development depends upon the appropriate synthesis of structural and functional proteins. This, in turn, is governed by the genetic material inherited from the parental egg and sperm, as well as environmental factors.

FERTILIZATION

Fertilization occurs when a sperm and an oocyte (egg) combine and their nuclei fuse. Because each of these reproductive cells is a haploid cell containing half of the genetic material needed to form a human being, their combination forms a diploid cell.

This new single cell, called a **zygote**, contains all of the genetic material needed to form a human – half from the mother and half from the father.

Fertilization is a numbers game. During ejaculation, hundreds of millions of sperm (spermatozoa) are released into the vagina. Almost immediately, millions of these sperm are overcome by the acidity of the vagina (approximately pH 3.8), and millions more may be blocked from entering the uterus by thick cervical mucus. Of those that do enter, thousands are destroyed by phagocytic uterine leukocytes. Thus, the race into the uterine tubes, which is the most typical site for sperm to encounter the oocyte, is reduced to a few thousand contenders. Their journey – thought to be facilitated by uterine contractions – usually takes from 30 minutes to 2 hours.

If the sperm do not encounter an oocyte immediately, they can survive in the uterine tubes for another 3–5 days. Thus, fertilization can still occur if intercourse takes place a few days before ovulation. In comparison, an oocyte can survive independently for only approximately 24 hours following ovulation. Intercourse more than a day after ovulation will therefore usually not result in fertilization.

During the journey, fluids in the female reproductive tract prepare the sperm for fertilization through a process called **capacitation**, or priming. The fluids improve

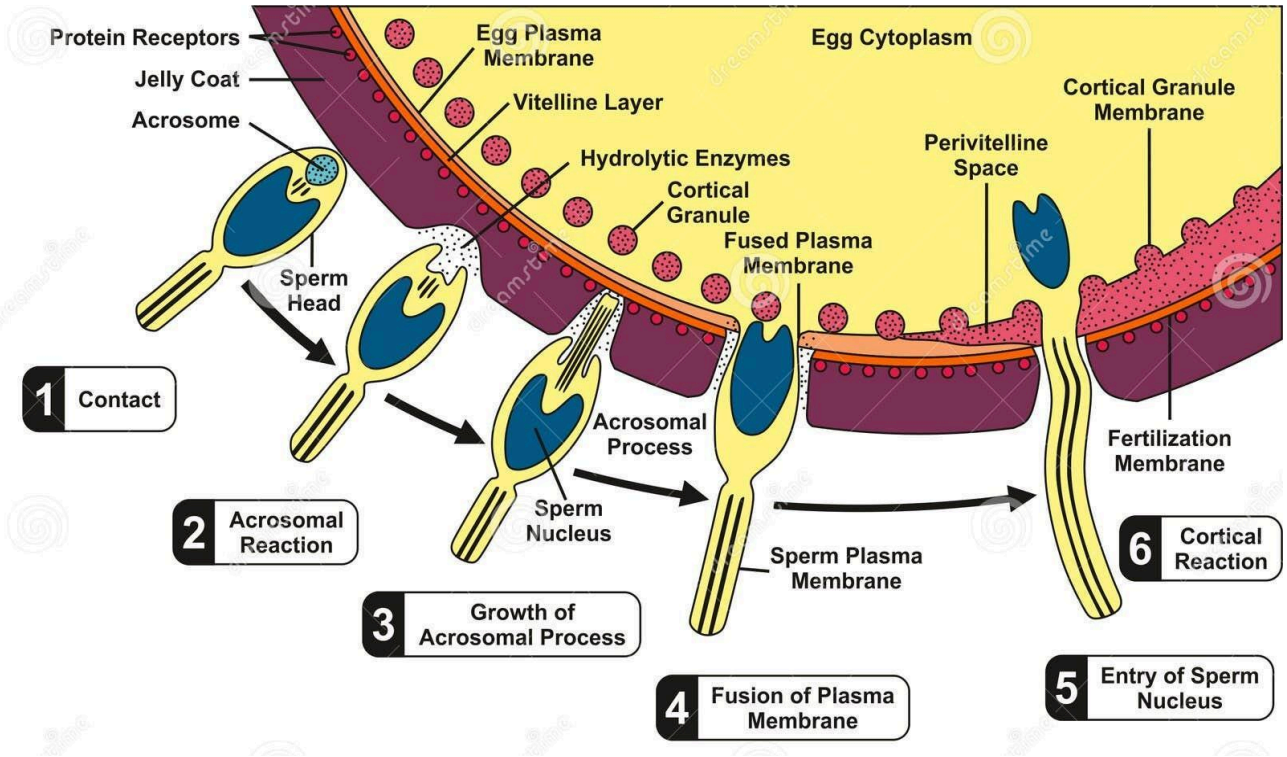
the motility of the spermatozoa. They also deplete cholesterol molecules embedded in the membrane of the head of the sperm, thinning the membrane in such a way that will help facilitate the release of the lysosomal (digestive) enzymes needed for the sperm to penetrate the oocyte's exterior once contact is made. Sperm must undergo the process of capacitation in order to have the "capacity" to fertilize an oocyte. If they reach the oocyte before capacitation is complete, they will be unable to penetrate the oocyte's thick outer layer of cells.

Upon ovulation, the oocyte released by the ovary is swept into – and along – the uterine tube. Fertilization must occur in the distal uterine tube because an unfertilized oocyte cannot survive the 72–hour journey to the uterus. As you will recall from your study of the oogenesis, this oocyte (specifically a secondary oocyte) is surrounded by two protective layers.

The **corona radiate** is an outer layer of follicular (granulosa) cells that form around a developing oocyte in the ovary and remain with it upon ovulation.

The underlying **zona pellucida** is a transparent, but thick, glycoprotein membrane that surrounds the cell's plasma membrane.

As it is swept along the distal uterine tube, the oocyte encounters the surviving capacitated sperm, which stream toward it in response to chemical attractants released by the cells of the corona radiata. To reach the oocyte itself, the sperm must penetrate the two protective layers. The sperm first burrow through the cells of the corona radiata. Then, upon contact with the zona pellucida, the sperm bind to receptors in the zona pellucida. This initiates a process called the **acrosomal reaction** in which the enzyme – filled "cap" of the sperm, called the **acrosome**, releases its stored digestive enzymes.



Scheme 1 – Human Sperm and Egg Fusion Diagram with all fertilization process and stages step by step including contact acrosomal cortical reaction growth fusion of plasma membrane entry of sperm nucleus

These enzymes clear a path through the zona pellucida that allows sperm to reach the oocyte. Finally, a single sperm makes contact with sperm–binding receptors on the oocyte's plasma membrane. The plasma membrane of that sperm then fuses with the oocyte's plasma membrane, and the head and mid–piece of the "winning" sperm enter the oocyte interior.

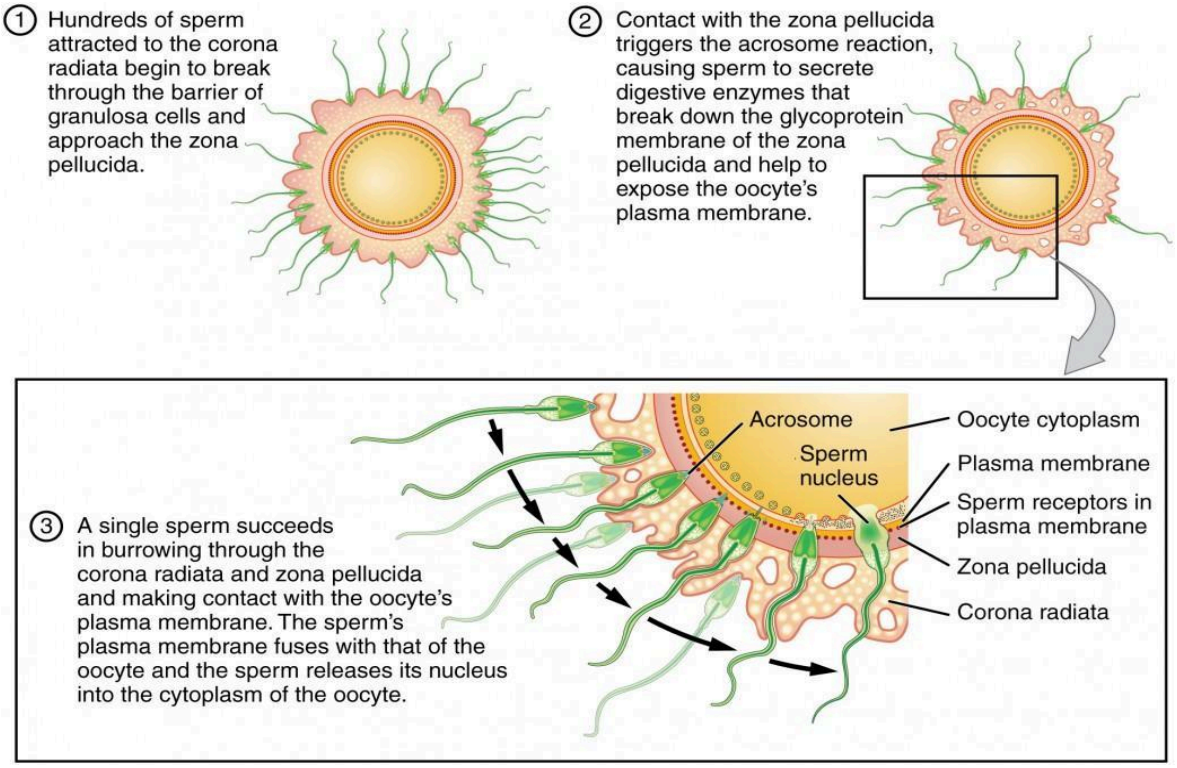
How do sperm penetrate the corona radiata? Some sperm undergo a spontaneous acrosomal reaction, which is an acrosomal reaction not triggered by contact with the zona pellucida. The digestive enzymes released by this reaction digest the extracellular matrix of the corona radiata. As you can see, the first sperm to reach the oocyte is never the one to fertilize it. Rather, hundreds of sperm cells must undergo the acrosomal reaction, each helping to degrade the corona radiata and zona pellucida until a path is created to allow one sperm to contact and fuse with the plasma membrane of the oocyte. If you consider the loss of millions of sperm

between entry into the vagina and degradation of the zona pellucida, you can understand why a low sperm count can cause male infertility.

When the first sperm fuses with the oocyte, the oocyte deploys two mechanisms to prevent **polyspermy**, which is penetration by more than one sperm. This is critical because if more than one sperm were to fertilize the oocyte, the resulting zygote would be a triploid organism with three sets of chromosomes. This is incompatible with life.

The first mechanism is the fast block, which involves a near instantaneous change in sodium ion permeability upon binding of the first sperm, depolarizing the oocyte plasma membrane and preventing the fusion of additional sperm cells. The fast block sets in almost immediately and lasts for about a minute, during which time an influx of calcium ions following sperm penetration triggers the second mechanism, the slow block. In this process, referred to as the **cortical reaction**, cortical granules sitting immediately below the oocyte plasma membrane fuse with the membrane and release zonal inhibiting proteins and mucopolysaccharides into the space between the plasma membrane and the zona pellucida.

Zonal inhibiting proteins cause the release of any other attached sperm and destroy the oocyte's sperm receptors, thus preventing any more sperm from binding. The mucopolysaccharides then coat the nascent zygote in an impenetrable barrier that, together with hardened zona pellucida, is called a **fertilization membrane**.



Scheme 2 – Stages of penetration of the spermatozoon to the egg cell

The Zygote. Recall that at the point of fertilization, the oocyte has not yet completed meiosis; all secondary oocytes remain arrested in metaphase of meiosis II until fertilization. Only upon fertilization does the oocyte complete meiosis. The unneeded complement of genetic material that results is stored in a second polar body that is eventually ejected. At this moment, the oocyte has become an ovum, the female haploid gamete. The two haploid nuclei derived from the sperm and oocyte and contained within the egg are referred to as pronuclei. They decondense, expand, and replicate their DNA in preparation for mitosis.

The pronuclei then migrate toward each other, their nuclear envelopes disintegrate, and the male– and female–derived genetic material intermingles. This step completes the process of fertilization and results in a single – celled diploid zygote with all the genetic instructions it needs to develop into a human.

Most of the time, a woman releases a single egg during an ovulation cycle. However, in approximately 1 percent of ovulation cycles, two eggs are released and both are fertilized. Two zygotes form, implant, and develop, resulting in the birth of dizygotic (or fraternal) twins. Because dizygotic twins develop from two eggs

fertilized by two sperm, they are no more identical than siblings born at different times.

Much less commonly, a zygote can divide into two separate offspring during early development. This results in the birth of monozygotic (or identical) twins. Although the zygote can split as early as the two – cell stage, splitting occurs most commonly during the early blastocyst stage, with roughly 70 – 100 cells present. These two scenarios are distinct from each other, in that the twin embryos that separated at the two–cell stage will have individual placentas, whereas twin embryos that form from separation at the blastocyst stage will share a placenta and a chorionic cavity.

So hundreds of millions of sperm deposited in the vagina travel toward the oocyte, but only a few hundred actually reach it. The number of sperm that reach the oocyte is greatly reduced because of conditions within the female reproductive tract.

Many sperm are overcome by the acidity of the vagina, others are blocked by mucus in the cervix, whereas others are attacked by phagocytic leukocytes in the uterus. Those sperm that do survive undergo a change in response to those conditions. They go through the process of capacitation, which improves their motility and alters the membrane surrounding the acrosome, the cap–like structure in the head of a sperm that contains the digestive enzymes needed for it to attach to and penetrate the oocyte.

The oocyte that is released by ovulation is protected by a thick outer layer of granulosa cells known as the corona radiata and by the zona pellucida, a thick glycoprotein membrane that lies just outside the oocyte's plasma membrane.

When capacitated sperm make contact with the oocyte, they release the digestive enzymes in the acrosome (the acrosomal reaction) and are thus able to attach to the oocyte and burrow through to the oocyte's zona pellucida. One of the sperm will then break through to the oocyte's plasma membrane and release its haploid nucleus into the oocyte. The oocyte's membrane structure changes in response (cortical reaction), preventing any further penetration by another sperm and forming a fertilization membrane.

Fertilization is complete upon unification of the haploid nuclei of the two gametes, producing a diploid zygote.

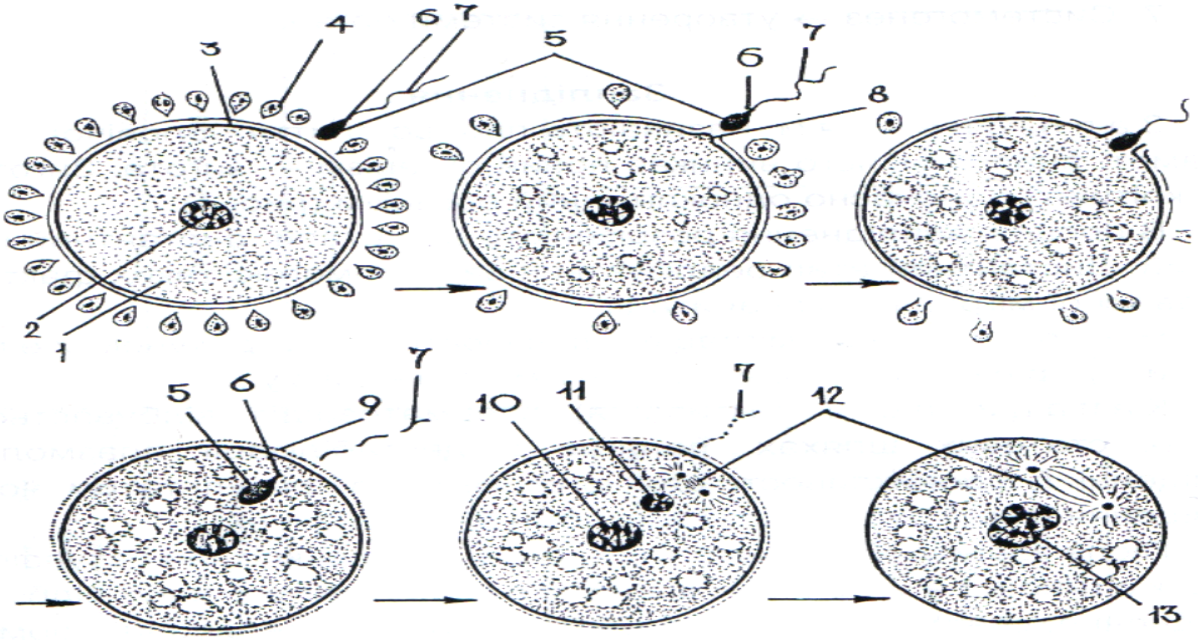


Figure 9 – Fertilization

1 – cytoplasm; 2 – nucleus; 3 – zone pellucida; 4 – corona radiate; 5 – head of spermatozoon; 6 – neck of spermatozoon; 7 – tail of spermatozoon; 8 – penetration of spermatozoon into the female sex cell; 9 – membrane of fertilization; 10 – pronucleus of the female sex cell; 11 – pronucleus of the male sex cell; 12 – centrosome; 13 – syncarion.

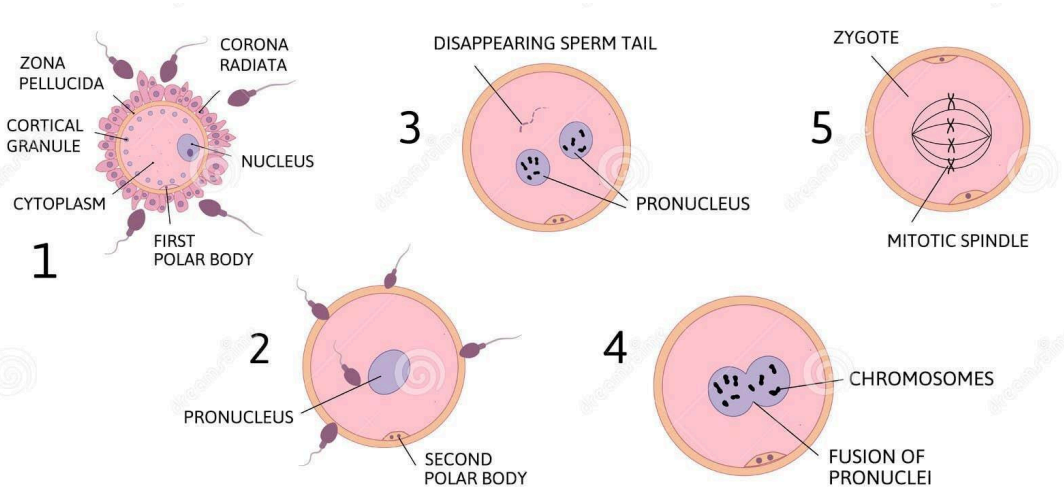


Figure 10 – Fertilization

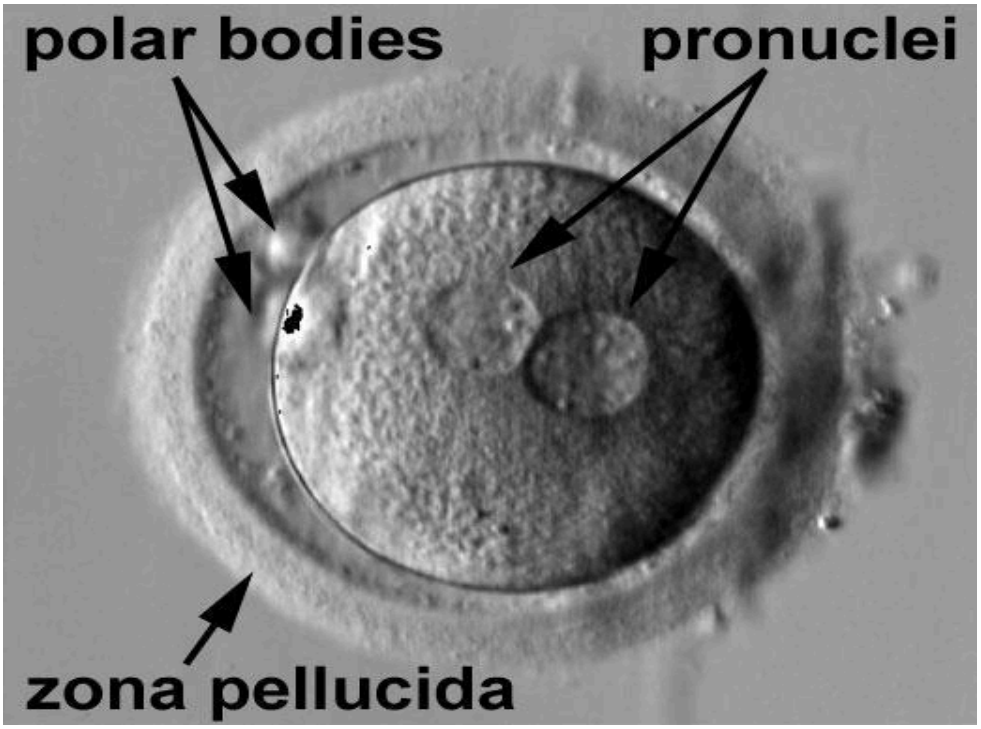
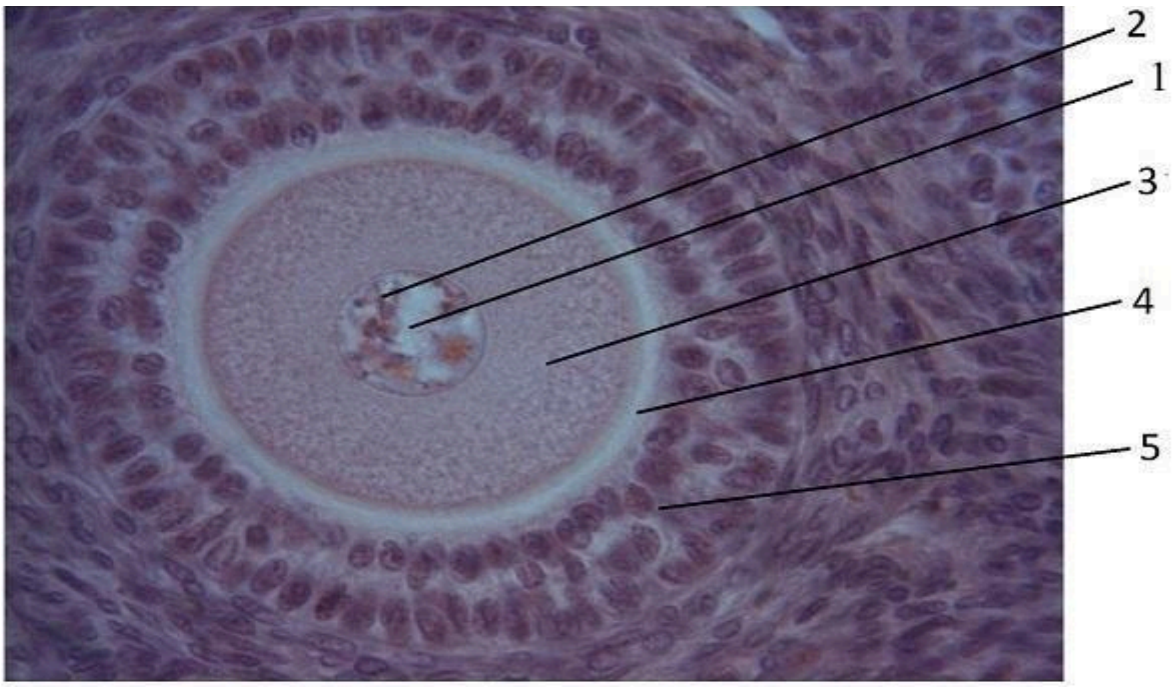


Figure 11 – First human cell (called a zygote)

QUESTIONS ON THE TOPIC: SEX CELLS. FERTILIZATION

1. Embryogenesis, embryology definition.
2. Main stages of human embryogenesis.
3. Main features of the female sex cell.
4. Oocytes types.
5. Structure of the ovum.
6. Main features of the male sex cell.
7. Structure of the spermatozoon.
8. Fertilazation, stages and biological significance.
9. Ovarian cycle
10. Follicular development
11. Graafian (mature) follicle
12. Corpus luteum

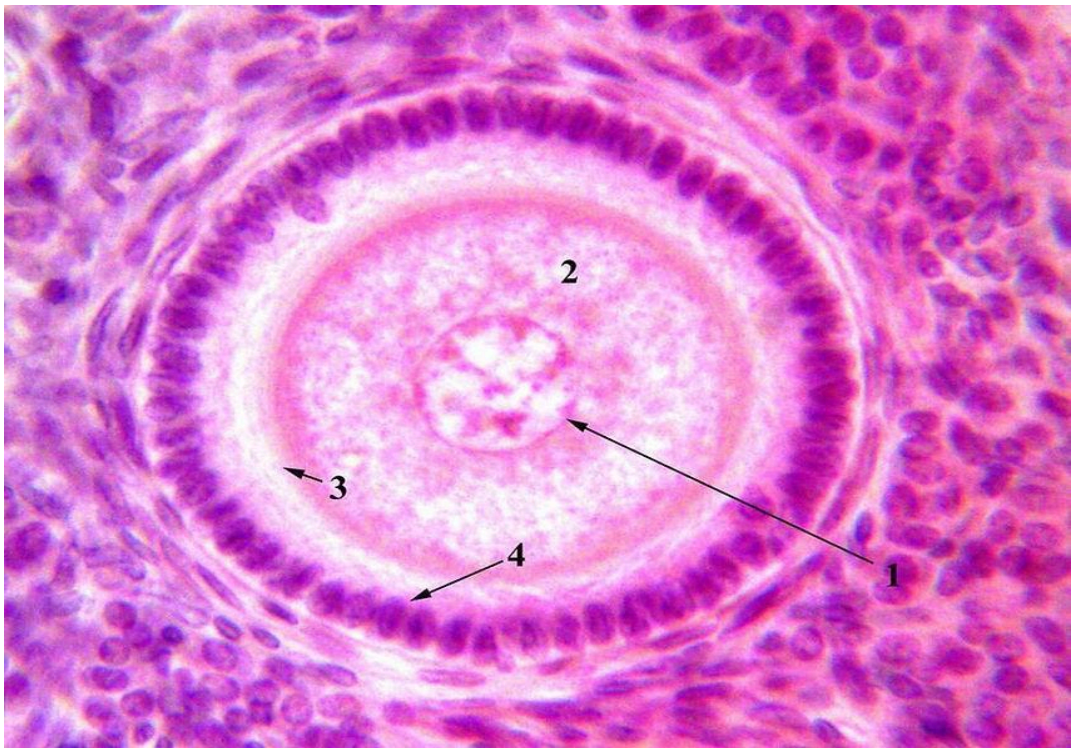
PRACTICAL PART I



Slide 1 – Oocyte

Staining: hematoxylin–eosin.

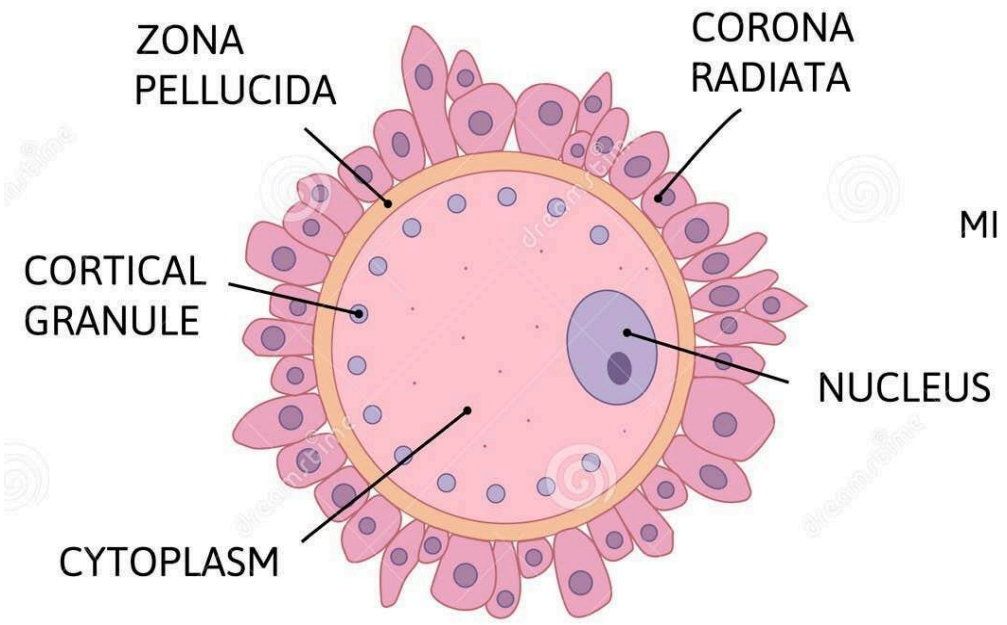
1 – nucleus with nucleolus; 2 – heterochromatin; 3 – cytoplasm; 4 – zona pellucida; 5 – corona radiata.



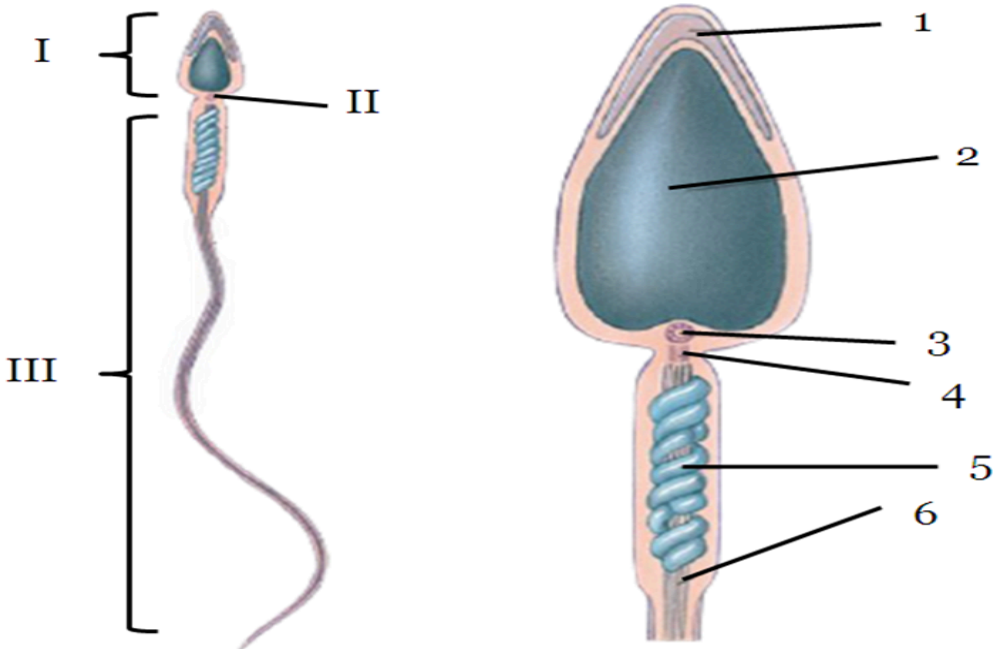
Slide 2 – Human ovum and its coverings

Staining: hematoxylin– eosin

1 – nucleus, 2 – yolk granules 3 – zona pellucida, 4 – corona radiata



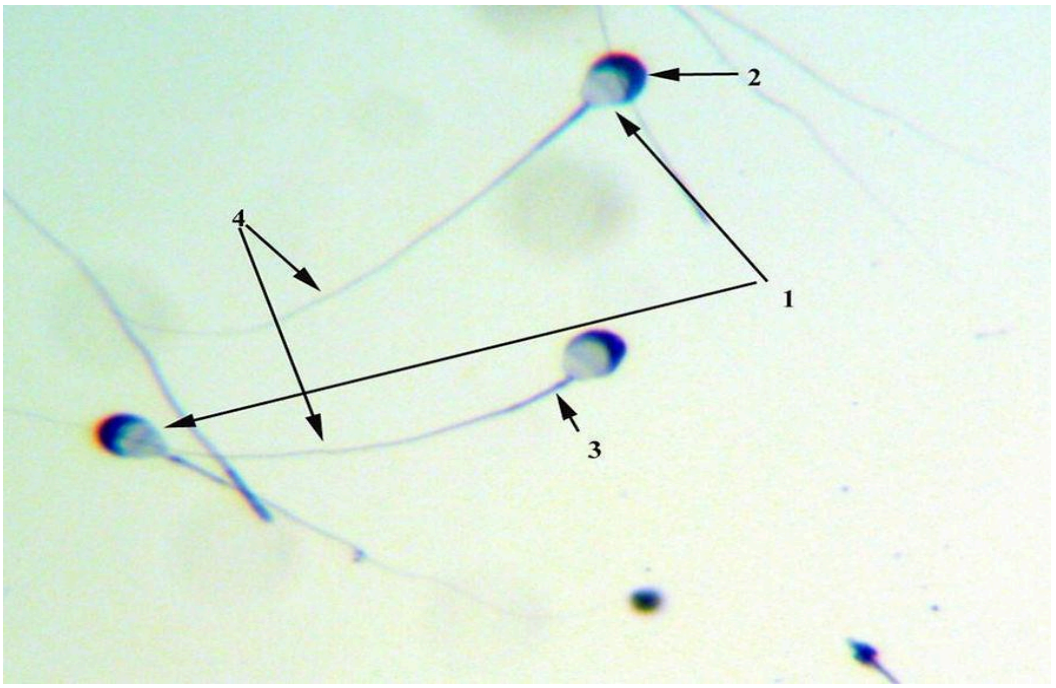
Slide 3 – Structure of ovum



Slide 4 – Sructure of spermatozoon

I. Head. II. Neck. III. Tail.

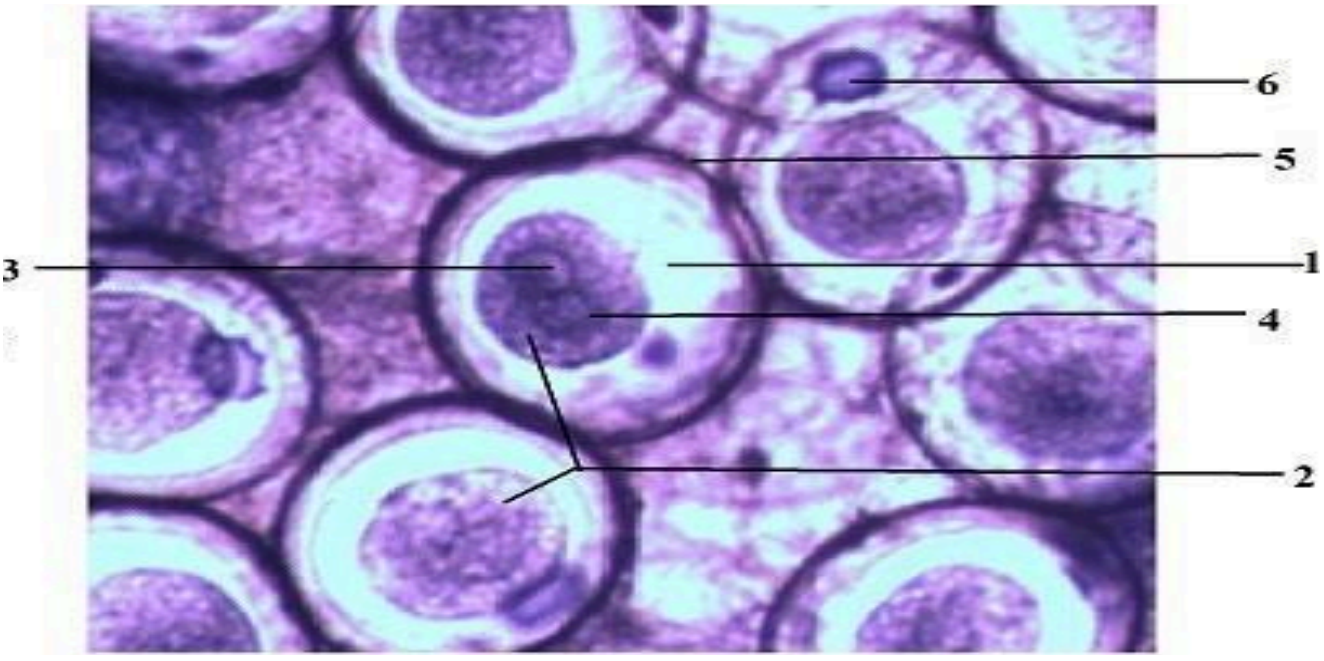
1 – acrosome; 2 – nucleus; 3 – proximal centriole; 4 – distal centriole; 5 – mitochondria; 6 – axoneme.



Slide 5 – Spermatozoon guinea pig

Staining:

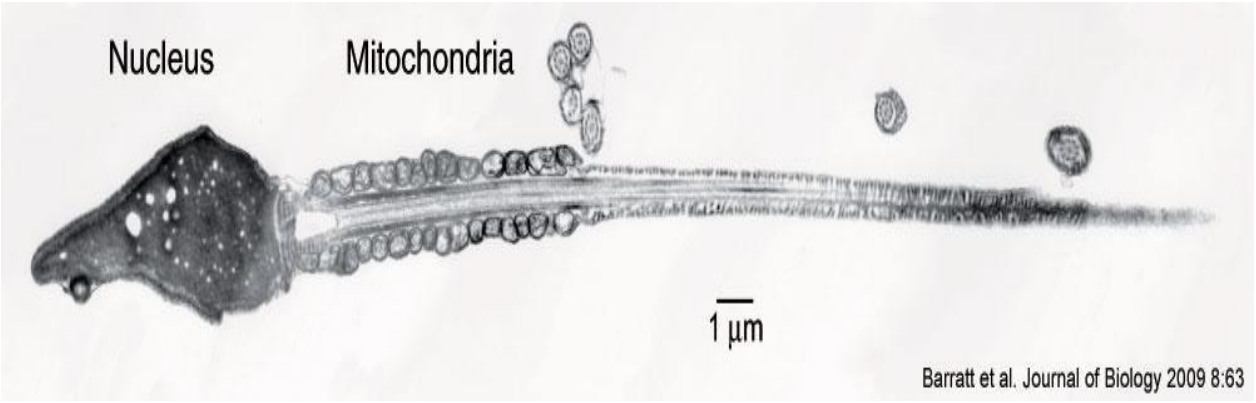
1 – нead with nucleus. 2 – acrosome, 3 – neck, 4 – tail.



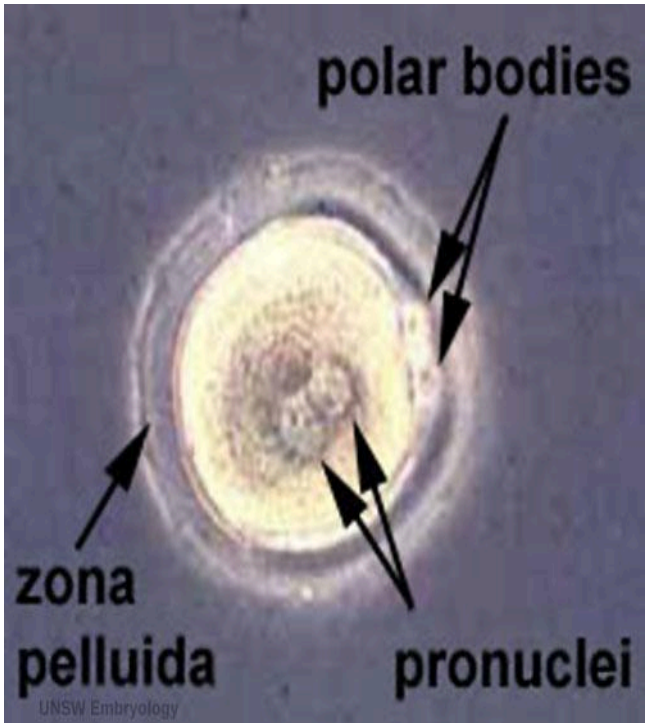
Slide 6 – Syncarion

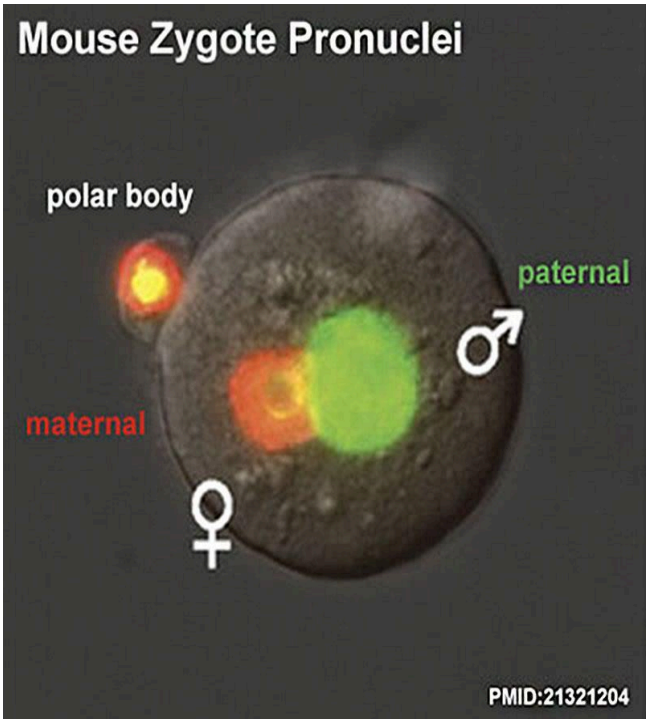
Staining:

1 – perivitellin's space; 2 – cytoplasm of the ovum; 3 – female pronucleus; 4 – male pronucleus; 5 – fertilization tunic; 6 – polar body.



Slide 7 – Human spermatozoa (electron microscope)





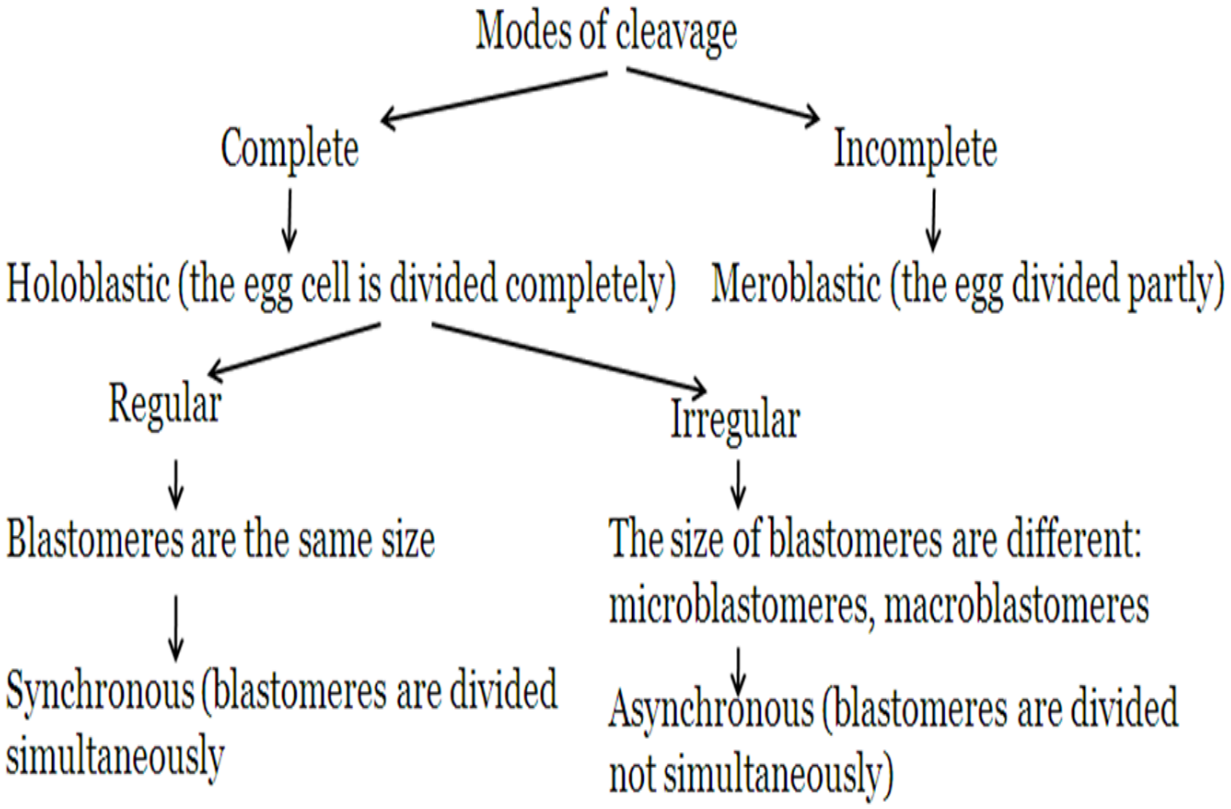
Slide 8 – Formation of the Zygote

CLEAVAGE. GASTRULATION

CLEAVAGE

Cleavage is the division of the zygote, in the result of which multicellula organism – blastula – is formed. Cleavage occurs by means of mitosis. This is a very short period of interphase between two mitosis and it begins with S phase of the cell cycle. G phase of the cell cycle, during which new formed cells are growing, is absent. Such division results in size decrease of dividing cells halfes, and as a result, the blastula size does not exceed the zygota size. Cells, from which the embryo is constituted during the cleavage, are called blastomeres.

Different types of animals have their own mode of cleavage. It depends on yolk amount in the egg cell, as yolk prevents the cleavage.



Scheme 3 – Models of cleavage

Cleavage is completed by blastula formation. *Blastula* is a multicellular monolayer embryo. It consists of blastula wall – blastoderm, which is composed of cells – blastomeres. There is a cavity – blastocell inside blastule:

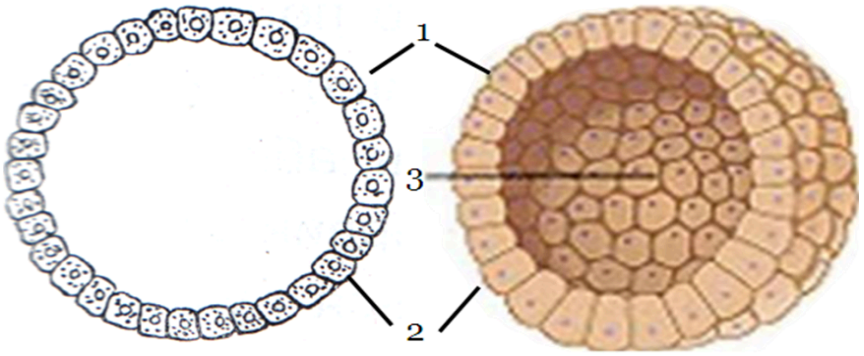


Figure 12 – Blastula

1 – blastoderm; 2 – blastomeres; 3 – blastocell.

The cleavage peculiarities in the human. Chronology of the process

In thirty hours after fertilization the zygote, which is in the uterine tube enters the cleavage. For the human zygote cleavage is complete and asynchronous, that is such cleavage during, which some blastomeres are divided more often, others – more seldom. That is blastomeres are divided with different speed. After the stage of two blastomeres the stage of three blastomeres comes and so on. A group of cells, consisting of 12 – 16 blastomeres is called morula.

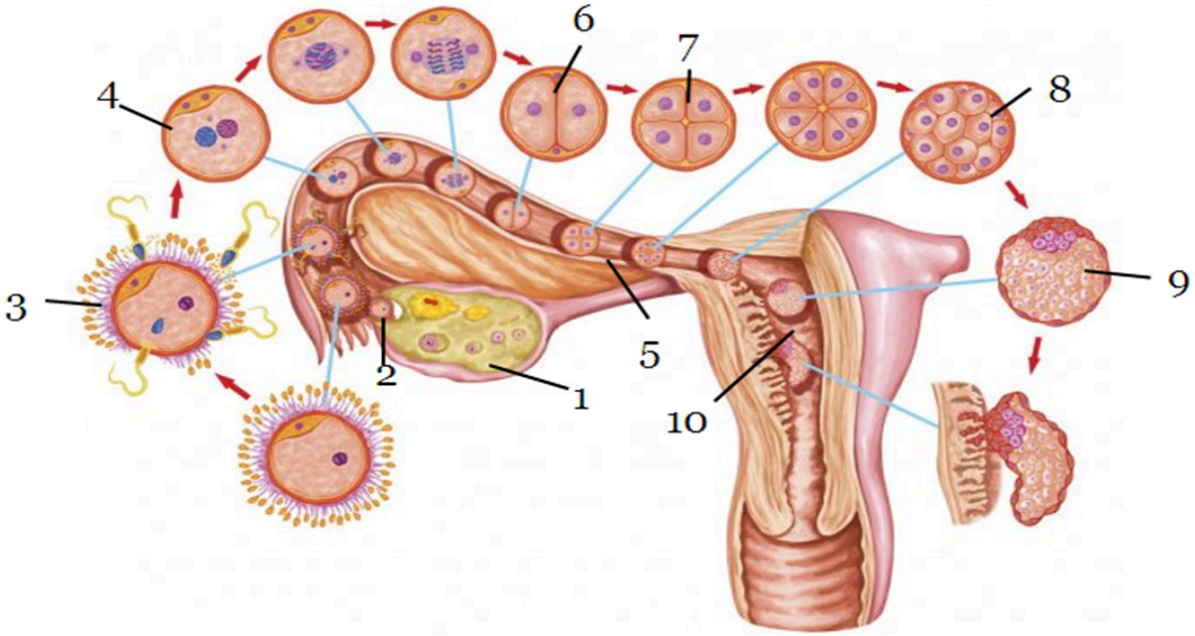


Figure 13 – Fertilization and the first 6 days of development

1 – ovary; 2 – ovulation; 3 – fertilization; 4 – zygote; 5 – uterine tube; 6 – two cell stage; 7 – four cell stage; 8 – morula; 9 – blastocyst; 10 – cavity of uterus.

At the stage of 16 blastomeres all cells of morula are totipotent. This means that any blastomere can become the starting–point structure for development of the organism, as a whole 16 separate twins may develop. On the fourth day after fertilization the number of blastomeres increases up to 50 – 60 and blastula is formed.

For a human the type of blastula – blastocyste – is typical. Blastocyste takes the form of vesicle. The transparent tunic is dissolved. If dissolving of the transparent tunic does not occur blastocyste won't be able to attach to the surface of uterus endometrium.

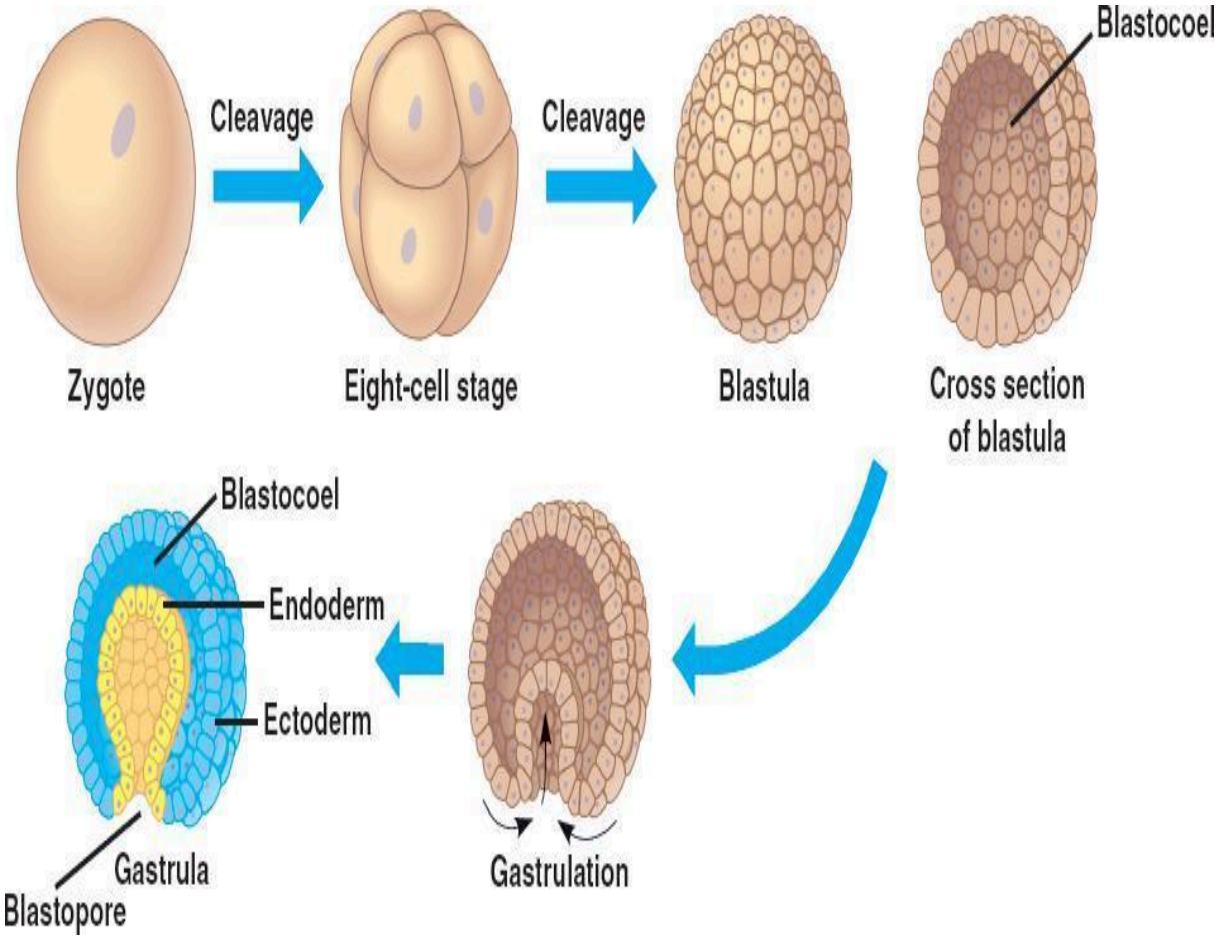


Figure 14 – Chronology of the process embryonic development

During the first four days the germ is in the cavity of uterine tube and moves, with the fluid current and under the influence of peristaltic contraction into the uterine cavity. This is the tubal period in the development of the germ. The germ as free blastocyste is in the uterine cavity from the fifth till seventh day.

During the period (from the first till seventh day) nutrition is carried out partly by oocyte nutrients, partly by secretion of uterine tube and endometrium glands and is called *vitelotrophic*.

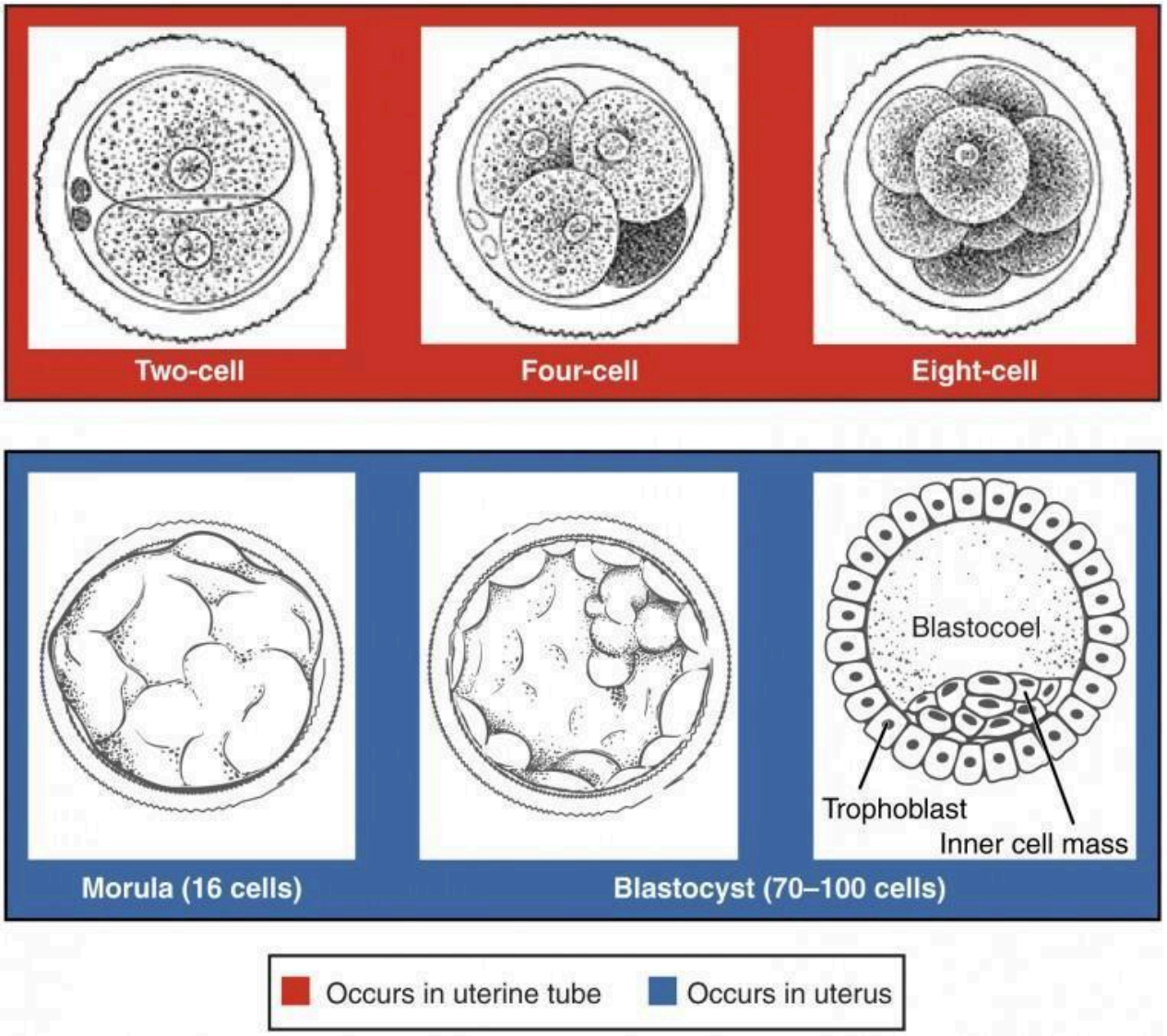


Figure 15 – Pre–embryonic cleavages make use of the abundant cytoplasm of the conceptus as the cells rapidly divide without changing the total volume.

On the seventh day implantation comes. At this time blastocyst consists of 107 blastomeres, from which 69 form *trophoblast*, 8 – *embryoblast*, and 30 group around embryoblast and form the inner cell mass. Under the influence of secretion of glycoproteins the membrane of fertilization is eroded. Blastocyst gets into contact with uterus endometrium.

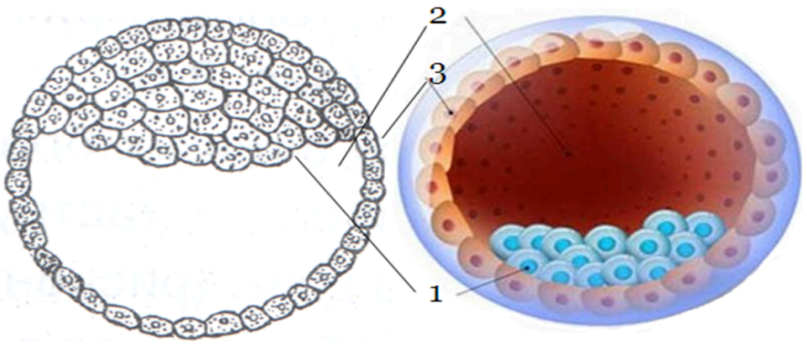


Figure 16 – Blastocyst

1 – embryoblast; 2 – blastocell; 3 – trophoblast.

1. The phase of adhesion – adhesion or attachment of blastocyst between excretory ducts of uterine glands.

2. Invasion phase – penetration of blastocyst into uterine mucosa with the help of proteolytic enzymes, which are produced by trophoblast. First epitheliocytes are eroded, then the connective tissue and, at last, the walls of vessels of endometrium. A hollow is formed in which blastocyst is located and then the hollow overgrown by the connective tissue. Prolifiration of endometrium epitheliocytes eliminates the defect of epithelium.

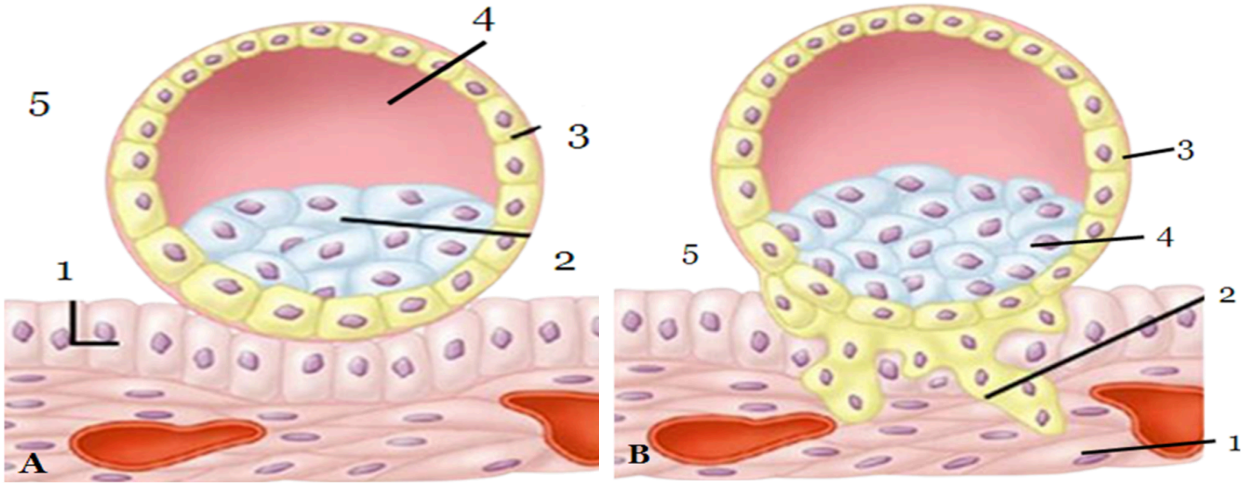


Figure 17 – Implantation

A – Adhesion: 1 – wall of the uterus; 2 – inner cell mass; 3 – trophoblast; 4 – blastocyst cavity; 5 – cavity of the uterus. B – Invasion: 1 – endometrium with blood vessels and glands; 2 – syncytiotrophoblast; 3 – cytotrophoblast; 4 – inner cell mass; 5 – lumen of uterus.

From the seventh day and until getting of trophoblast in contact with mother's blood (the end of the fourth week), *histiotrophic period* of embryogenesis continues. Embryo's nutrition is provided by secretion of uterine glands and erosion products of endometrium tissues by trophoblast.

From the moment of embryo's contact with mother's blood and untill newborn's birth (from the second till ninth month) *haematotrophic period* continues. During this period provision of the embryo and fetus with nutritious substances and gas exchange takes place by mother's blood.

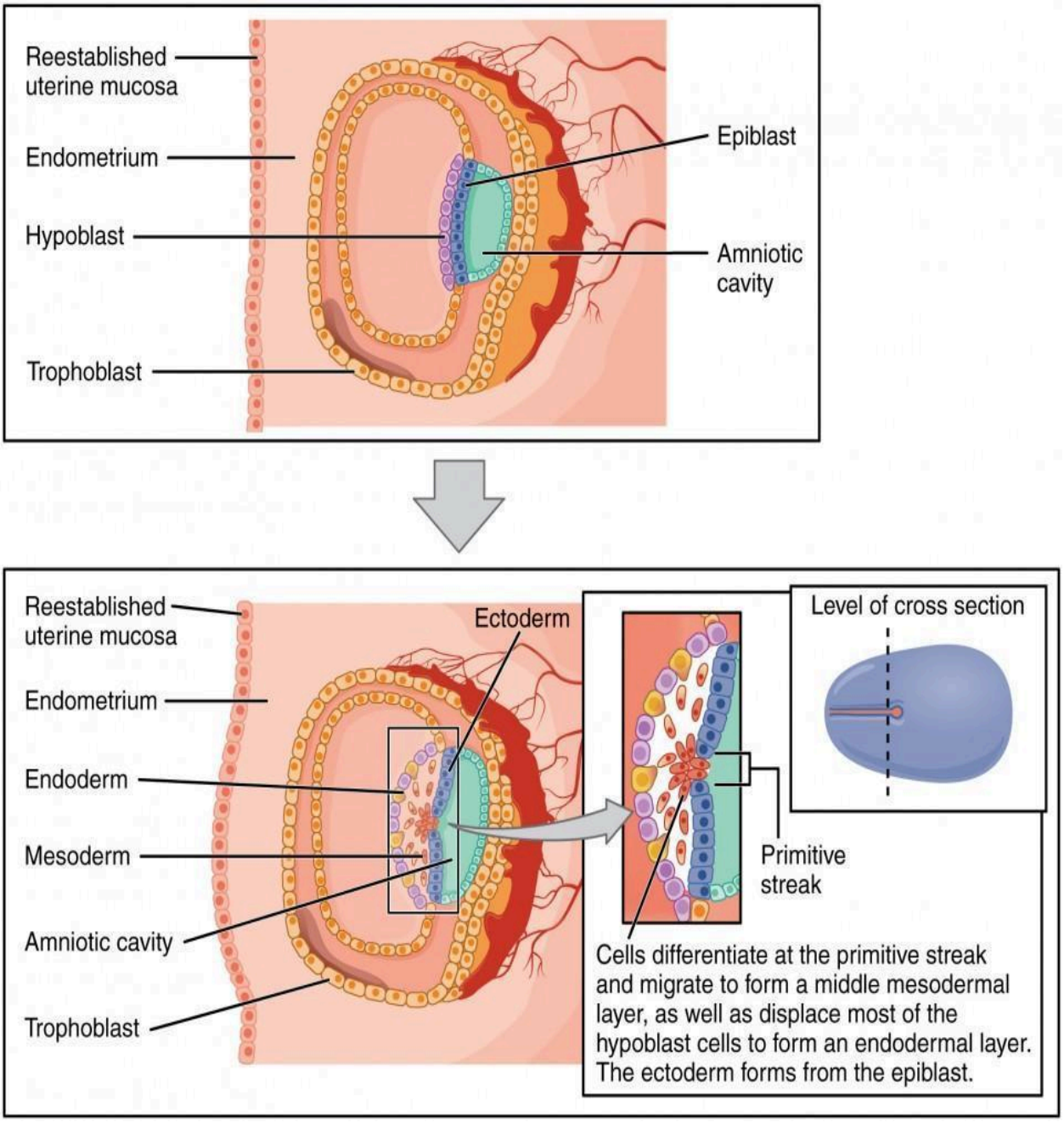


Figure 18 – Haematotrophic period

Formation of the three primary germ layers occurs during the first 2 weeks of development. The embryo at this stage is only a few millimeters in length.

Trophoblast cells are actively divided and it turns from monolayer into bilayers. The internal layer has cellular structure and is called *cytotrophoblast*. The external layer does not have cellular structure and is called *syncytiotrophoblast*.

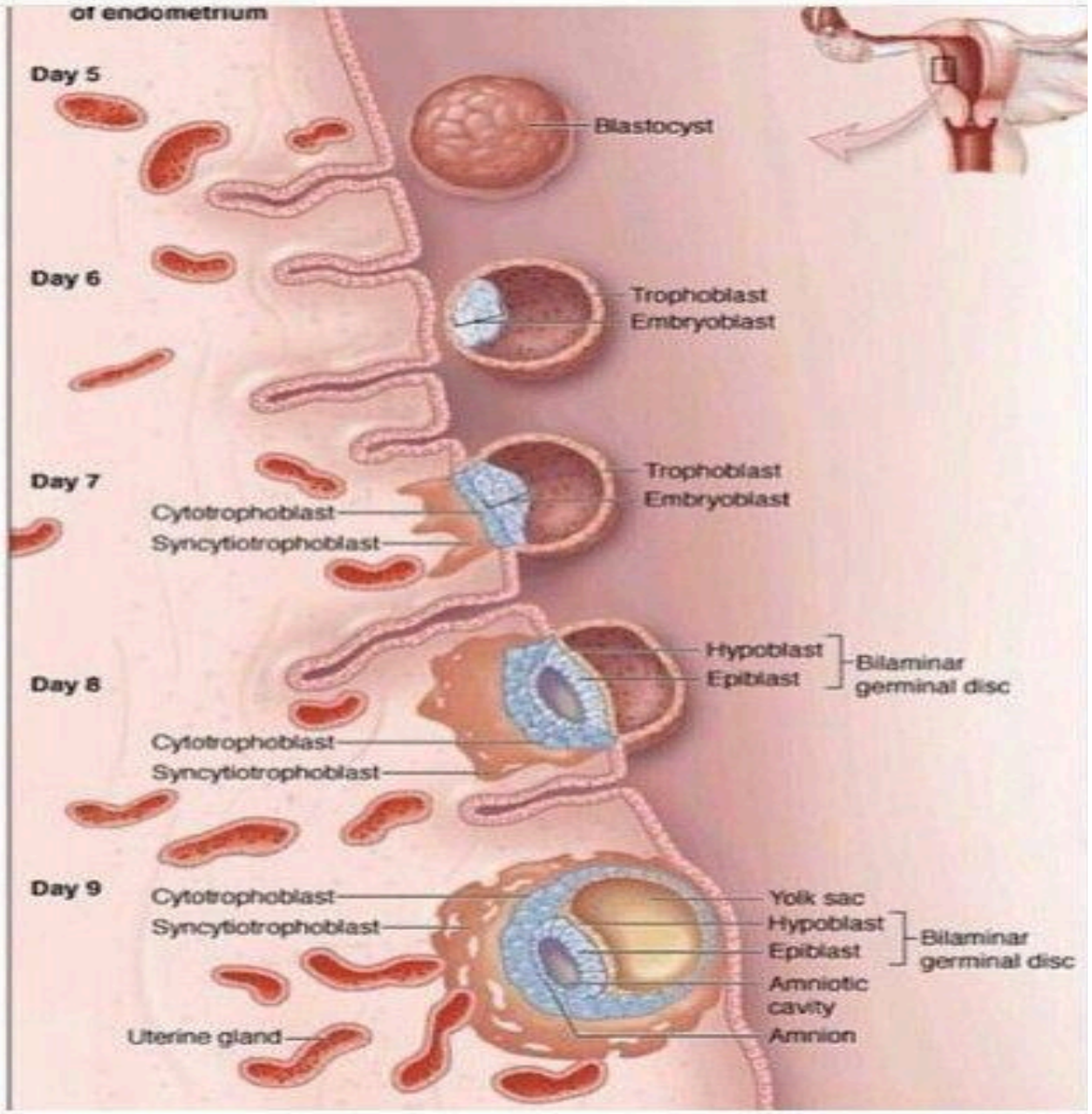
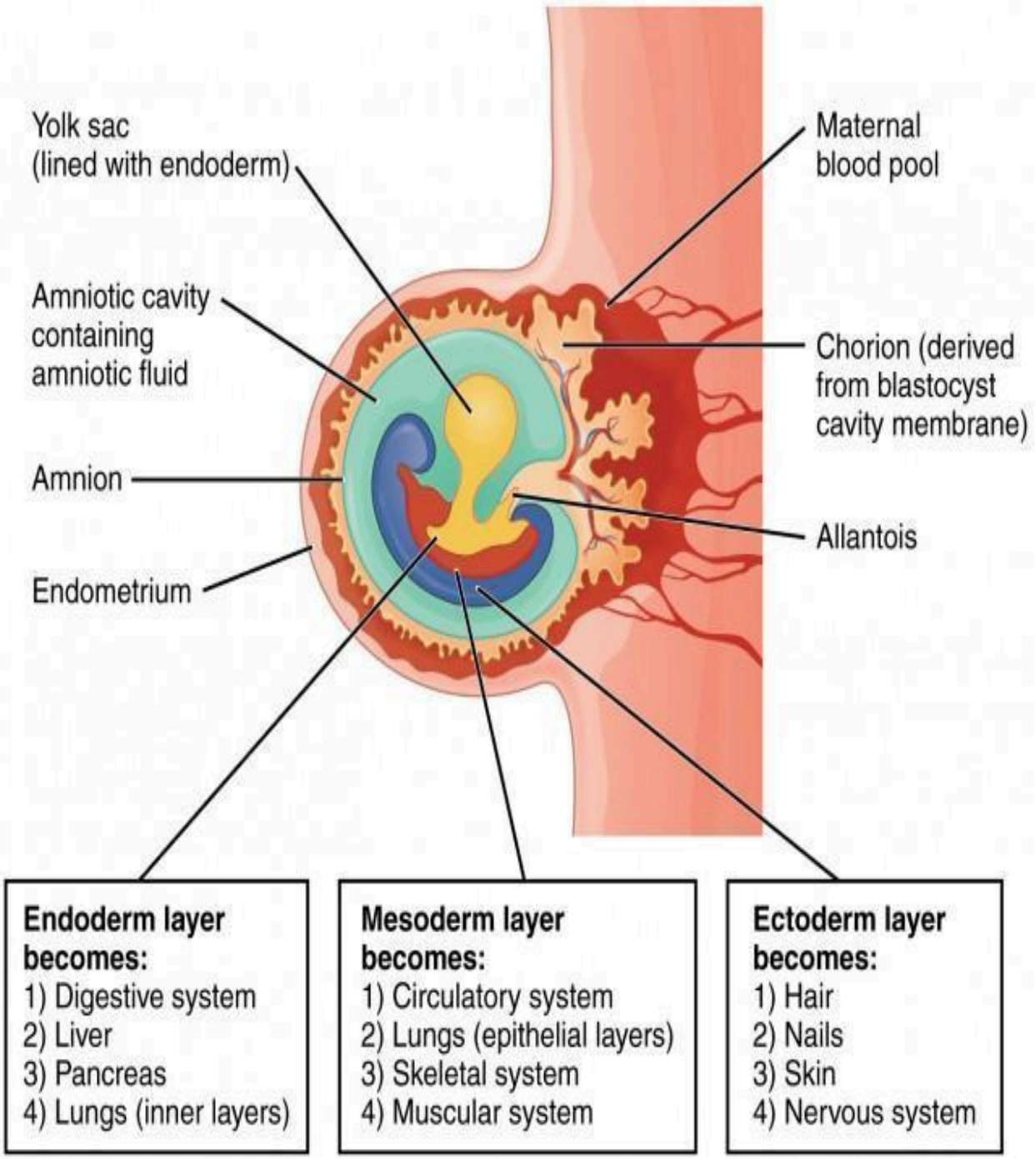


Figure 19 – Implantation

Each of these germ layers will develop into specific structures in the embryo. Whereas the ectoderm and endoderm form tightly connected epithelial sheets, the

mesodermal cells are less organized and exist as a loosely connected cell community. The ectoderm gives rise to cell lineages that differentiate to become the central and peripheral nervous systems, sensory organs, epidermis, hair, and nails. Mesodermal cells ultimately become the skeleton, muscles, connective tissue, heart, blood vessels, and kidneys. The endoderm goes on to form the epithelial lining of the gastrointestinal tract, liver, and pancreas, as well as the lungs (Scheme 4).



Scheme 4 – Formation of organ systems from germ layers

Following gastrulation of the embryo in the third week, embryonic cells of the ectoderm, mesoderm, and endoderm begin to migrate and differentiate into the cell lineages that will give rise to mature organs and organ systems in the infant.

Fertilization in some species leads to radical cytoplasmic movements that are essential for ensuring the cytoplasmic determinants are located in the correct positions relative to subsequent cleavage events.

Patterns of embryonic cleavage

Pattern of embryonic cleavage is determined both by the position of the mitotic spindles and by the amount and distribution of yolk. Yolk tends to inhibit cleavage. It slows it down or actually prevents complete cleavage. Yolk is an adaptation of those animals that go through more or less of embryogenesis isolated from any food supply. Some animals, like sea urchin, have relatively little yolk because they rapidly develop into a free swimming larval form that acquires nutrients from their environment. Other animals such as marsupials are born prematurely, but are provided nourishment in a parental pouch. Placental mammals develop a specialized organ through which the embryo is nourished throughout development and so also have little yolk.

The types of eggs based on yolk characteristics are described as:

Isolecithal: sparse evenly distributed yolk, eg., sea urchin, mouse;

Mesolecthal: moderate amount of yolk, often unevenly distributed, eg., frog;

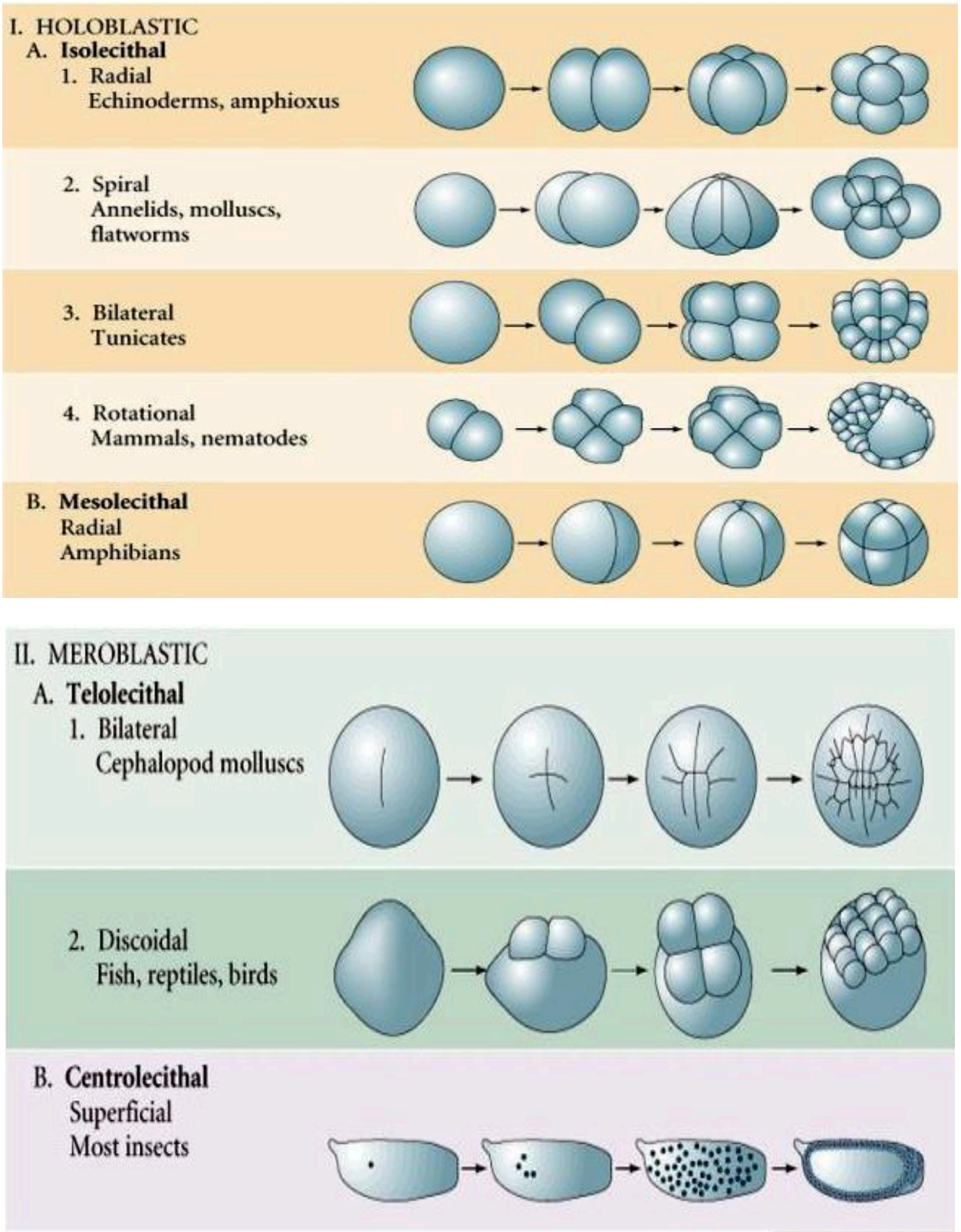
Telolecithal: dense yolk concentrated at one end, eg., bird, reptile;

Centrolecithal: yolk concentrated at the middle of the egg, eg. fly.

Many eggs are polarized with a yolk rich pole, termed the vegetal pole and a yolk poor pole termed the animal pole, eg., frog.

The zygotic nucleus is generally displaced towards the animal pole. Zygotes with relatively little yolk (isolecithal and mesolecithal) cleave *holoblastically*. The cleavage furrow extends all the way through the egg. While telolecithal and centrolecithal zygotes undergo *meroblastic* cleavage where the cleavage plane extends only to the accumulated yolk. In centrolecithal eggs (many insect eggs)

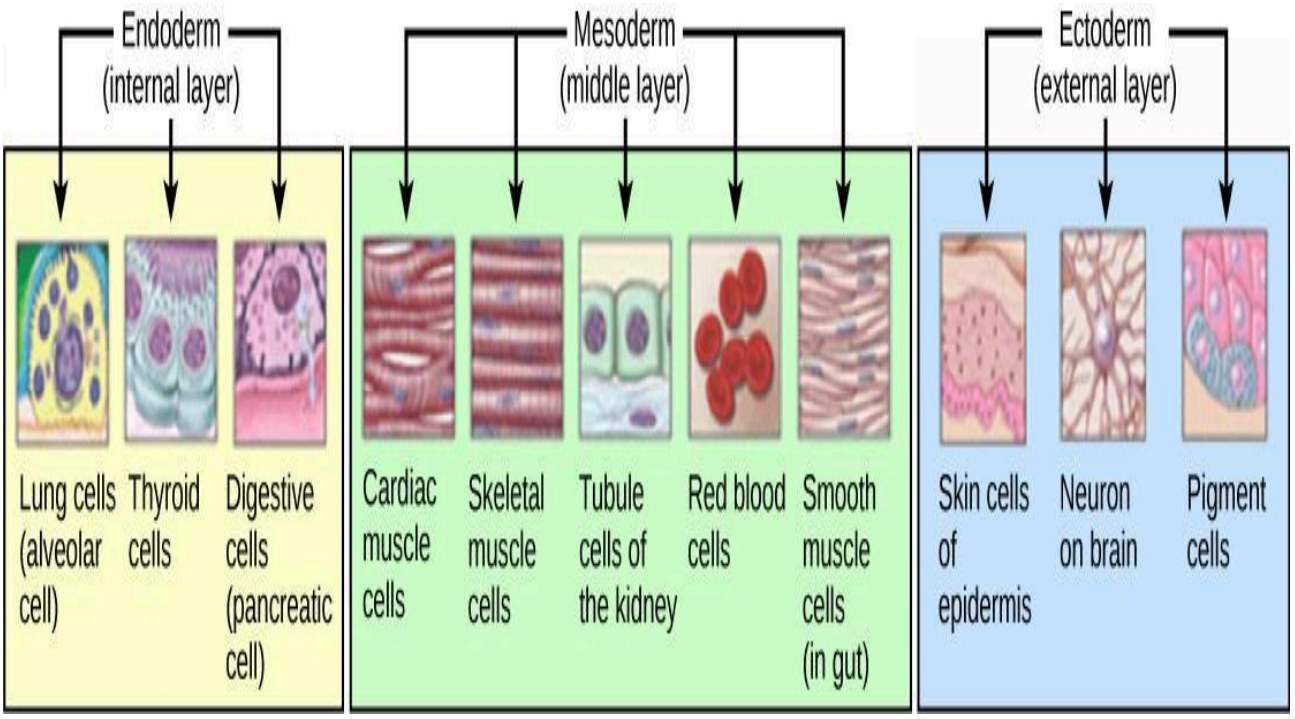
cleavage is meroblastic and superficial, while in telolecithal eggs (birds and fish) cleavage is discoidal



Scheme 5 – Examples of holoblastic and meroblastic cleavage symmetries.

GASTRULATION

Gastrulation is the stage of embryogenesis when three germ layers are formed: *ectoderm*, *endoderm* and *mesoderm*.



Scheme 6 – Gastrulation

During gastrulation:

1) division and growth of cells;

2) translocation of cells;

3) differentiation of cells take place.

Gastrulation is divided into two phases: *early* and *late*. During early gastrulation the formation of ectoderm (external) and entoderm (internal) germ layers take place. During late gastrulation formation of mesoderm (middle germ layer) and axial germs of organs complex (neural tube, chordomesodermal germ and primary intestine) take place.

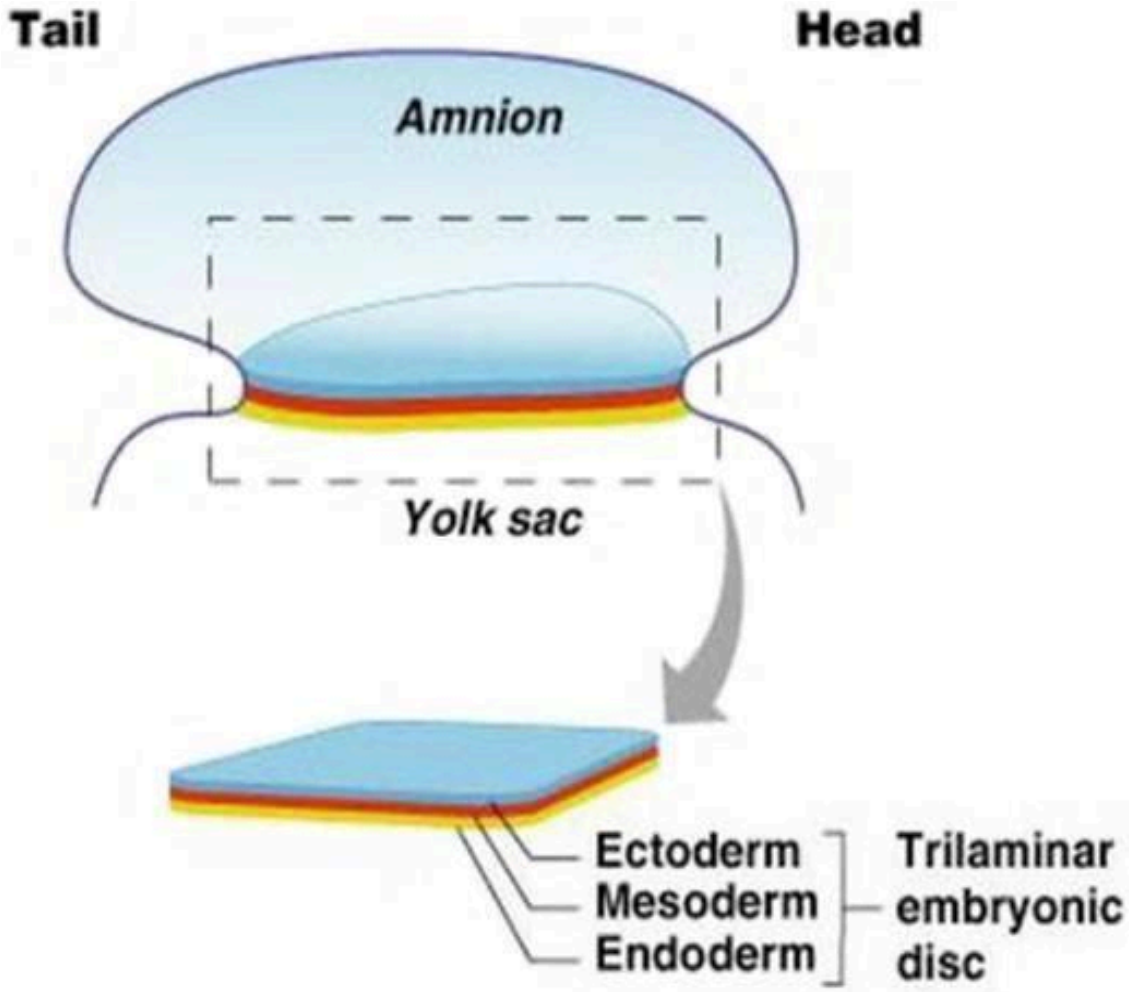


Figure 20– Primary germ layers

Although gastrulation patterns exhibit enormous variation throughout the animal kingdom, they are unified by the five basic types of cell movements that occur during gastrulation:

- Invagination
- Immigration
- Delamination
- Epiboly

Ways of gastrulation

1. *Invagination* is observed at simple chordata. The bottom of blastula into blastocele is invaginated and two germ layers are formed: ecto– and entoderm.

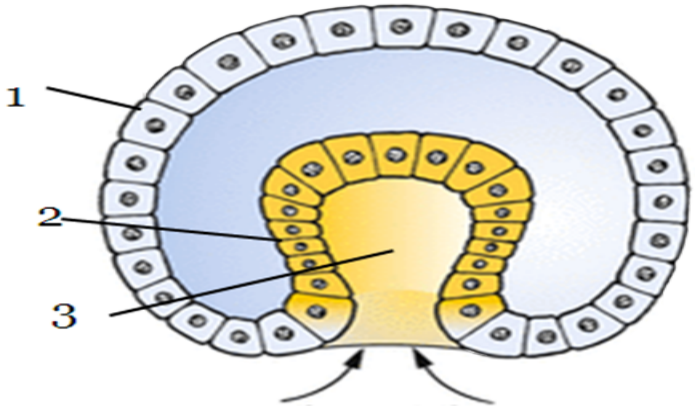


Figure 21 – Invagination

1 – ectoderm; 2 – endoderm; 3 – gastrocoel.

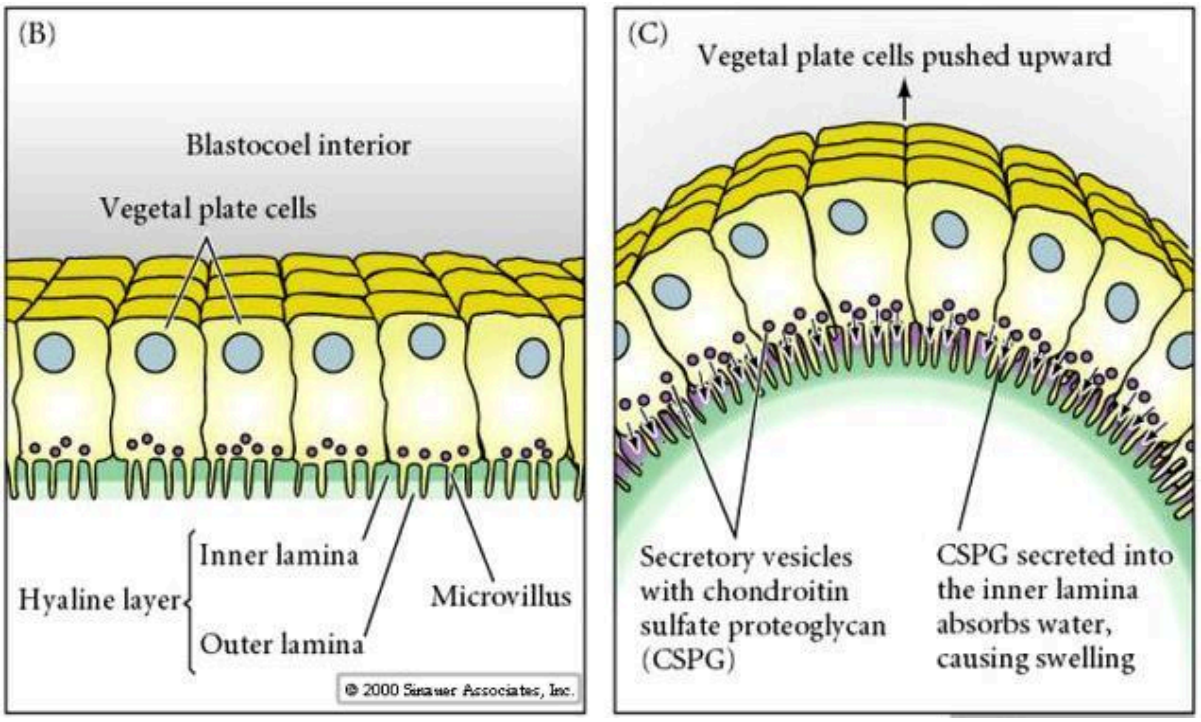


Figure 22 – Invagination

2. *Epiboly* is defined as the movement of cells on the surface of the embryo. Epiboly is mainly classified under Morphogenetic movements. The movement of cells from one place to another to attain a new shape to the developing embryo is known as morphogenetic movements.

Epiboly is characteristic for frogs. Small blastomeres are quickly divided and surround large blastomeres.

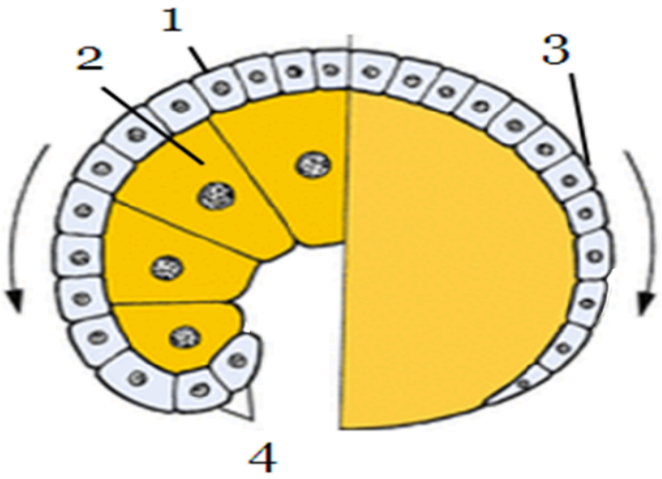


Figure 23 – Epiboly

1 – ectoderm; 2 – endoderm; 3 – epiboly; 4 – involution.

3. *Delamination* is characteristic for birds, mammalia and humans. Division or split of blastomeres into two layers external (ectoderm) and internal (entoderm) takes place.

The *delamination* is a process in which the separation into layers occurs, or it is the initial splitting of the cells in an embryo. It refers to the mass separation of a layer of cells from another layer by splitting. The separation of endodermal, mesodermal and notochordal cells from each other.

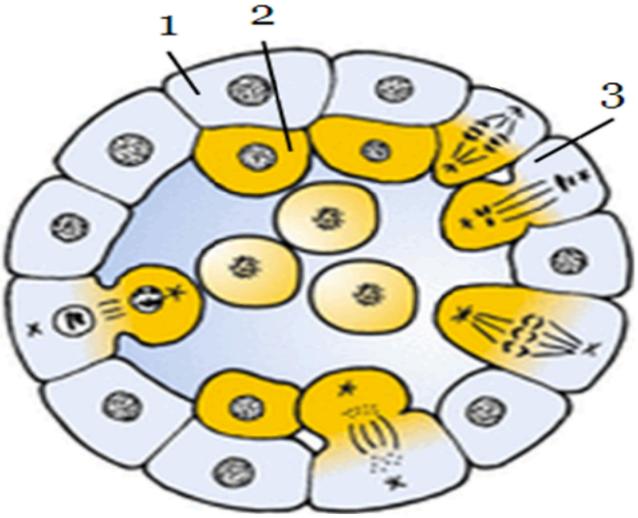


Figure 24 – Delamination

1 – ectoderm; 2 – endoderm; 3 – blastoderm's cells division.

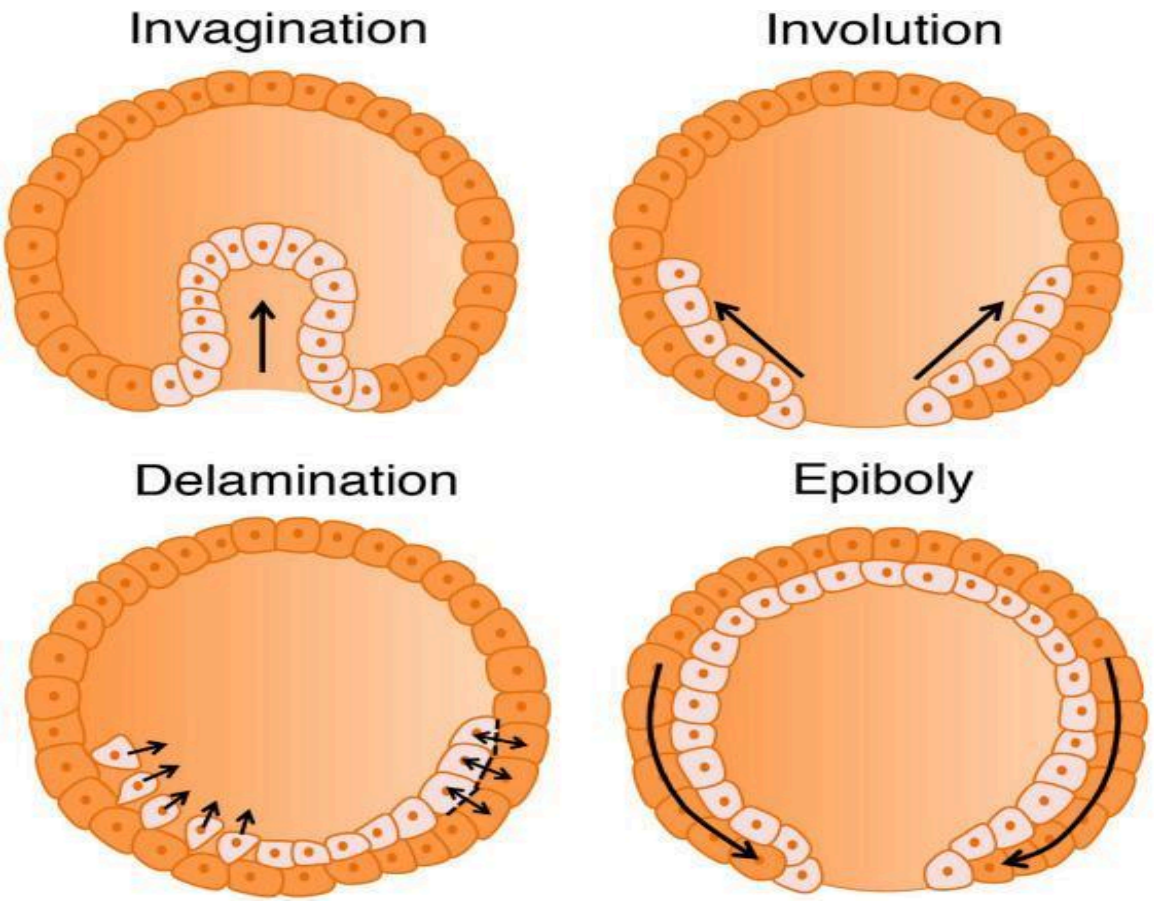


Figure 25 – Delamination

4. *Immigration* is characteristic for birds and humans. Migration of part of blastomere into blastocele ocurs.

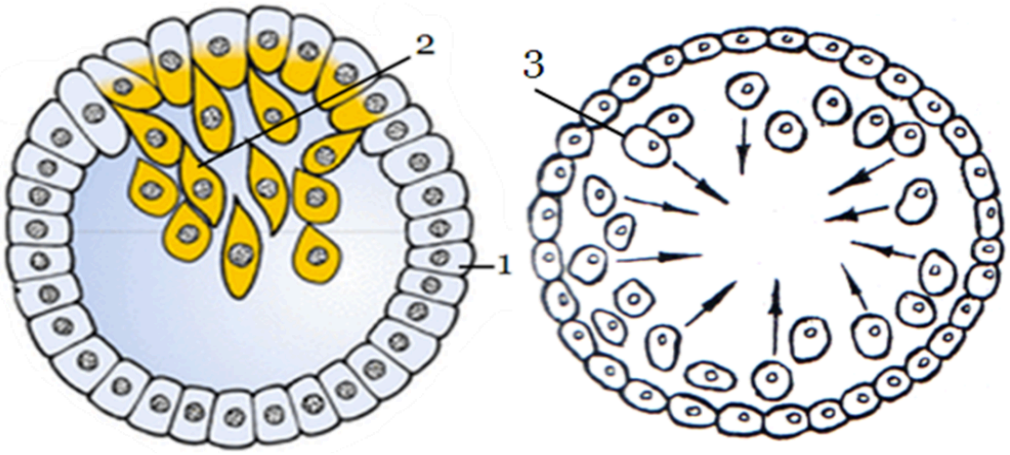


Figure 26 – Immigration

1 – ectoderm; 2 – unipolar immigration; 3 – multipolar immigration.

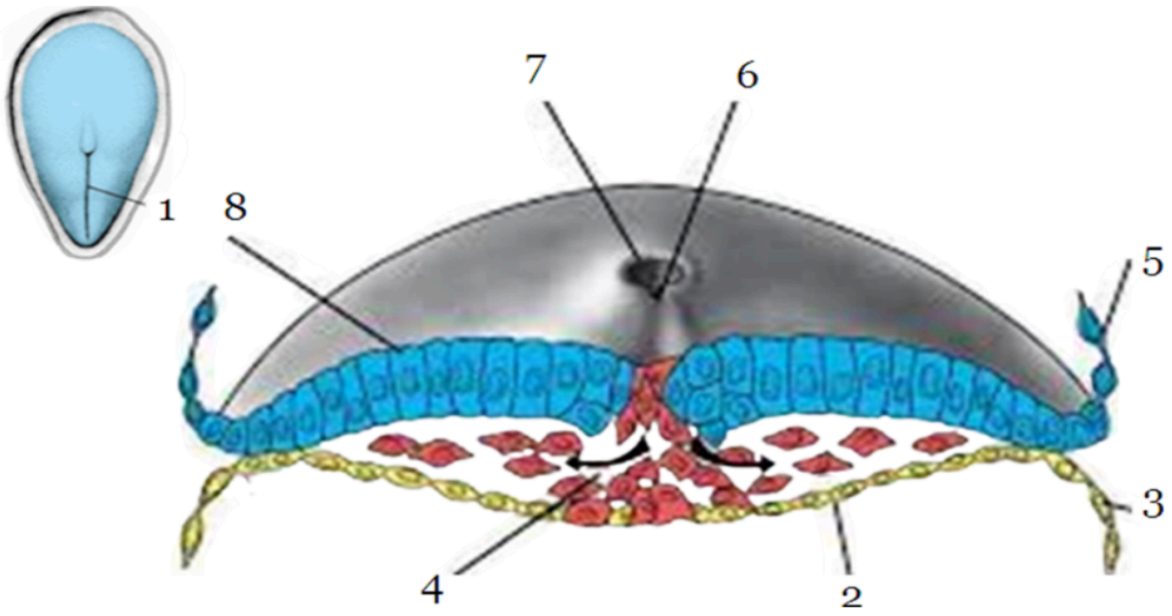


Figure 27 – Transverse section through the embryonic disc at the primitive streak (immigration mesoderm cells)

1 – primitive streak; 2 – hypoblast; 3 – yolk sac lining; 4 – mesoderm; 5 – cut edge of amnion; 6 – primitive streak; 7 – primitive node; 8 – epiblast (will become ectoderm).

Early gastrulation

The period of early gastrulation is from the seventh to fourteenth day. By delamination division or split of embryoblast into *epiblast* and *hypoblast* takes place. At the same time *cavitation* or dissolution of internal cellular mass, which surrounds embryoblast, occurs. The cells of epiblast and hypoblast are divided.

Epiblast cells go upwards, connect and form *amniotic vesicle*. The edges of hypoblast go downwards and form *yolk sac*. The bottom of amniotic vesicle is formed by *epiblast* and the rest parts of it forms *extraembryonic ectoderm*. The roof of yolk sac is formed by *hypoblast* and from the rest part of it *extraembryonic entoderm* is formed. The bottom of amniotic vesicle and the roof of yolk sac formed embryonic disc.

From hypoblast only extraembryonic entoderm is formed, and from epiblast embryo and extraembryonic ectoderm develop. Cells of germ disc begin to divide and move into the cavity of blastocyte and form *extraembryonic mesoderm*. These cells

move in three currents. The first current surround the amniotic vesicle and form the external wall of amnion; the second current forms the external wall of yolk sac, and the third – attaches to trophoblast and participates in formation of *chorion* internal wall.

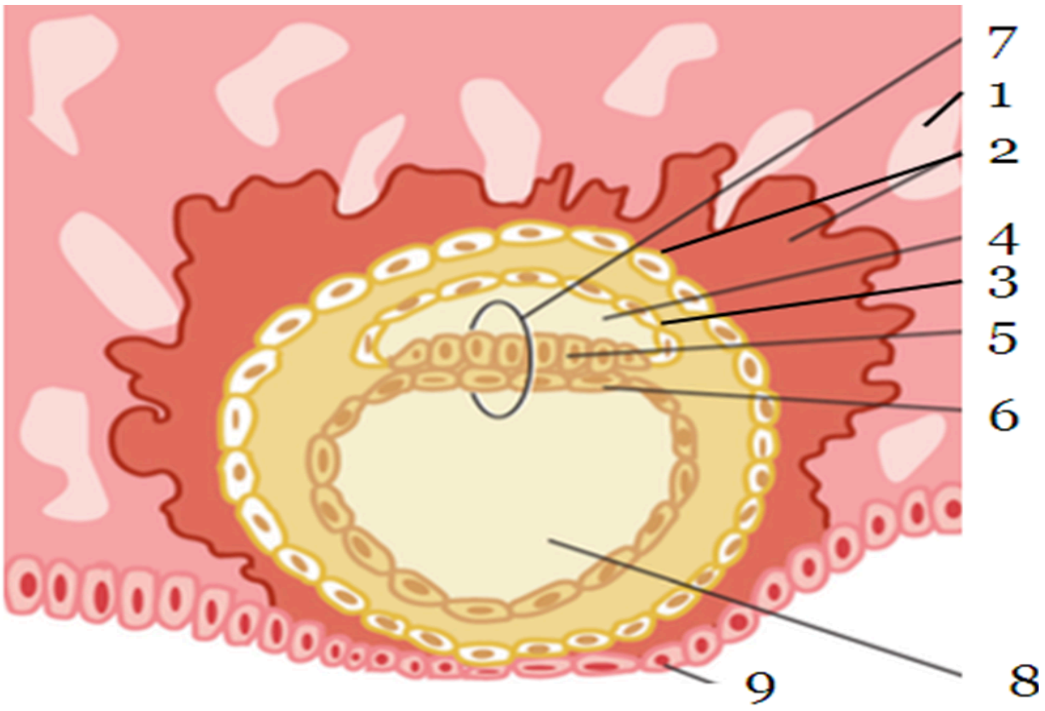


Figure 28 – Embryo at day 9

1 – wall of uterus; 2 – layers from trophoblast; 3 – amnion; 4 – amniotic sac cavity; 5 – epiblast; 6 – hypoblast; 7 – bilaminar embryonic disc; 8 – yolk sac cavity; 9 – endometrium of uterus.

So, in human extraembryonic organs – chorion, amnion and yolk sac become the most developed during early gastrulation. *Amnion wall* is composed of *extraembryonic mesoderm* and *extraembryonic ectoderm*. *Yolk sac wall* is composed of extraembryonic mesoderm and extraembryonic entoderm. *Chorion wall* is composed of 3 layers: external – syncytiotrophoblast, middle – cytotrophoblast, internal – extraembryonic mesoderm.

Amniotic vesicle is attatched to chorion with the help of amniotic stalk, formed from extraembryonic mesoderm. Further, on the place of amnionic stalk, umbilical cord will be developed.

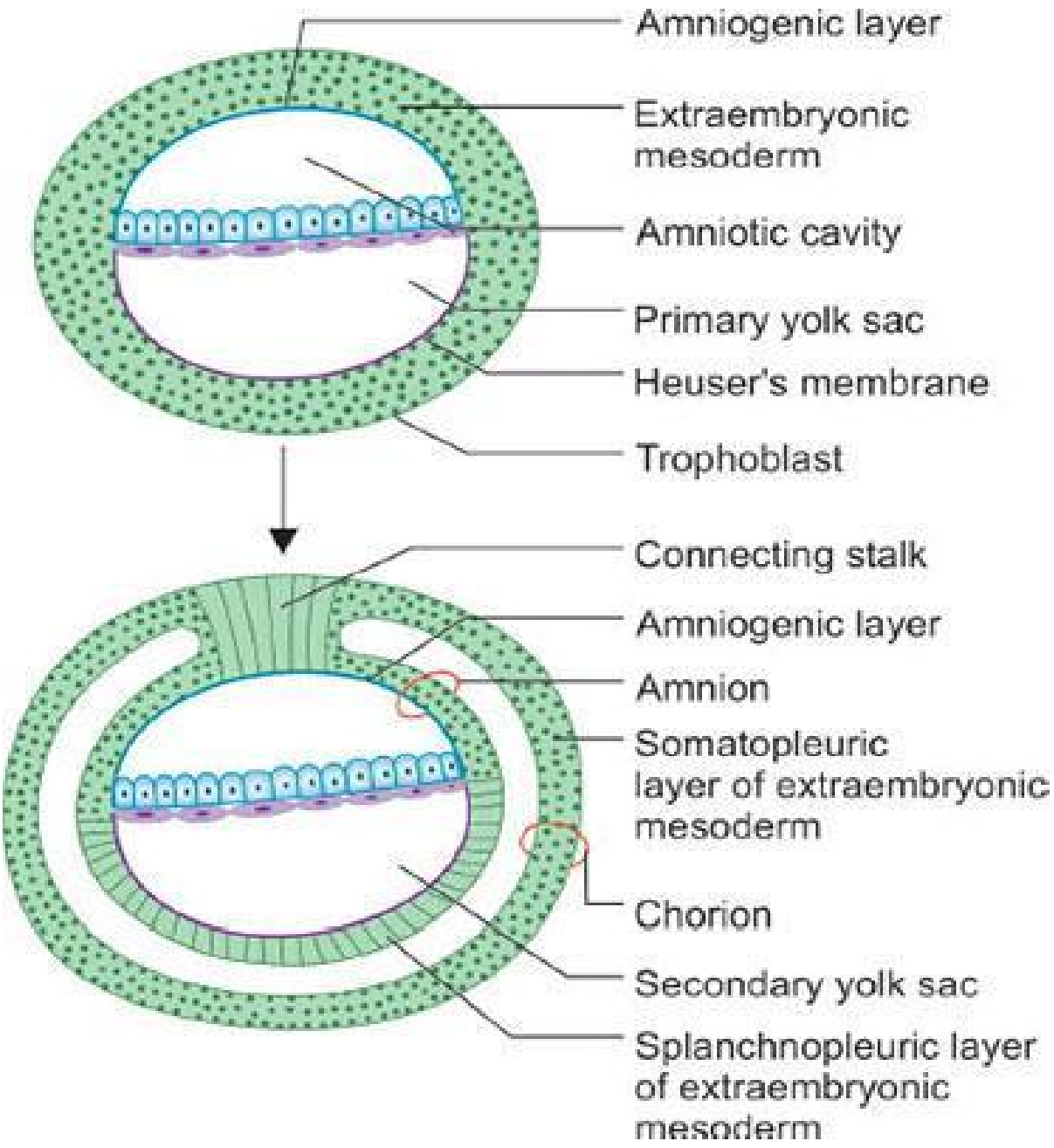


Figure 29 – Early gastrulation

Late gastrulation

Late gastrulation begins on the 14–15 day. Epiblast cells are intensively divided and imigrate from the head end to the caudal one in two currents. Here they meet and turning in the opposite direction, forms thickened cellular band along the middle line of germ disk – *primary streak*. On the anterior part of primary stripe cellular thicking looking like tubercle – *primary knot* – is formed.

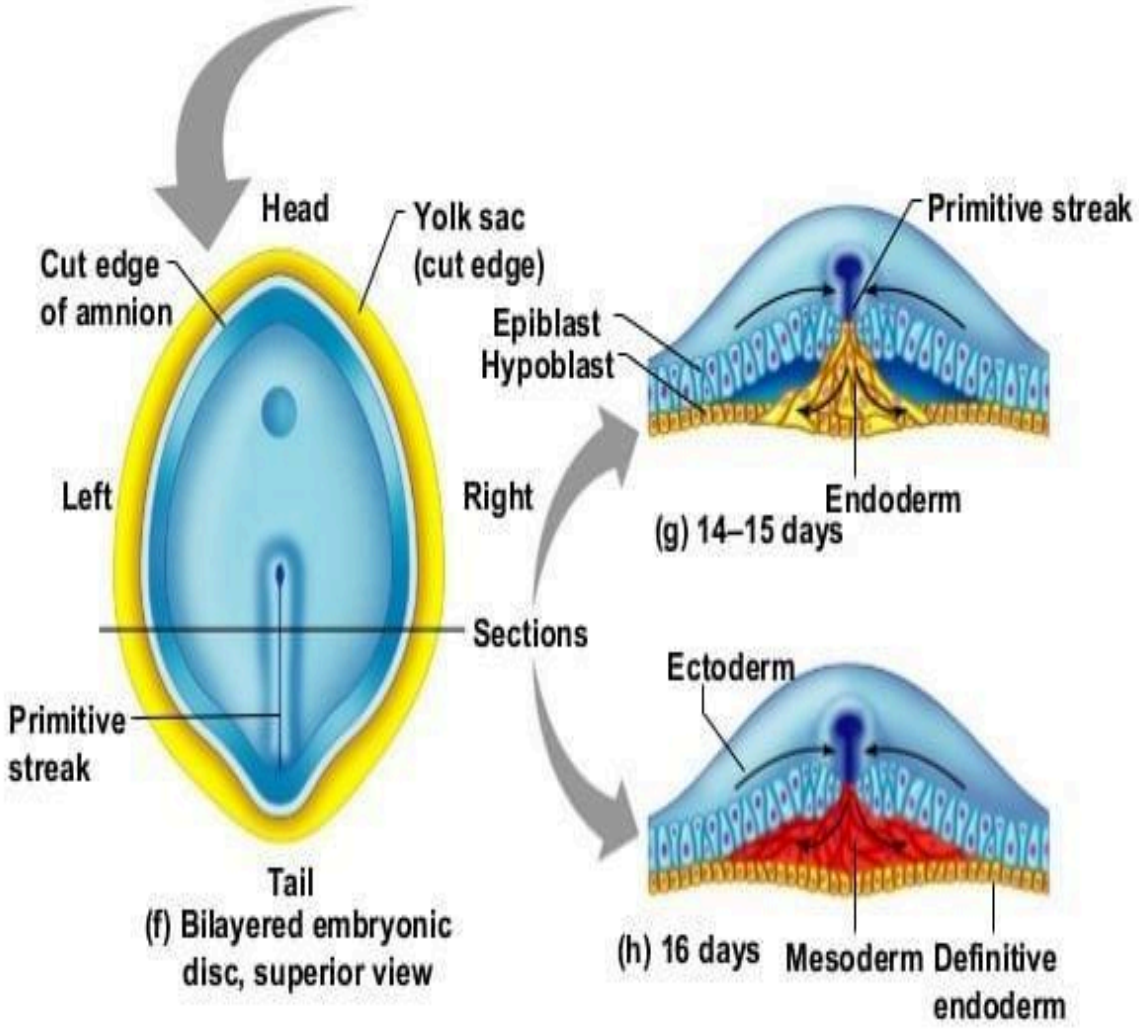


Figure 30 – Formation of the e primary germ layers

From the cells of the anterior part of primary stripe *embryonic entoderm* is formed, from the cells of middle part of primary steak embryonic mesoderm is formed, and from the cells of the posterior part form *extraembryonic mesoderm*. Cells of primary knot and site of epiblast, lying before it, move into a formed pit on the place of primary streak, extending in the form of cellular band – *chorda.*

Embryonic ectoderm is formed owing to those epiblast cells, which stay in their own place. Space between embryonic layers is filled with embryonic connective tissue – *mesenchima*, which is mainly formed from mesoderm. From 17–20 days the formation of axial germ of organs is completed. Just after the formation, the cells of chorda they are induce the ectoderm cells overlying it.

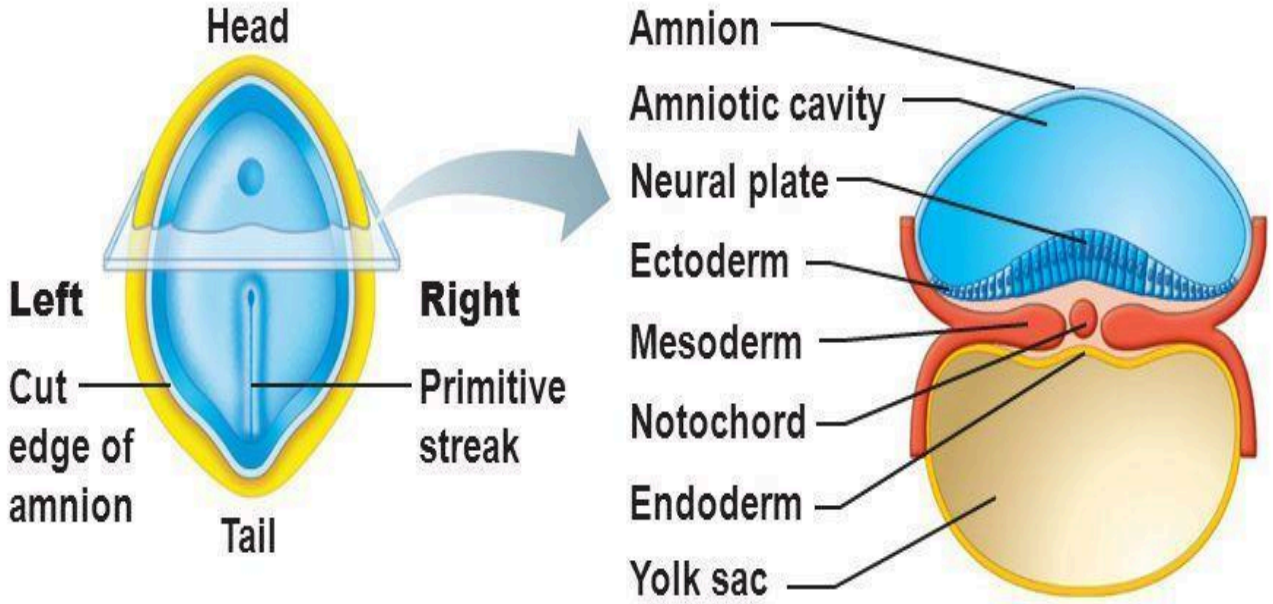


Figure 31 – Early mesodermal differentiation, 17 days

This cause their prolifiration, formation of neural plate, its caving in towards chorda. This results in the formation of neural groove and neural elevations. These elevations fuse and formation of neural tube begins in the neck region of embryo and continues in the caudal direction. Further, cerebral vesicles are formed on the head end of neural tube enlargements.

Cells, from which neural crest is formed, are located between neural tube and ectoderm. Further, spinal ganglia are formed from neural crest. Neural crest cells: these cells arise from both dorsal epidermis and neural plate. They migrate throughout the body. Neural crest cells form a variety of cell types including cartilage, pigment cells of skin, neurons, smooth muscle cells, and adrenal medulla. Migration staging area: the cells originate at the crests of the neural folds during neurulation. Both epidermal tissue and neural tissue contribute to this lineage.

There are 2 patterns of migration neural crest cells in the trunk region: dorsolateral path: enter skin and form melanocytes.

Ventral path: form afferent neurons of dorsal route ganglia, sympathetic and parasympathetic ganglia, and adrenal medulla Neural crest cells help to form addition structures in the head such as bones, connective tissue, eyes, ears, and teeth. They

also help to form blood vessels and connective tissue in the trunk. The process of neurulation is the process of neural tube formation.

The neural tube gives rise to the central nervous system and contributes to the peripheral nervous system central nervous system: brain and spinal cord. From the time of neural tube closure to birth, approximately 250,000 neurons are formed each minute.

The CNS contains over 100 billion neurons when complete. The early neural epithelium contains a pseudostratified layer of stem cells. The basement membrane is at the outer edge and tight junctions form at the inner surface. Different cell types are formed.

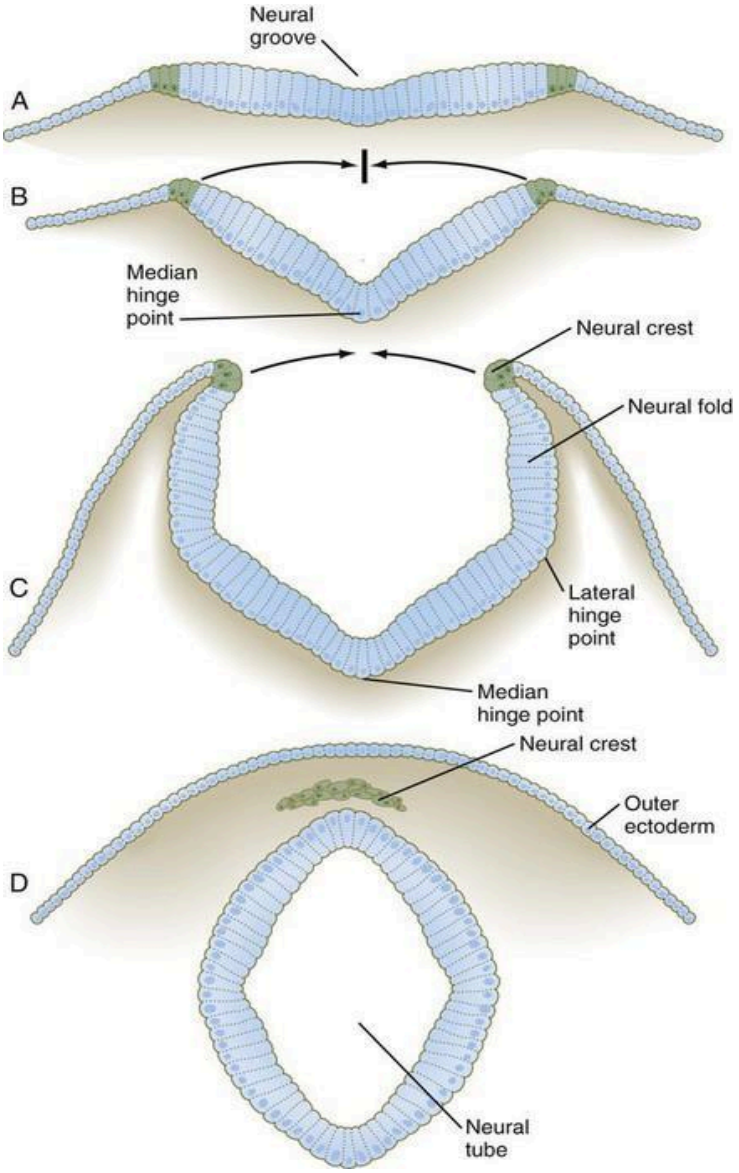
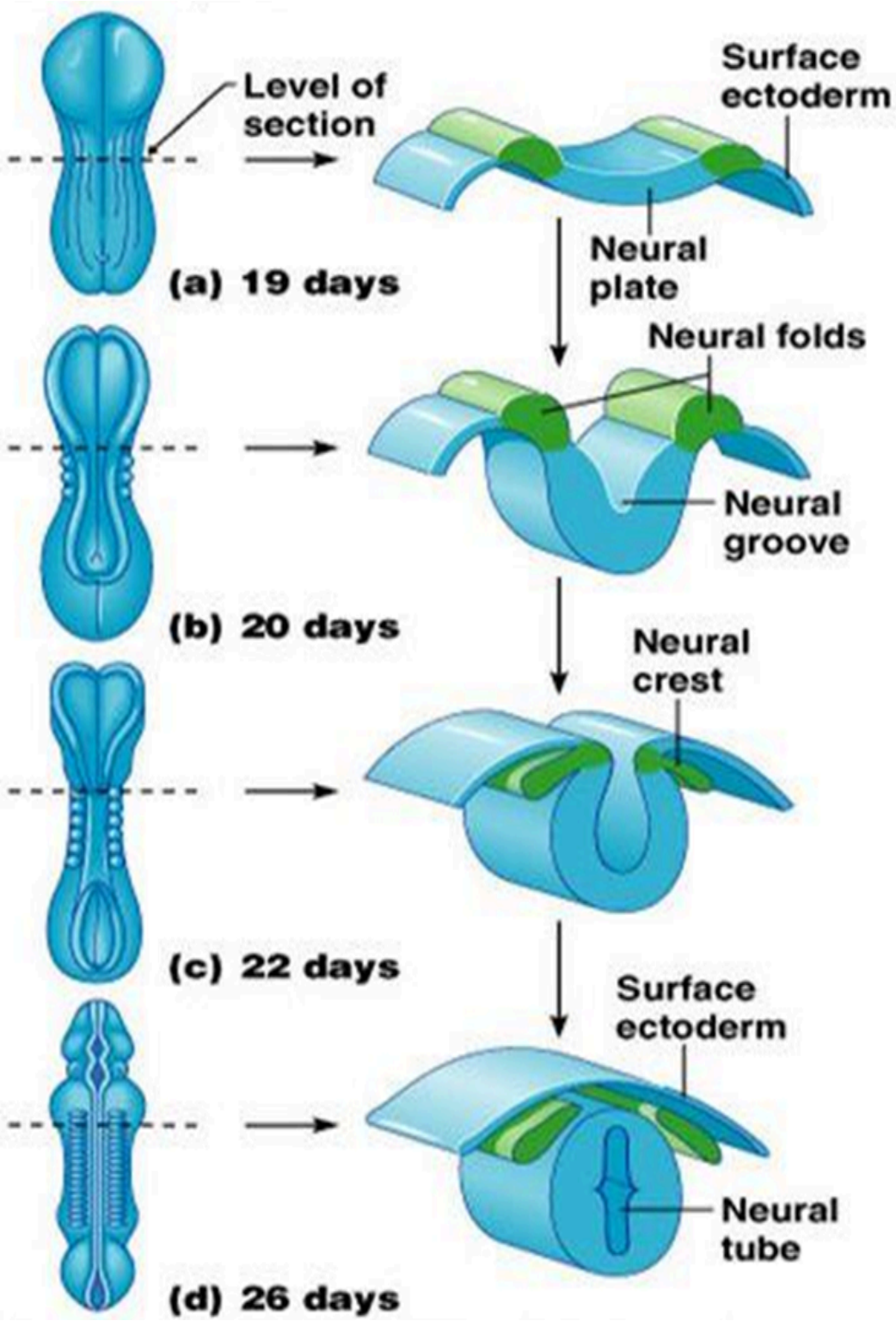


Figure 32 – Process of neural tube formation.

Simultaneously (at the same time) differentiation of mesoderm occurs. On the 20 day of embryonic development *somitic period* begins. Dorsal sites of mesoderm, which lie on both sides of chorda, begin to divide into separate segments – *somites*.



Scheme 7 – Neurulation

The process of segmentation and the formation of somites are taking place from the head towards the cauda of embryo.

The term somitogenesis is used to describe the process of segmentation of the paraxial mesoderm within the trilaminar embryo body to form pairs of somites, or balls of mesoderm.

In humans, the first somite pair appears at day 20 and adds caudally at 1 somite pair/90 minutes until on average 44 pairs eventually form.

A somite is added either side of the notochord (axial mesoderm) to form a somite pair. The segmentation does not occur in the head region, and begins cranially (head end) and extends caudally (tailward) adding a somite pair at regular time intervals. The process is sequential and therefore used to stage the age of many different species embryos based upon the number visible somite pairs.

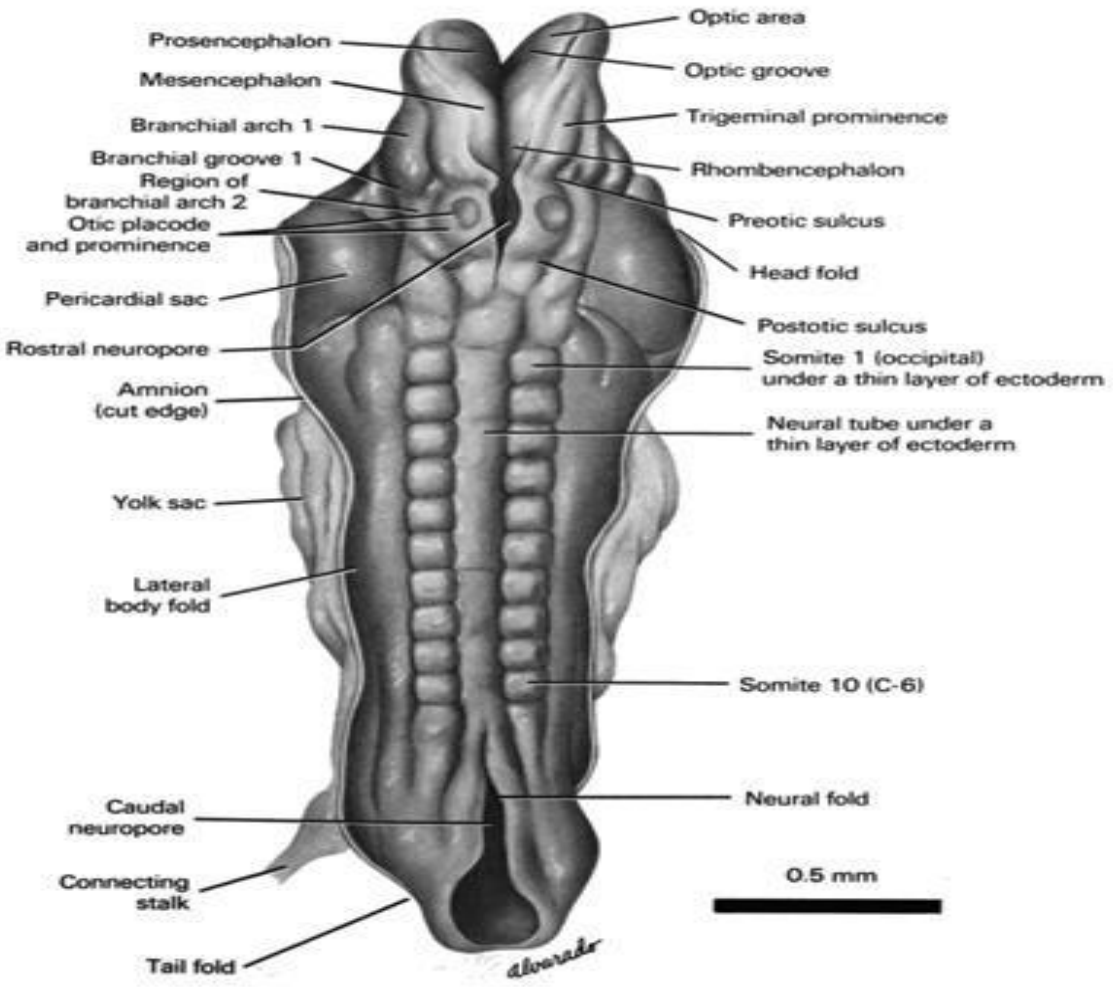


Figure 33 – The fourth week of life 10–somite embryo and neural tube period

By the 35 day 44 pairs of somites are formed. Every somite differentiates into three parts, from the external part – *dermatome* – the source of connective tissue of skin (derma) is formed, from the central part – *myotome* – the source of skeletal muscular tissue, from internal part – *sclerotome* – the source of cartilaginous and osseous tissues.

Ventral mesoderm is *splanchnotome*. It is divided into two layers: *visceral*, which adjoins to entoderm and forms *splanchnopleura*, and *parietal*, layer adjoining to ectoderm and forming *somatopleura*. Visceral and parietal layers give rise to coelomic epithelium. The cavity between these layers formd the secondary cavity of the body – *coelom*, represented in the formed organism as pleura, pericardial and abdominal cavities.

A small part of mesoderm, located between somites and splanchnotome, is called intermediate mesoderm or *nephrotome*. The head part of nephrotomes are segmented into *urogenital stalks*, and the caudal part is not segmented. Nephrotomes are source of urinary and genital systems.

Each nephrotome develops into an epithelialized pronephros glomerulus. Laterally, they form the pronephros tubules that can partly bind with the coelom. Via the fusion of these tubules between two nephrotomes the hollow pronephros duct arises that is the anlage of the pronephric collecting duct.

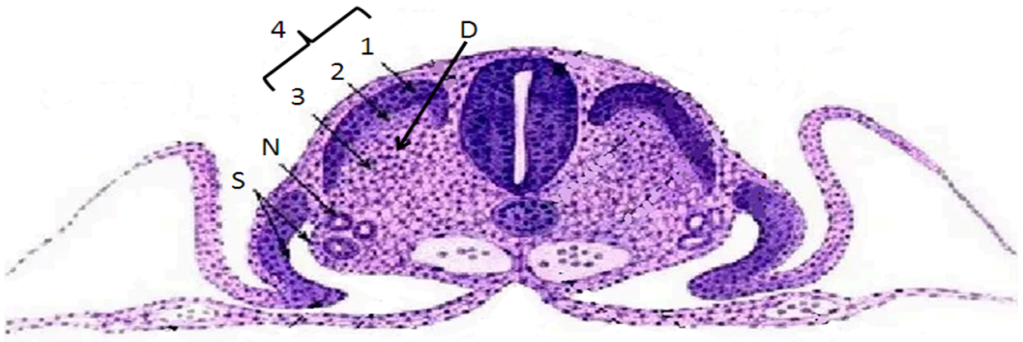


Figure 34 – Differentiation of mesoderm

D – dorsal mesoderm: 1 – dermatome; 2 – myotome; 3 – sclerotome; 4 – somite; N – intermediate mesoderm – nephrotome; S – internal mesoderm – splanchnotome.

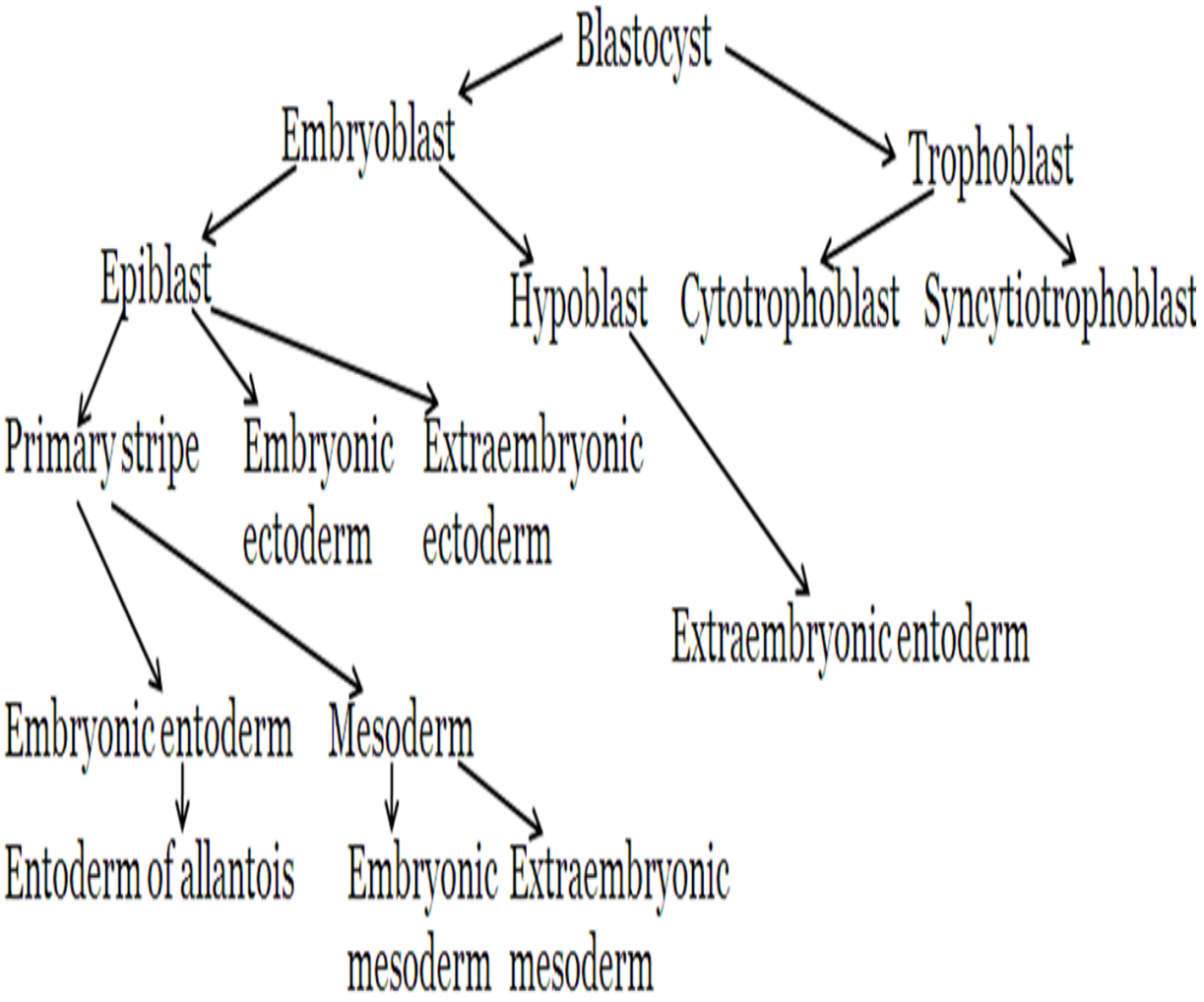
By the end of the first month neurulation and differentiation of mesoderm is completed. The process of tissue formation – histogenesis – begins.

Histogenesis is the process by which cells and tissues acquire functional specialization.

In humans: cleavage (2 weeks) → gastrulation (1 week) → organogenesis (4 weeks) → histogenesis (7 months).

Organogenesis: the formation of organ rudiments to establish the basic body plan. Histogenesis: differentiation of cells within the organs to form specialized tissues. Tissues are composed of cells and extracellular material that perform a specific function. Each specific tissue develops mainly from one germ layer.

Histogenesis is taking place simultaneously with organogenesis and systemogenesis, and is given in the tables.



Scheme 8 – Organogenesis and systemogenesis

The flat three–layered embryo has completed gastrulation. Notochord and neural plate are present.

The neural folds have closed, forming the neural tube which has detached from the surface ectoderm and lies between the surface ectoderm and the notochord. Embryonic body is beginning to undercut.

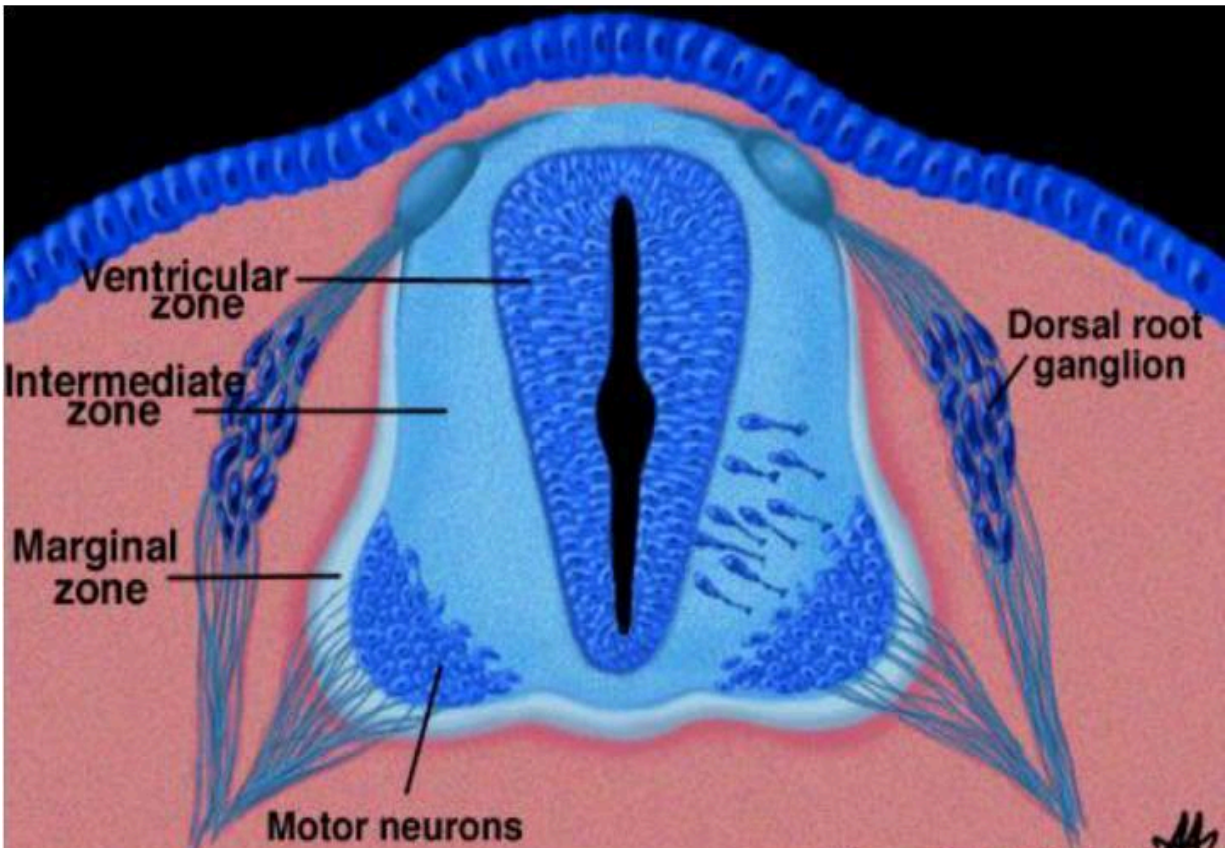


Figure 35 – Folding of the embryonic body

Embryo undercutting is complete. Somites have subdivided into sclerotome, myotome, and dermatome, which form the vertebrae, skeletal muscles, and dermis respectively. Body coelom present.

QUESTIONS ON THE TOPIC: CLEAVAGE. GASTRULATION

1. Cleavage definition.

2. Different modes of cleavage.

3. Structure of blastula.

4. The cleavage peculiarities in the human. Chronology of the process.

5. Structure of blastocyst.

6. Implantation site, significance and stages.

7. Gastrulation definition and attribute.

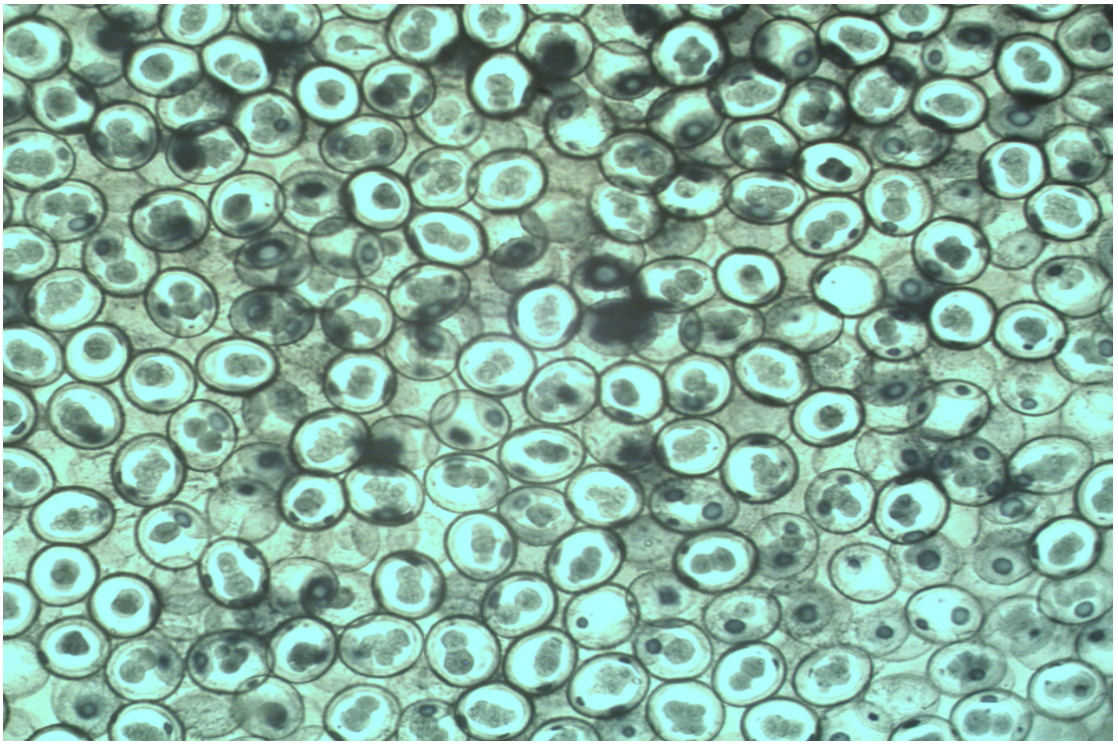
8. Ways of gastrulation.

9. Human gastrulation early stage. Manners of germ layers and extraembryonal organs formation.

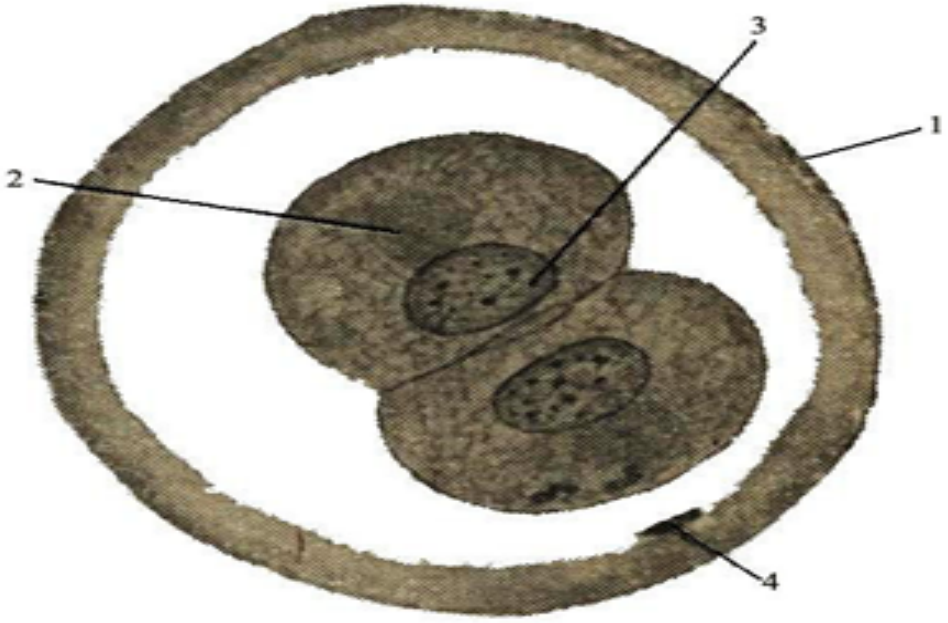
10. Gastrulation later stage.

11. Differentiation of mesoderm.

PRACTICAL PART II

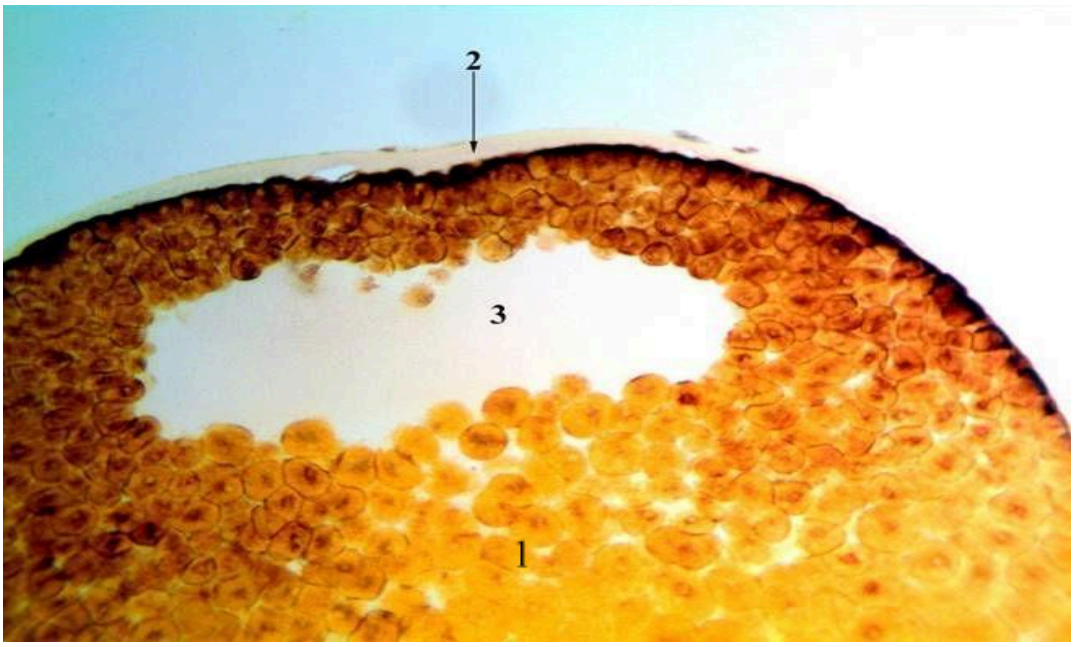


Slide 1 – blastomeres created by mitotic cleavage of embryonic cells



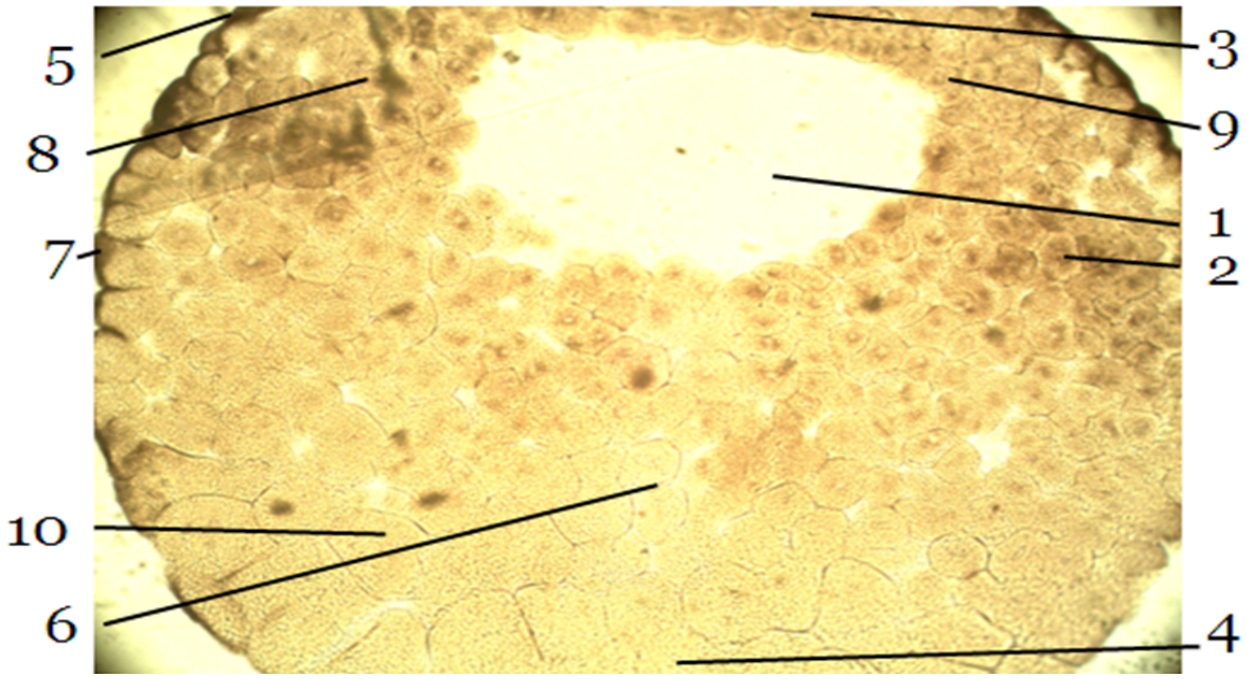
Slide 2 Cleavage (stage of the two blastomeres).

Staining: iron hematoxylin
1 – fertilization membrane; 2 – cytoplasm; 3 – nucleus; 4 – polar bodies.



Slide 3 – Amphiblastula

Staining: iron hematoxylin
1 – vegetal pole 2 – animal pole, 3 – blastocoel;



Slide 4 – Amphiblastula

Staining: iron hematoxylin
1 – blastocoel; 2 – blastomere; 3 – animal pole; 4 – vegetal pole; 5 – the roof of the blastula; 6 – the bottom of the blastula; 7 – blastoderm; 8 – marginal zone; 9 – micromere; 10 – megamere.

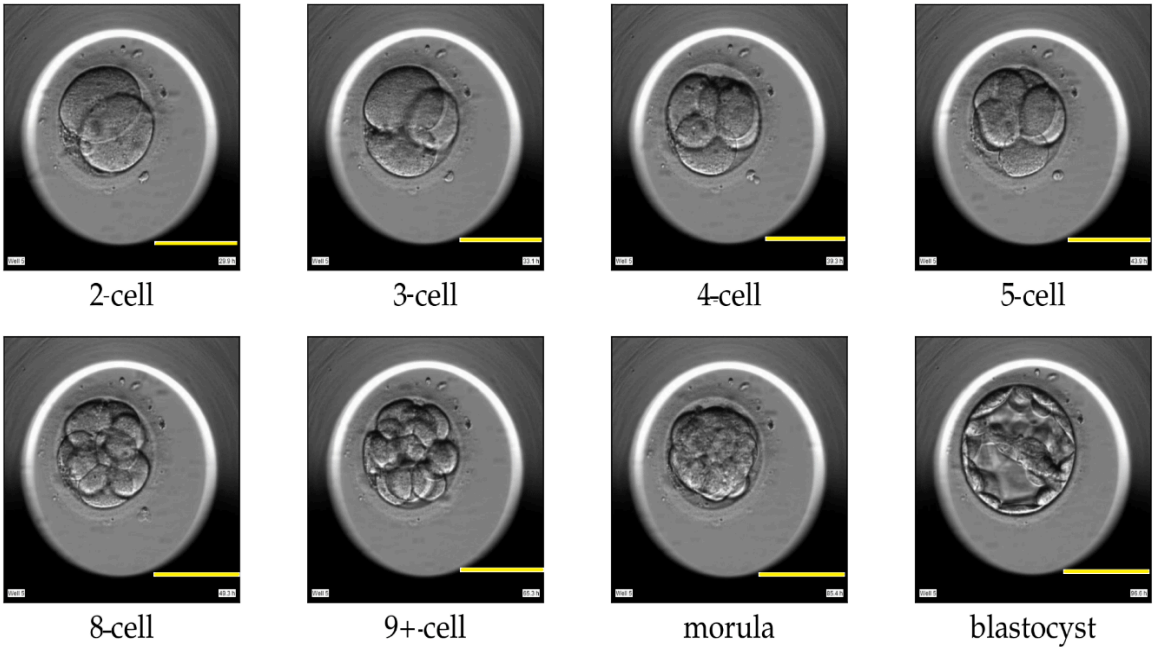
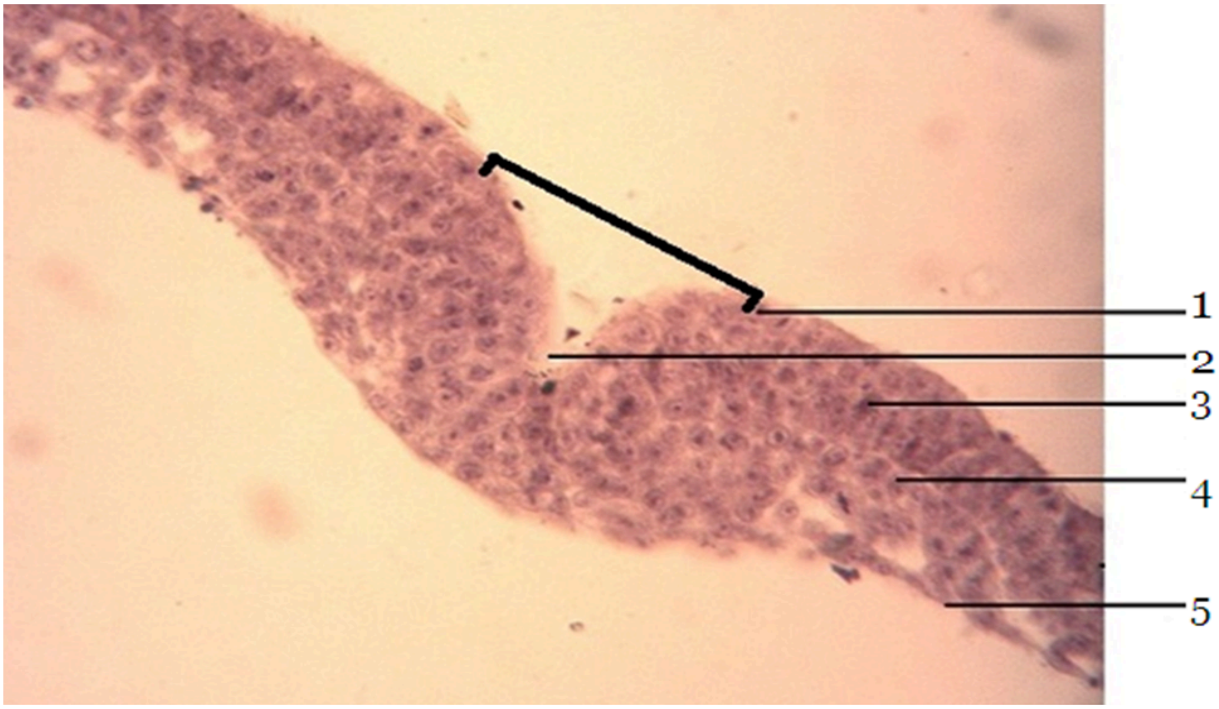


Figure 1 – cell cleavage stages of human embryo development.

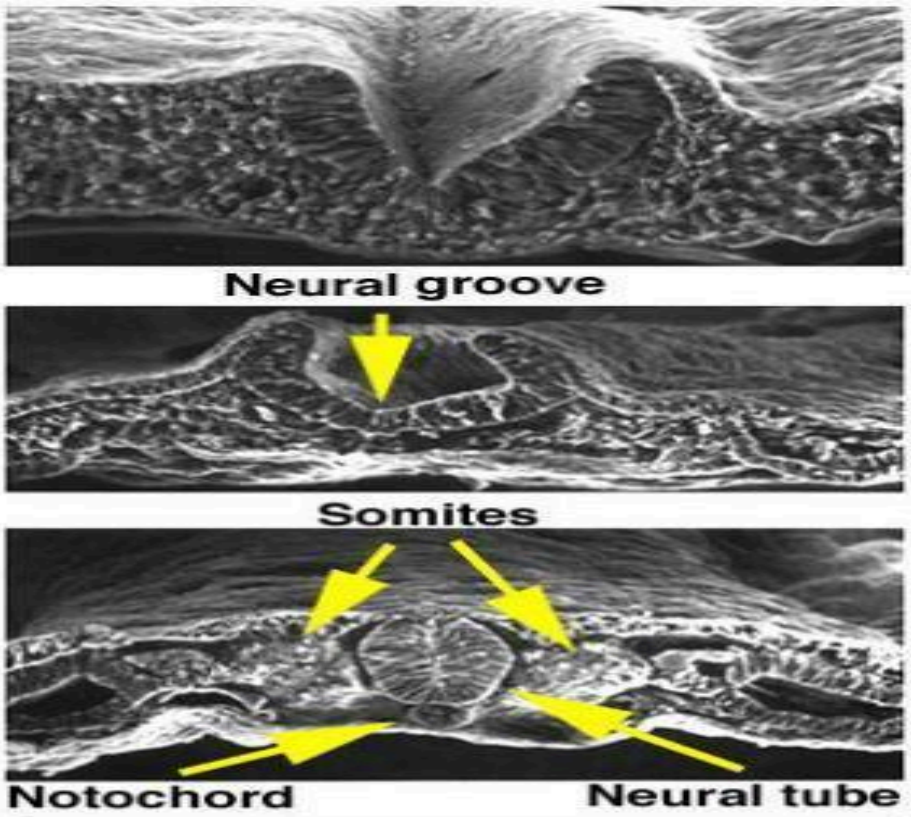
Scale bar: 100 μm.



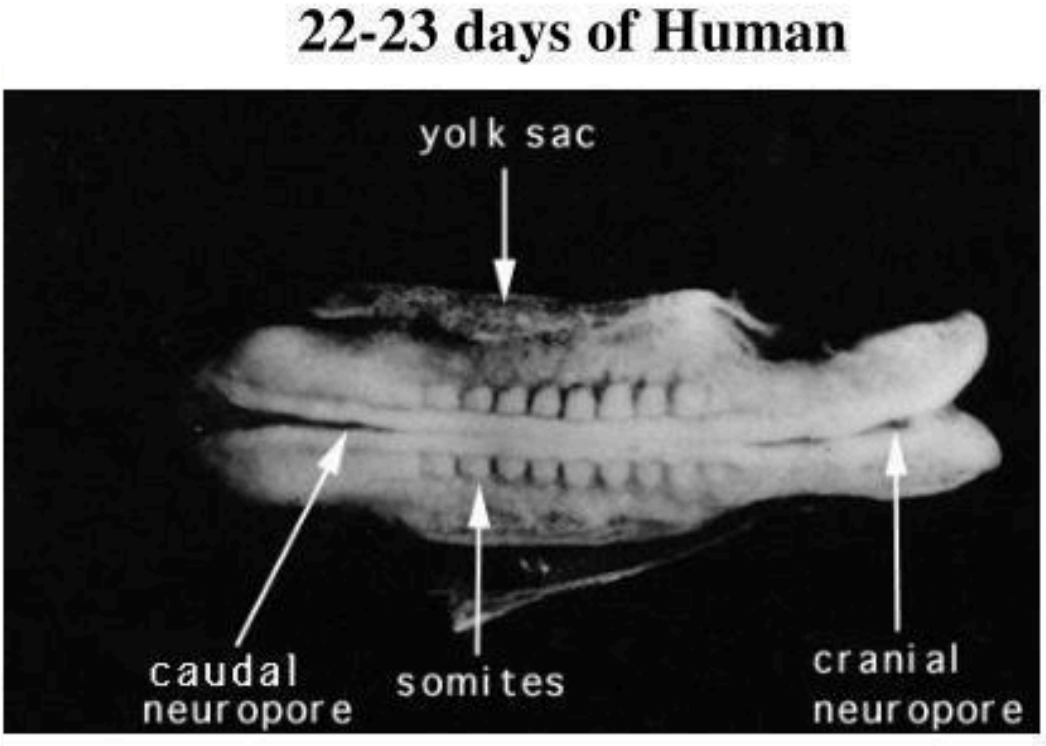
Slide 5 – Primitive streak

Staining: hematoxylin–eosin.

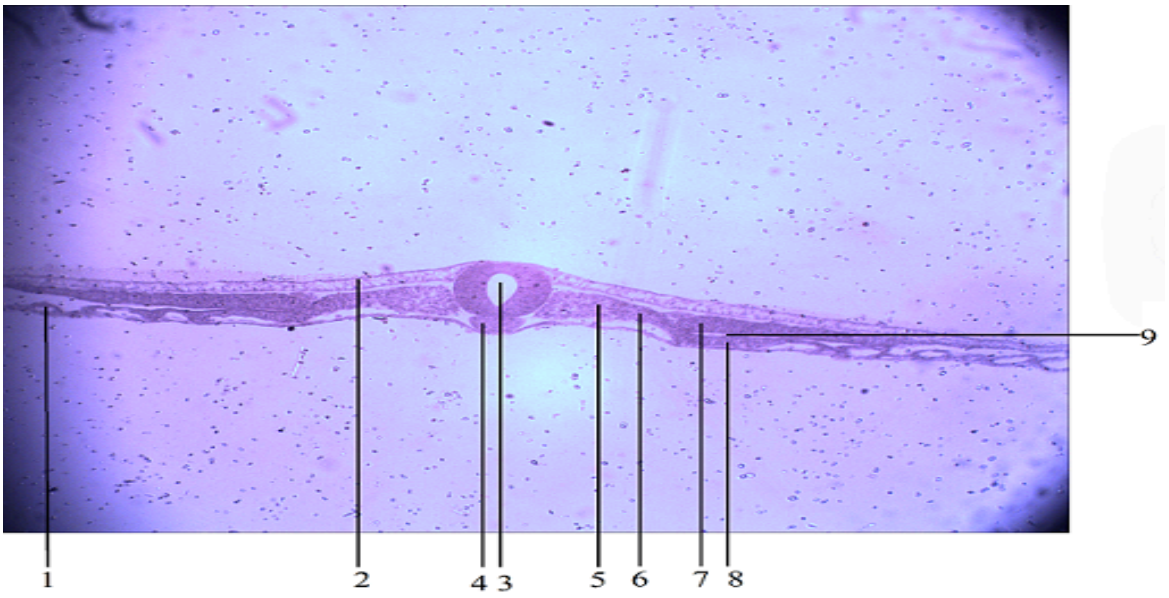
1 – primitive streak; 2 – primitive groove; 3 – neuroectoderm (neural plate); 4 – mesoderm; 5 – entoderm.



Slide 6 – Neurulation



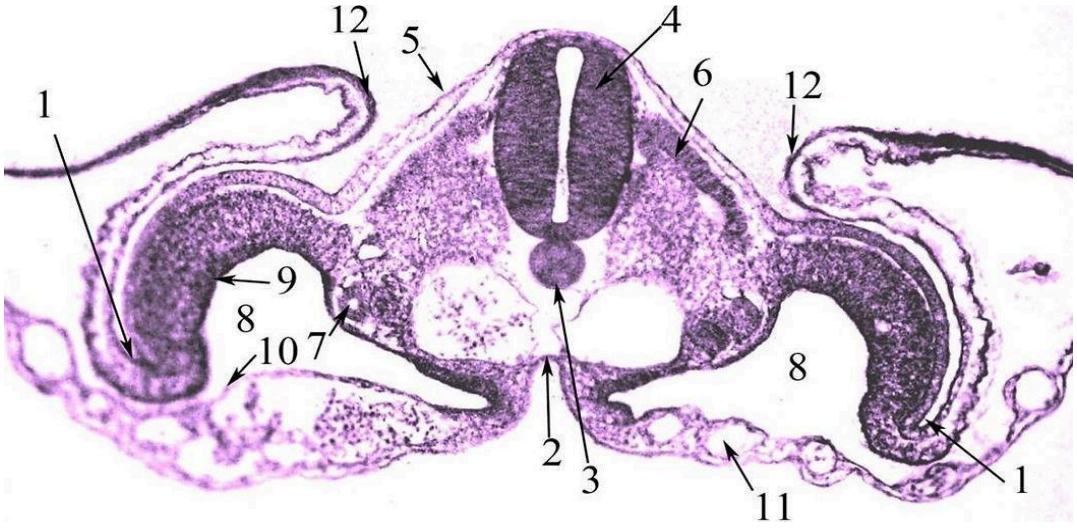
Slide 7 – Neurul tube



Slide 8 – Notochord, somite, neural tube

Staining: hematoxylin–eosin.

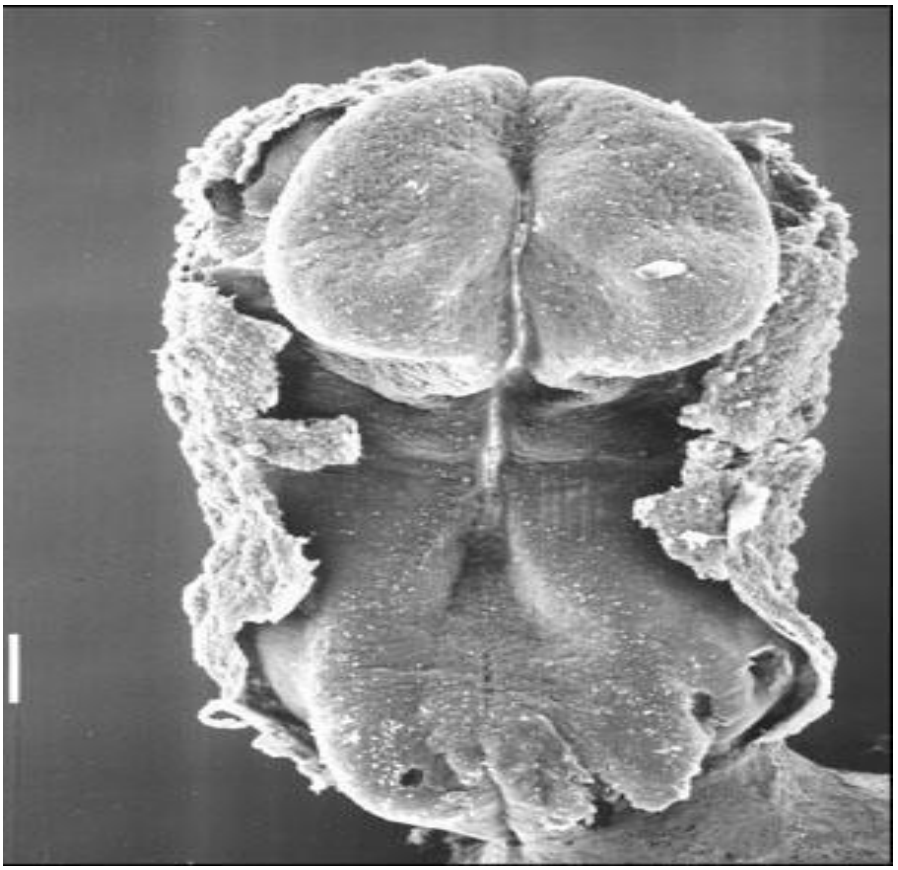
1 – entoderm; 2 – ectoderm; 3 – neural tube; 4 – notochord; 5 – somite; 6 – intermediate mesoderm; 7 – visceral splanchnic mesoderm; 8 – parietal splanchnic mesoderm; 9 – coelom.



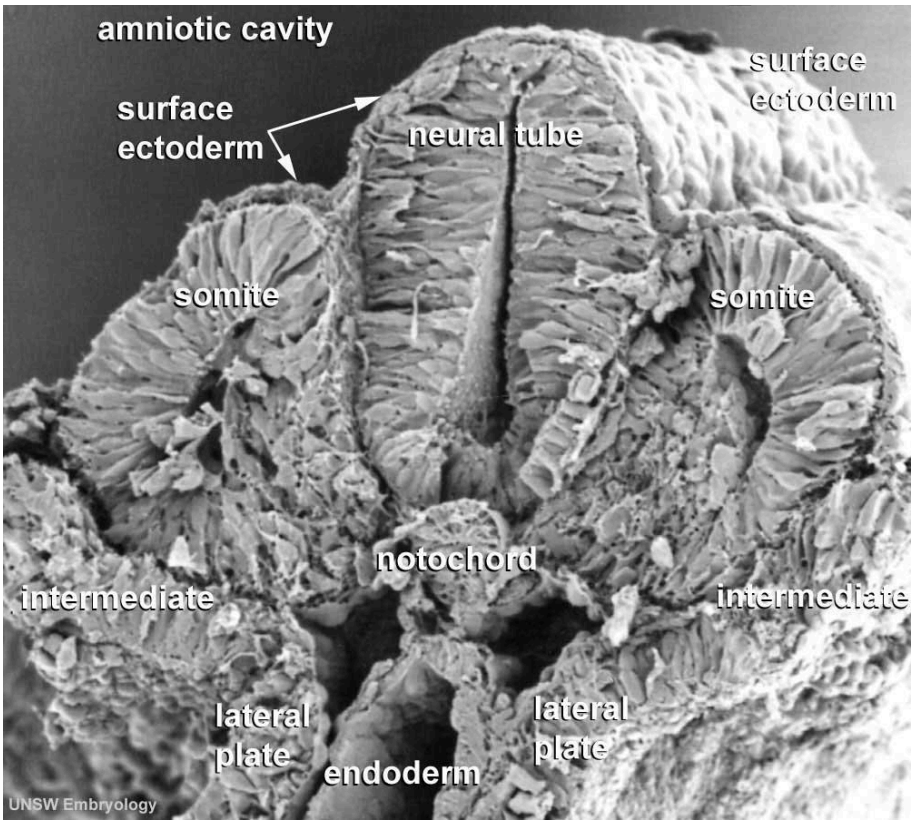
Slide 9 – Body and amniotic folds of embrion

Staining: hematoxylin–eosin.

1 – body fold; 2 – gastrocele, 3. – notochord, 4 – neural tube, 5 – skin ectoderm, 6 – dermatome, 7 – nephrotoma, 8 – celom, 9 – parietal splanchnotome layer, 10 – visceral splanchnotome layer, 11 – blood vessels, 12 – amniotic fold



Slide 10 – Human embryo first somite pair week 4



Slide 11 – Human embryo week 4 (somite).

PROVISIONAL ORGANS

Provisional (temporary) organs are formed at early stages of development and provide favourable conditions for life, growth and development of embryo. They functions only during embryonic period. Provisional organs are:

1. amnion;
2. yolk sac;
3. allantois;
4. chorion;
5. placenta;
6. umbilical cord.

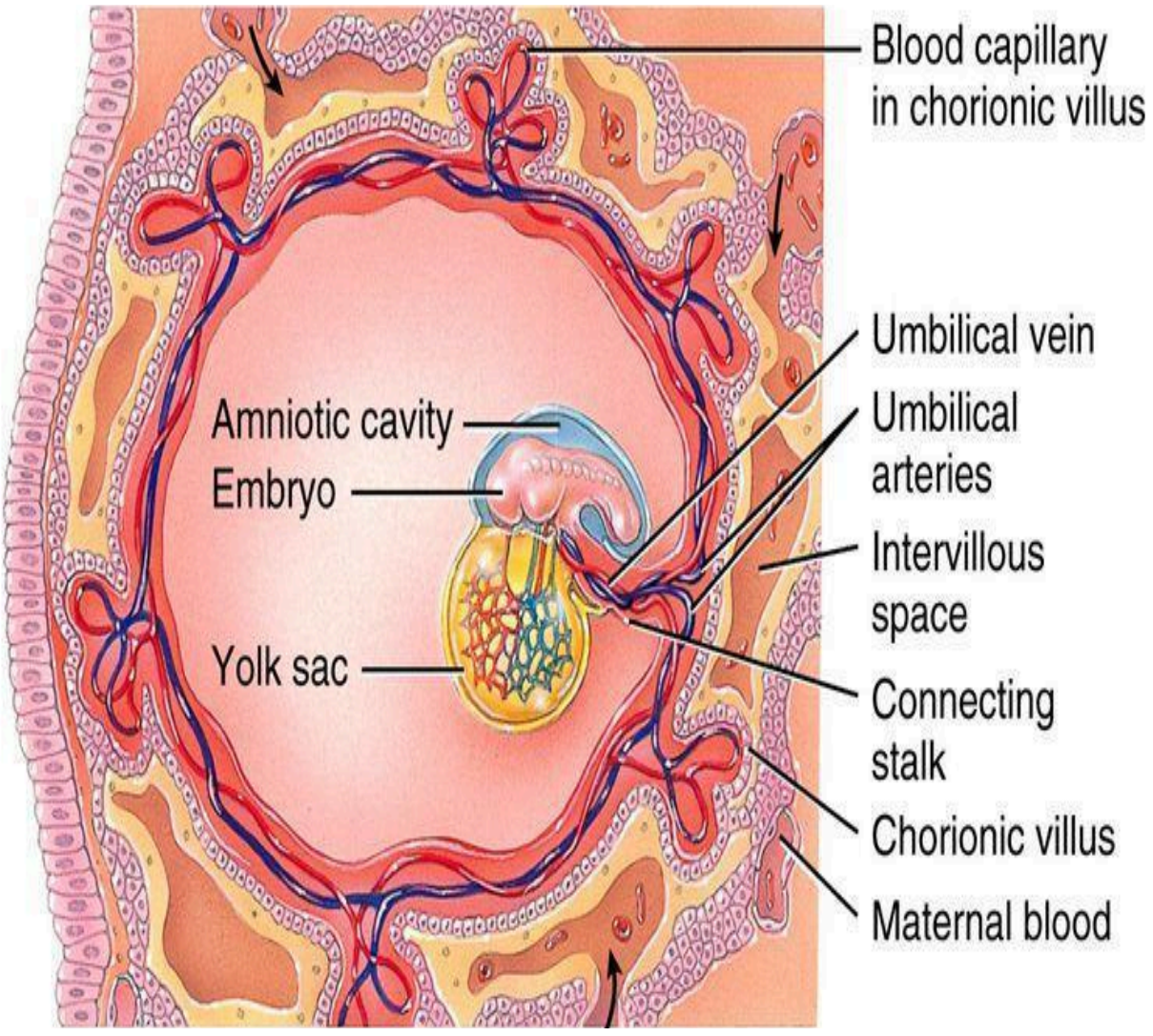


Figure 36 – Provisional organs in the early stages of embryonic development (21 days after fertilization)

Amnion is the entire tunic, located around fetus and is filled with amniotic fluid. Amniotic tunic is composed of two parts – internal epithelial and external connective tissue.

Epithelium has formed from extra embryonic ectoderm, and connective tissue – from parietal layer of extra embryonic mesoderm.

Until the 3d month of development amnion epithelium is monolayer and flat, but after the third month – prismatic at the place of connection of amnion and chorion. At the rest places it is cubic. Prismatic epithelium produces amnion water, and cubic epithelium makes their resorption.

Functions:

1. Produces fluid, which defends the fetus from becoming dry.
2. Promotes optimal conditions of fetus development in aqueous medium.
3. Defends the fetus from mechanical injures.

For the pregnancy, the only cavity within the uterus is that of the fluid – filled amniotic sac.

Clear watery fluid fills the amniotic sac. The embryo is suspended in this fluid and thus can maintain its shape and mold its body form without hindrance. Throughout pregnancy the amniotic sac serves as a water cushion, absorbing jolts, equalizing pressures, and permitting the fetus to change posture. At childbirth it acts as a fluid wedge that helps dilate the neck of the uterus. When the sac ruptures, about a quart of fluid escapes as the "waters." If the sac does not rupture or if it covers the head at birth, it is known as a *caul*.

Caul, a portion of the amnion, or bag of waters, which is sometimes found remaining around the head of a child after birth. The term also is applied occasionally to the serous membrane covering the heart, brain, or intestines. It is derived from the original meaning of a close–fitting woman's cap, especially one made of network. Many superstitions were attached to the infant caul; it was looked on as a sign of good luck and, when preserved, was kept as a protection against drowning.

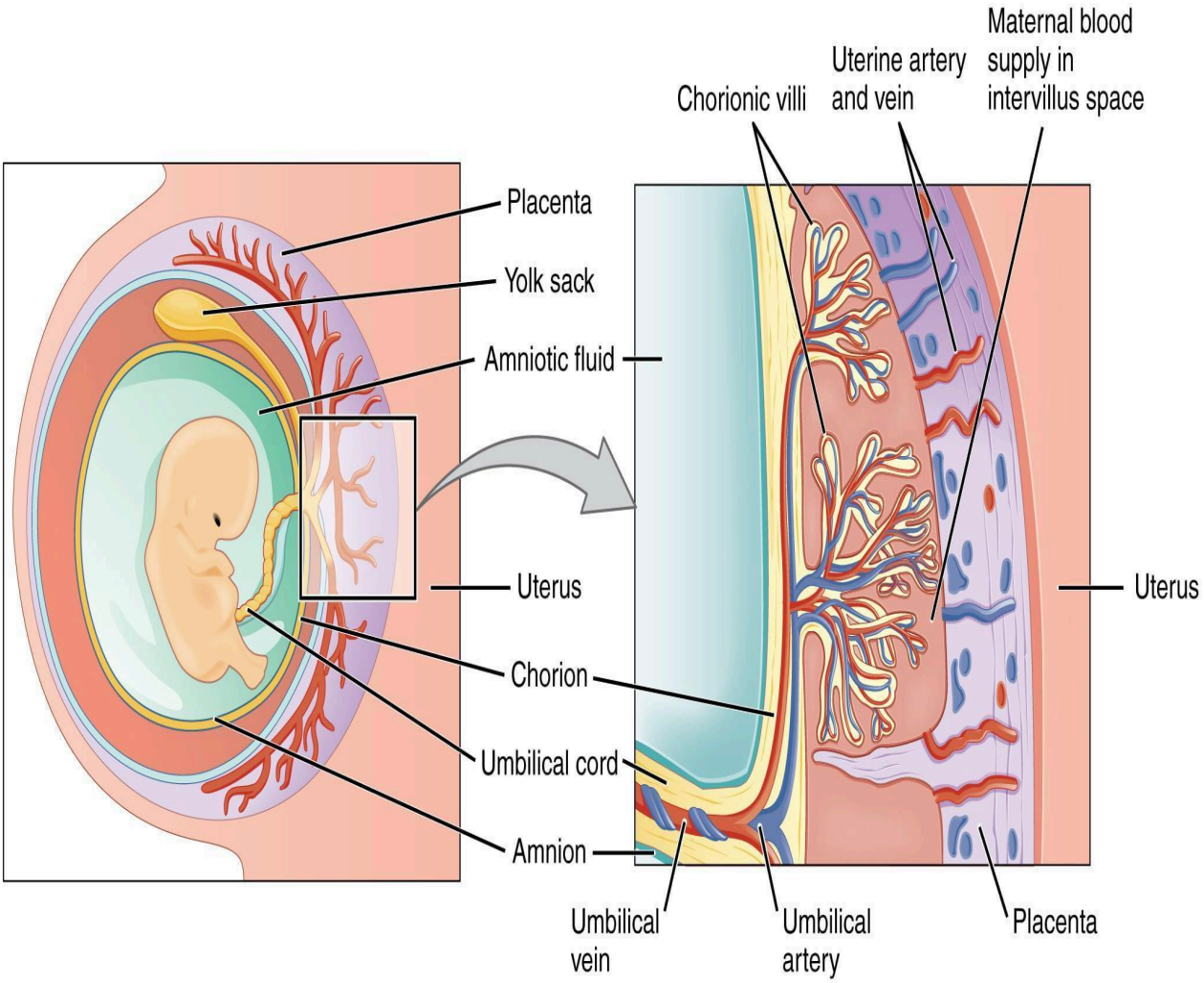


Figure 37 – Amnion

Yolk sac is a part of primary intestine, which is located outside the fetus. Its wall is composed of two layers: inner layer is formed by extra embryonic entoderm; external layer is formed by visceral layer of extra embryonic mesoderm. Yolk sac is connected with intestinal tube by *yolk petiole.*

Functions:

1. Extra embryonic mesoderm is the place of embryonic hemopoiesis. Blood islands are formed here. In these blood islands blood cells differentiate from stem cells.

2. Extra embryonic entoderm is the source of primary sex cells. They migrate into the gonad germs, where they differentiated into gametes.

From the 8th week of embryogeneses quick decrease of the yolk sac occurs and its residues can be found in the composition of umbilical cord.

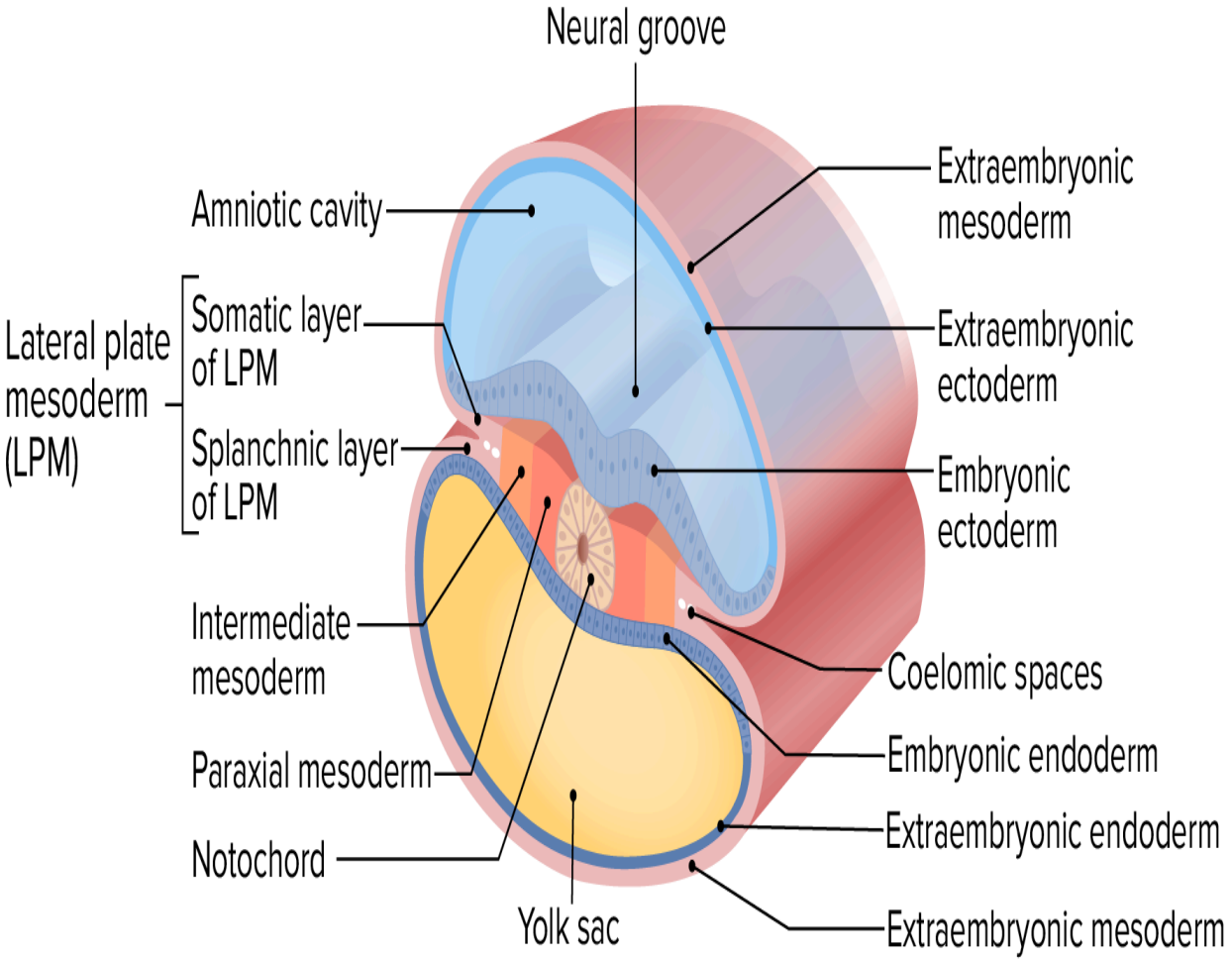


Figure 38 – Yolk sac

Allantois. On the 16th day of development, the posterior wall of the yolk sac forms a small diverticulum – allantois. The wall is formed from extra embryonic entoderm and visceral layer of extra embryonic mesoderm. The allantois, grows out of the early yolk sac in a region that soon becomes the hindgut. The tube extends into a bridge of mesoderm (the middle germ layer) that connects embryo with chorion and will become incorporated into the umbilical cord. The human allantoic tube is tiny and never becomes a large sac with important functions, as it does in many other mammals and in reptiles and birds. In the second month it ceases to grow, and it soon is obliterated. Blood vessels, however, develop early in its mesodermal sheath, and

these spread into the chorion and vascularize it. Throughout pregnancy they will keep the embryo in close relationship with the mother's uterine circulation.

Functions:

1. Participates in formation of vascular system of placenta. From the fetus vessels penetrate into chorion through the allantois. The end branches of vessels are located in the stroma of chorionic villi.

2. Gas exchange. Oxygen is supplied by the allantois vessels.

3. Excretory. Metabolic product of the fetus are excreted into allantois.

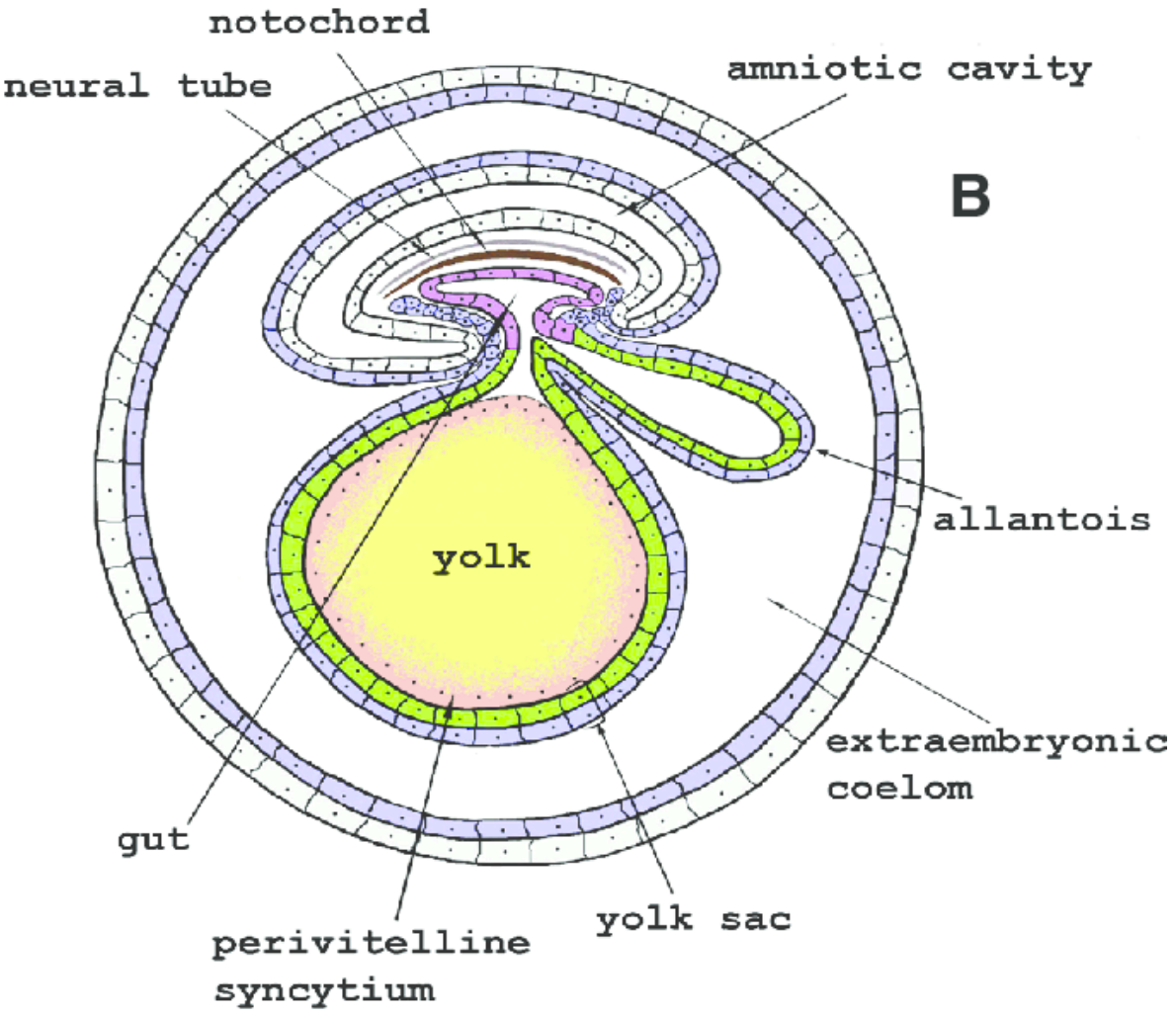
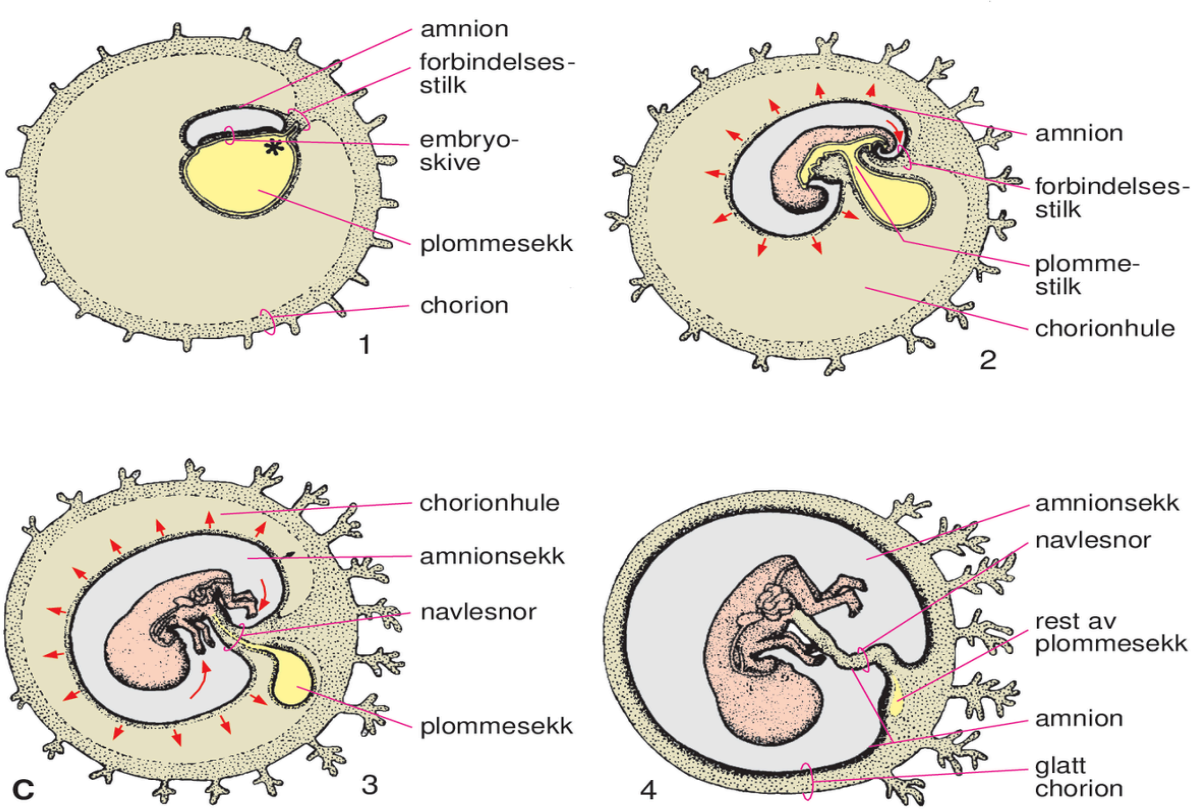


Figure 39 – Allantois

Chorion. Connection of trophoblast and extra embryonic mesoderm results in chorion formation. There are three periods in the chorion formation: *previlliferous*

period (seventh to eighth day of development); *the period of villi formation* (until fiftieth day); *the period of cotyledons* (from fiftieth to ninetieth day).

Previlliferous period. During implantation trophoblast cells proliferate and form cytotrophoblast. After erosion the fertilization tunic blastocyst, trophoblast is differentiated into two layers: *cytotrophoblast* (cellular structure), and *syncytiotrophoblast* (noncellular structure). Under the influence of cytolytic enzymes of trophoblast lacunae appear in the uterus endometrium. They are filled with maternal blood.



Scheme 9 – Amniotic membranes. 1–4: The main features of the development of the amniotic membranes in humans; shows how the amnion will form the surface covering of the umbilical cord. The yolk sac participates in the development of the fetal intestine. Asterisk (1) indicates the allantois, which generally plays a modest role during mammalian development. For the sake of comparison, all stages are reproduced here at the same size; 1) 3rd week of pregnancy, 2) 4th week, 3) 10th week, 4) 20th week.

The period of villi formation. During this period, primary, secondary and tertiary villi are consecutively formed.

Primary villi. It is diverticulum of chorion wall. They are composed of cytotrophoblast cells, surrouned by syncytiotrophoblast.

Secondary villi begin to form on the twelfth day of development. At that time extraembryonic mesoderm penetrate into primary villi, converting them into secondary villi. They are evenly distributed throughout the chorion surface.

Tertiary villi begin to form from the third week of development. They contain blood vessels. The period of connection of branches of umbilical vessels with local network of blood vessels coincide with the beginning of heart contraction, and in the tertiary villi embryonic blood circulation begins. Not all chorion villi are developed equally well. Villi, that face the capsular part of deciduous tunic, are weakly developed and are gradually disappearing. That's why chorion in this part is called *smooth.*

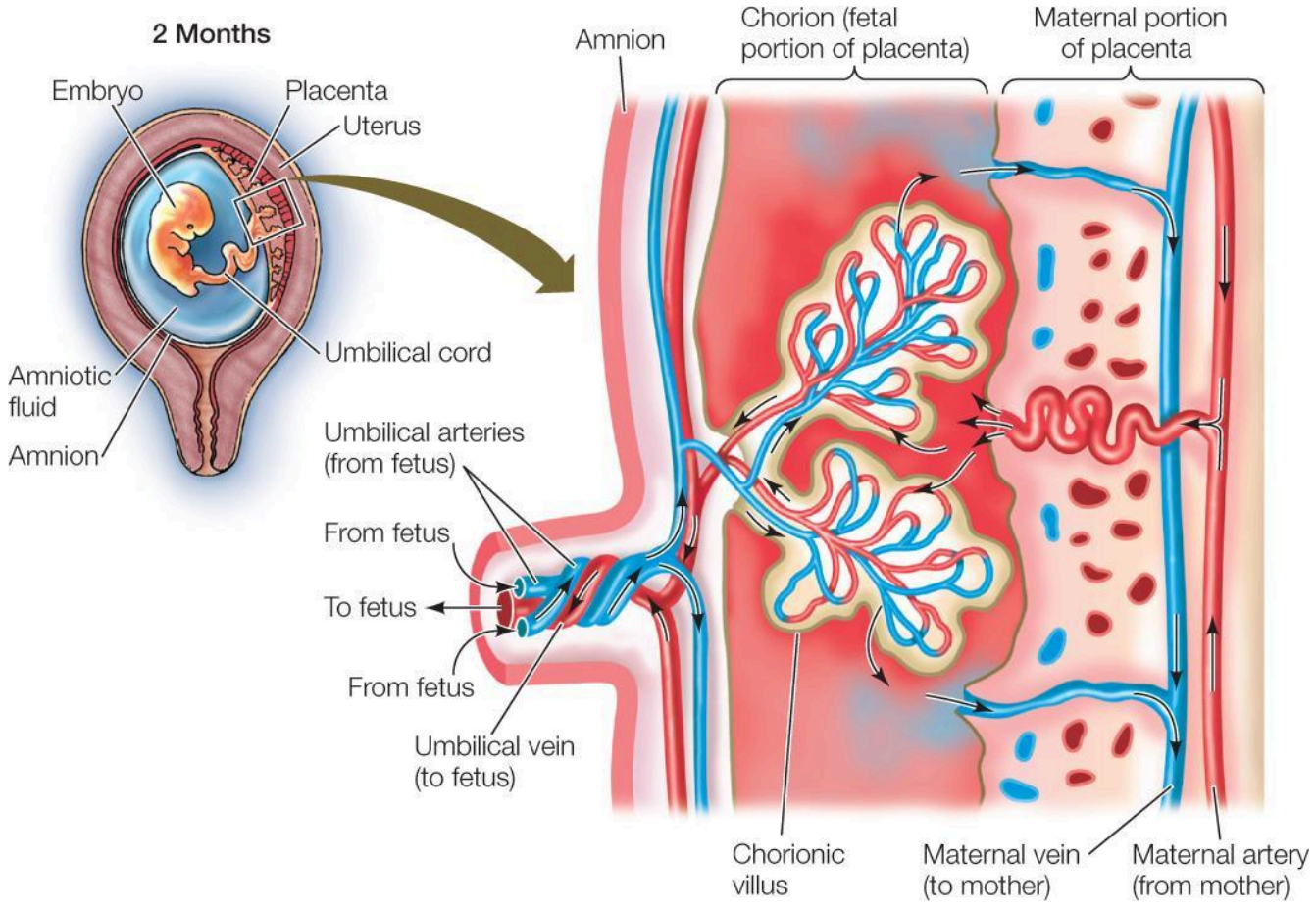


Figure 40 – Chorionic villi

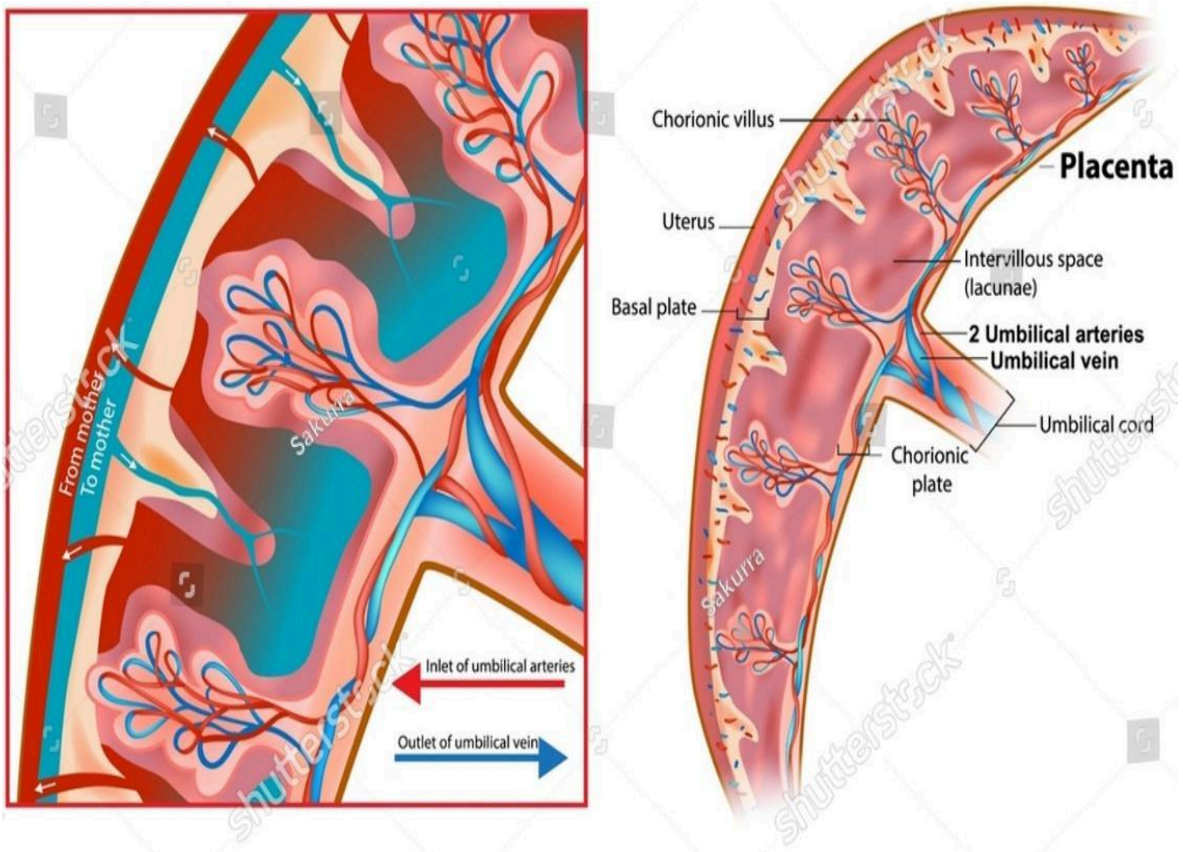


Figure 41 – Chorionic villi

Branched chorion forms villi, that enter into basal part of deciduous tunic. Villum is covered with mono–layer cubic epithelium – cytotrophoblast, which in its turn, is covered with syncytiotrophoblast. In the mesenchyma stroma of villi there are collagenic and elastic fibers and vessels.

According to their functions, villi are divided into: *anchoring* or *stem villi* and *end* or *trophic*. *Anchoring villi* penetrate into maternal part of placenta and connect two parts of placenta: fetal and maternal.

End or *trophic villi* are freely suspended in lacunes and are washed by maternal blood. Thus trophic function is provided.

The period of cotyledons. *Cotyledon* is a structural–functional unit of placenta. It is formed by stem villum and its branches, containg fetal vessels. All these are washed by maternal blood. There are 200 (two hundred) cotyledons in placenta.

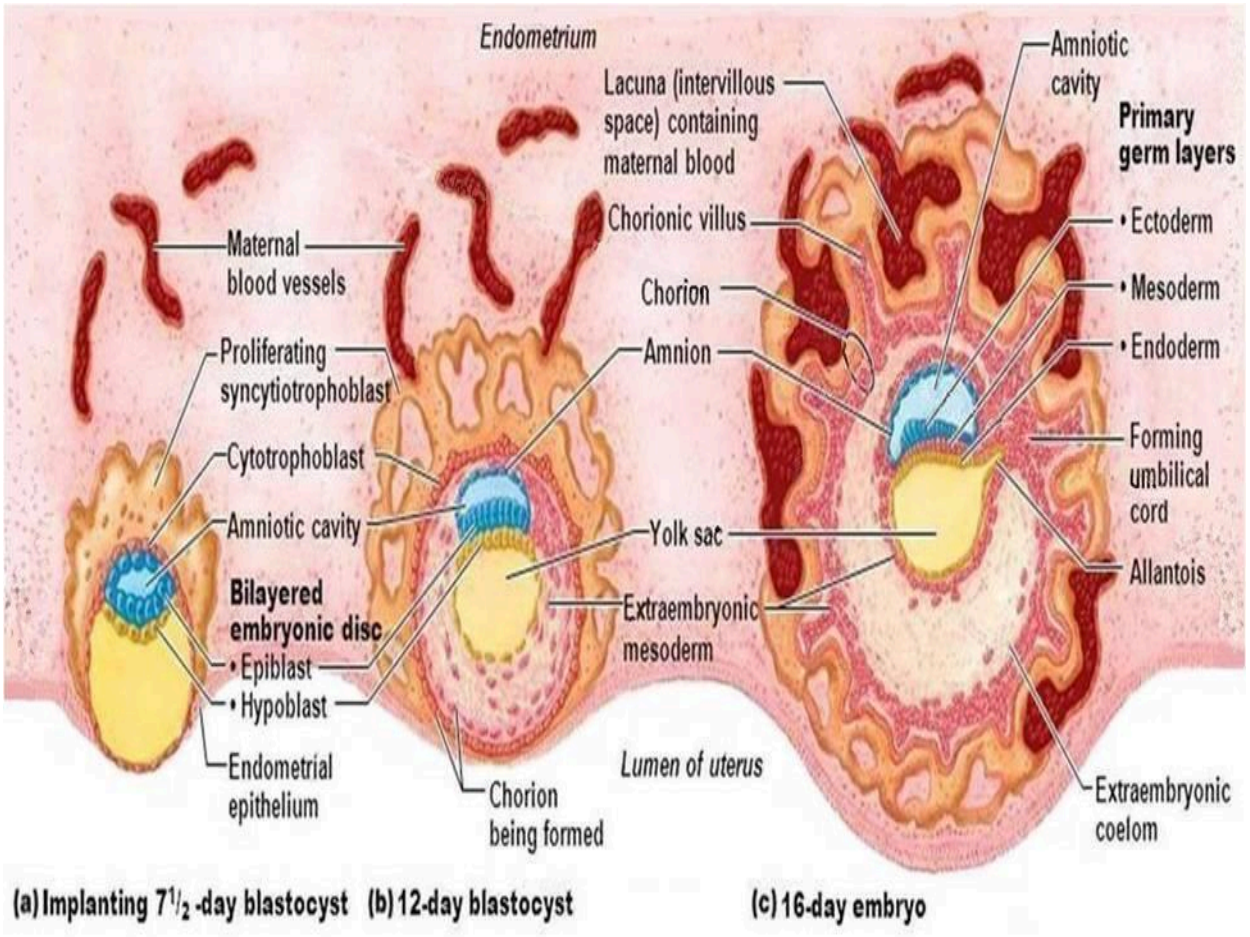


Figure 42 – Stages of placenta formation

(a) implanting blastocyst at 7 1/2 days after fertilization. The syncytiotrophoblast is eroding into the endometrium; (b) implantation is completed by day 12, and extraembryonic mesoderm appears deep to the cytotrophoblast. Spaces called lacunae appear in the syncytiotrophoblast and will soon fill with maternal blood; (c) by 16 days, the chorionic villi are elaborated, and the body stalk is present (future umbilical cord).

Placenta is a provisional organ with the help of which the connection between the fetus and the mother's organism is established. It has both maternal (deciduous tunic) and fetalic (villous chorion) components.

1. *Deciduous tunic.* The following parts are distinguished in deciduous tunic: *basal part, capsular part and parietal part.* Deciduous tunic forms the basal and capsular parts, surrounding chorion. In other regions, uterine cavity is lined with parietal deciduous tunic.

a) Basal part of deciduous tunic enters the composition of maternal part of placenta. It separates the fetus from uterus myometrium. The basal part includes: the basal plate and septa, which move away from the plate. Septa separate lacunae from each other. They are filled with maternal blood.

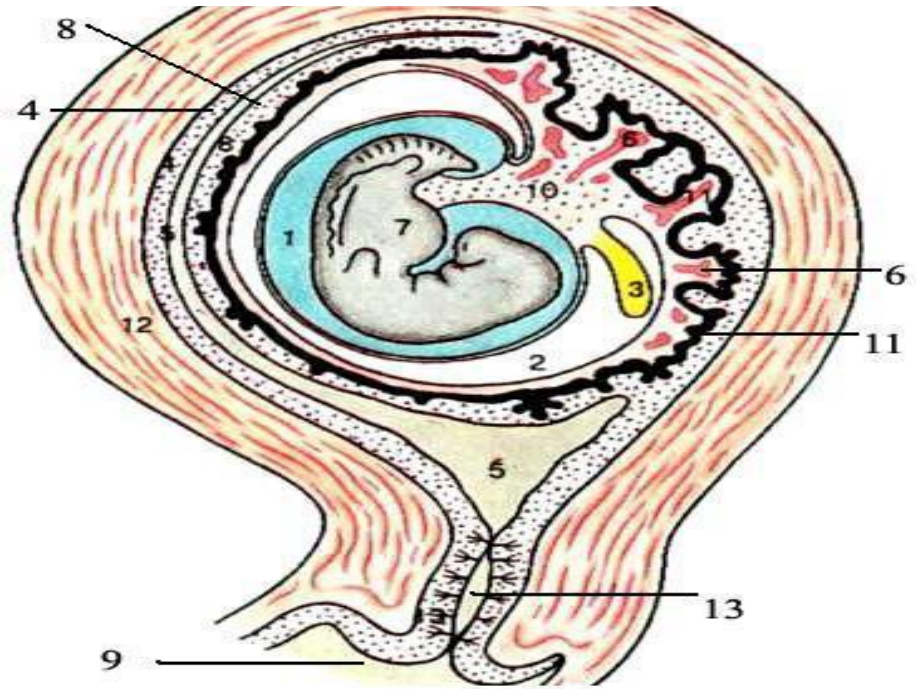


Figure 43 – The relationship of the developing human embryo with the endometrium of the uterus (3–week fetus)

1 – amniotic cavity; 2 – extraembryonic cavity; 3 – yolk sac; 4 – deciduous parietal; 5 – cavity of the uterus; 6 – deciduous basal; 7 – embryo; 8 – deciduous capsular; 9 – vagina; 10 – amniotic stalk; 11 – chorionic villi; 12 – myometrium; 13 – uterine cervix.

b) Capsular part is closed up above the implanted embryo and separates it from the uterus cavity.

c) Parietal part is composed of several layers of deciduous cells. Deciduous cells are the cells of loose connective tissue of uterus endometrium. Their size is large because of considerable inclusions of glycogene.

2. The fetal part of placenta is formed by villous chorion. It includes chorionic plate and chorionic villi. There is mono–layer epithelium and extra–embryonic connective tissue in the chorion plate.

Placenta functions:

1. Exchange of nutrients and gases between mother and fetus.
2. Immunologic defence.
3. Endocrine function.
4. Detoxification of some medical preparations.

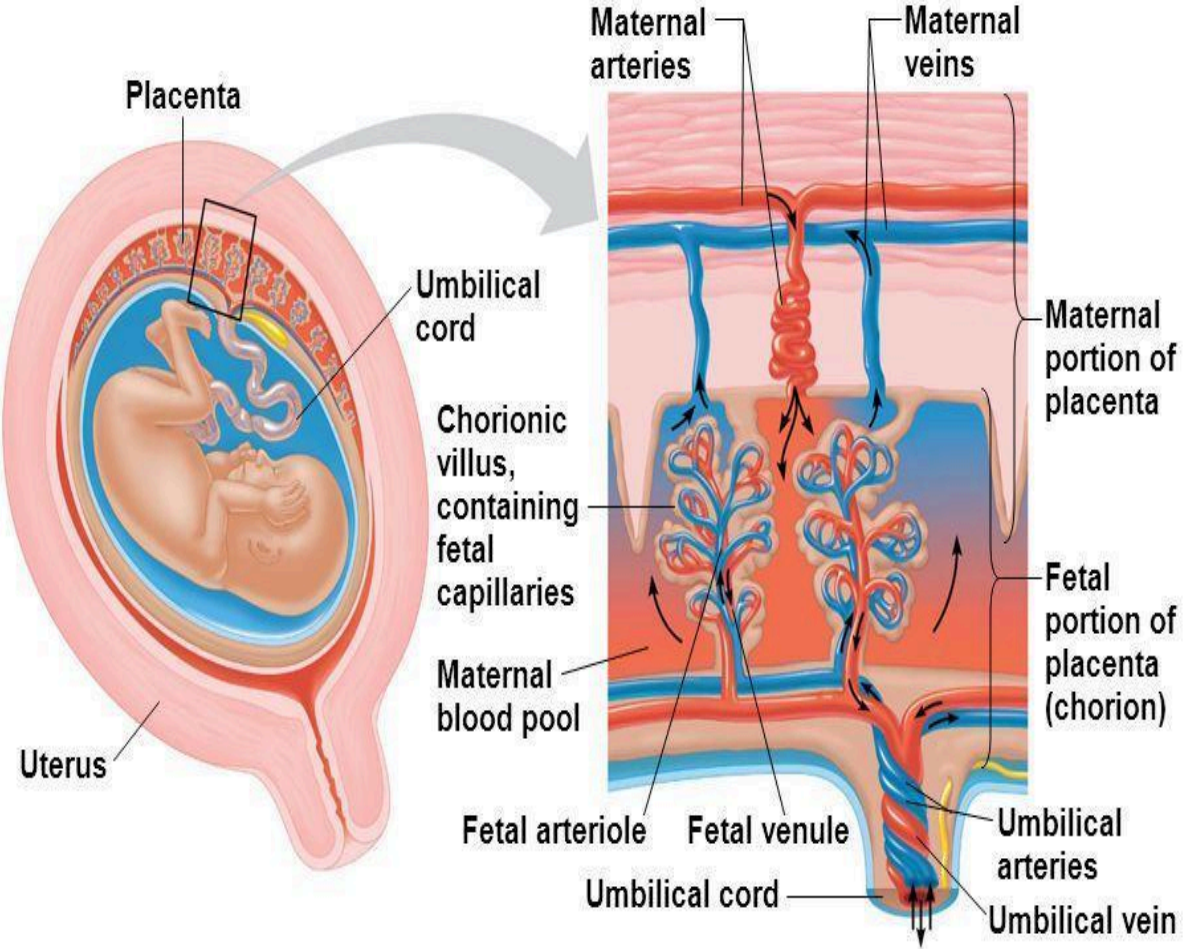


Figure 44 – Placenta of a three week old fetus

Placental barrier separates maternal blood from fetal blood. It includes: syncytiotrophoblast – cytotrophoblast – basal membrane of cytotrophoblast – connective tissue of the villi – basal membrane in the capillary wall of the fetus – endothelium of fetal capillary.

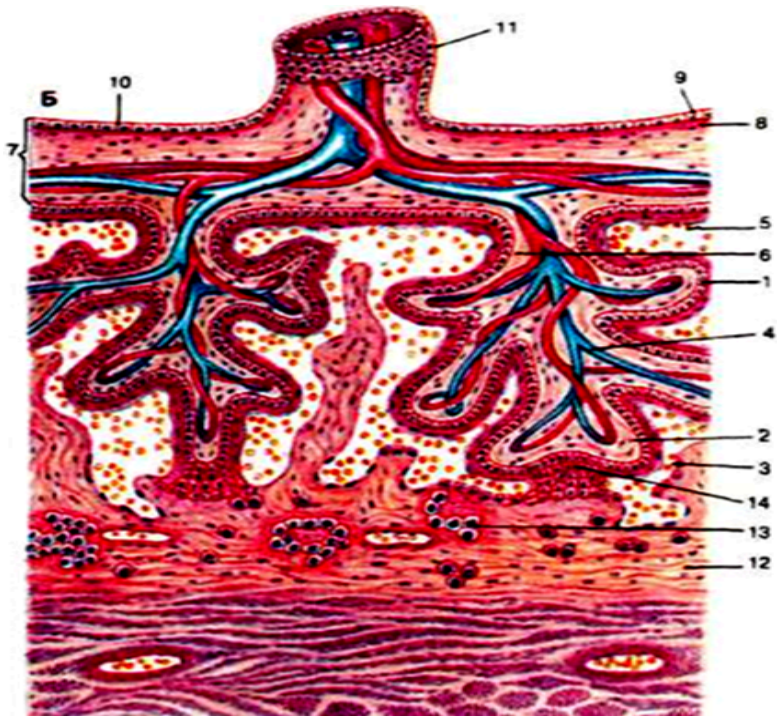


Figure 45 – Placenta

1 – cytiotrophoblast; 2 – connective tissue; 3 – syncytiotrophoblast; 4 – capillary; 5 – lacuna; 6 – stem villi of the chorion; 7 – chorion plate; 8 – connective tissue of the amnion; 9 – epithelium of the amnion; 10 – trophic villi; 11 – umbilical cord; 12 – endometrium; 13 – deciduous cells; 14 – myometrium; 15 – septa.

Placental barrier defends the fetal organism from harmful substances, which can penetrate from maternal blood into fetus. But it is permeable for alcohol, nicotin, drugs and many medical preparations.

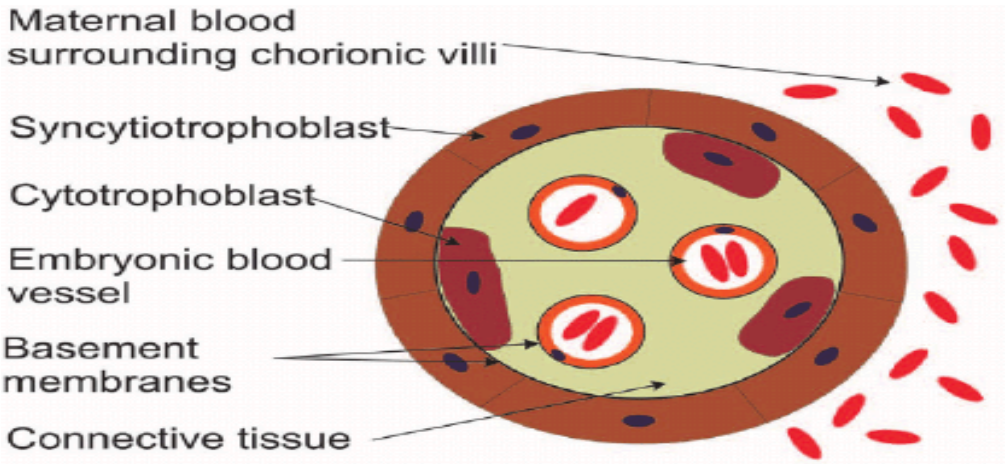


Figure 46 – Schematic representation of the placental barrier

Umbilical cord is composed of mucous tissue inside of which two arteries and a vein pass. They provide blood circulation between fetal organism and placenta. There are remnants of the yolk sac and allantois. Mucous tissue is a loose, amorphous connective tissue exhibiting a jelly–like matrix. This tissue is also known *Wharton's jelly.* It contains a considerable amount of hyaluronic acid, but the fibers are absent. This gives the elasticity to the umbilical cord. All these provide continuous connection between mother's organism and fetus. The umbilical cord is covered with mono–layer cubic amniotic epithelium.

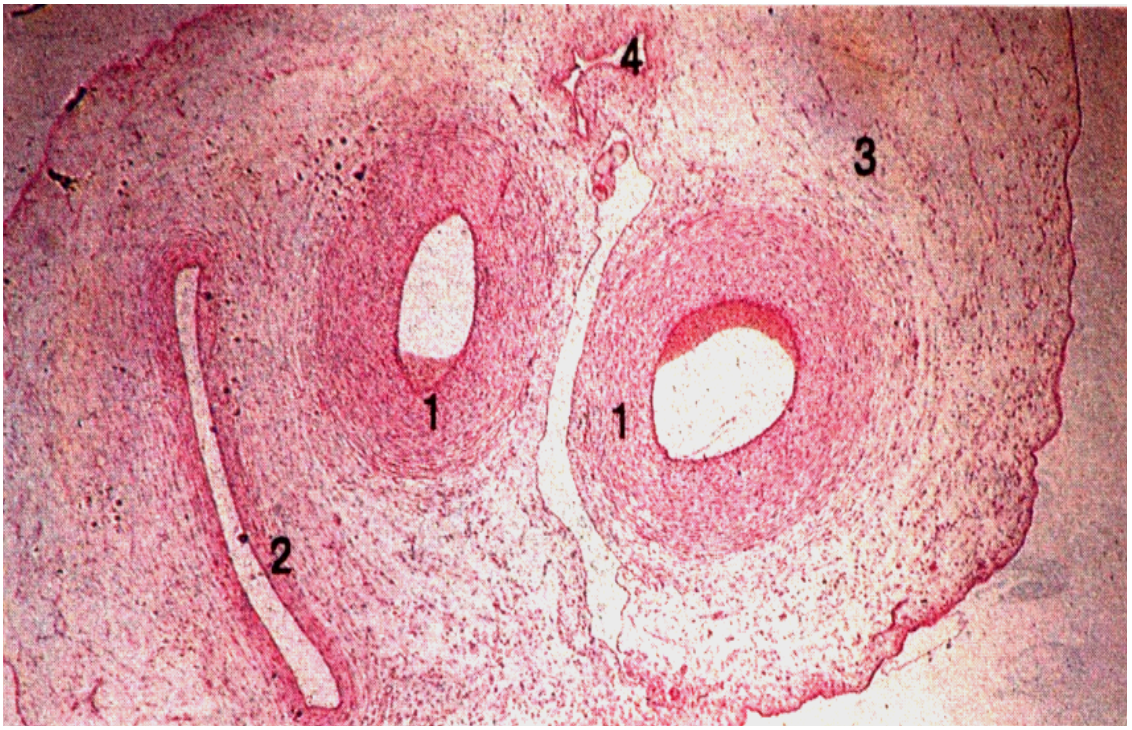
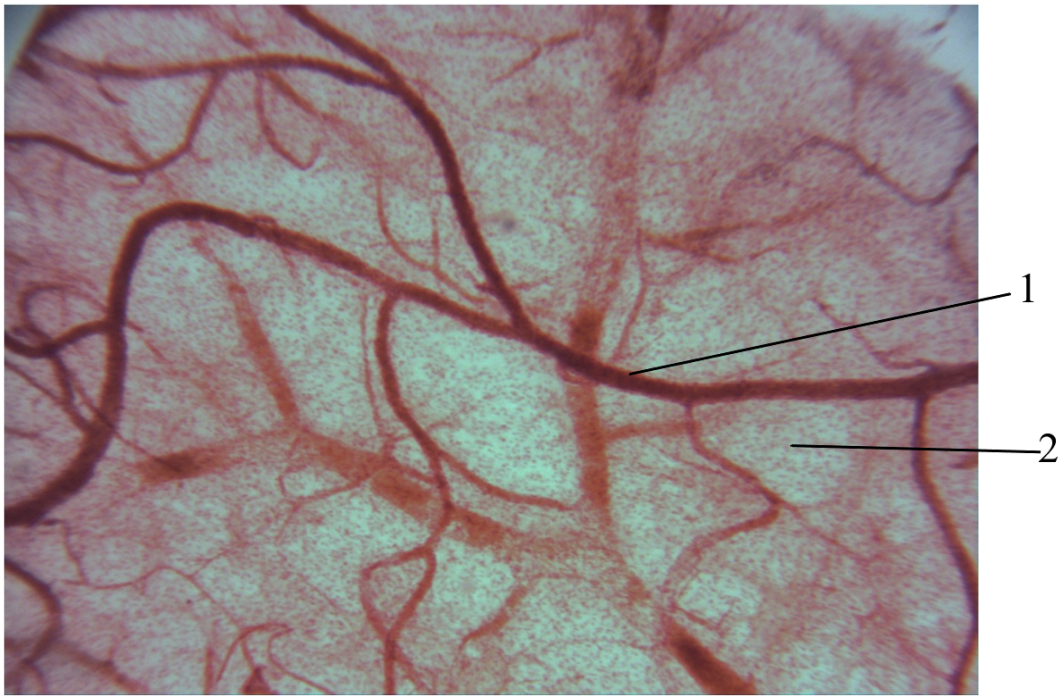


Figure 47 – Umbilical cord.

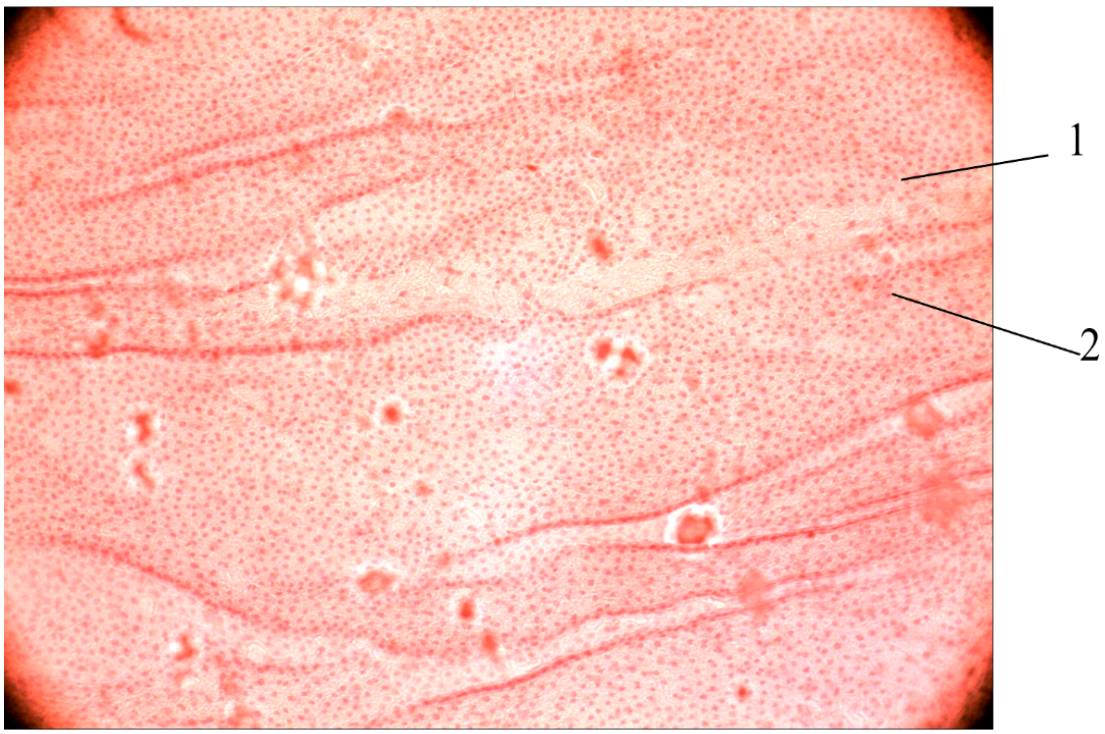
Staining: hematoxylin–eosin.
1 – arterial; 2 – vein; 3 – mucous tissue; 4 – remainder of the yolk sac.

PRACTICAL PART III



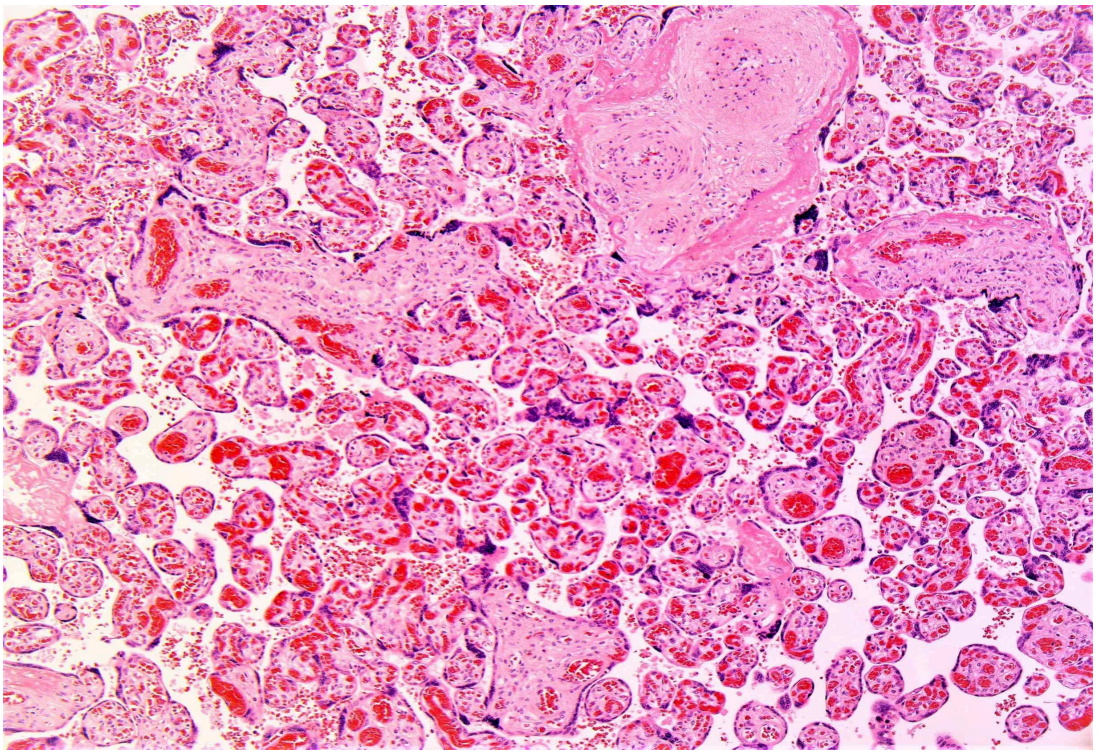
Slide 1 – Allantois

Staining: hematoxylin–eosin.
1 – blood vessels, 2 – nucleus of epithelial and mesenchyme cells



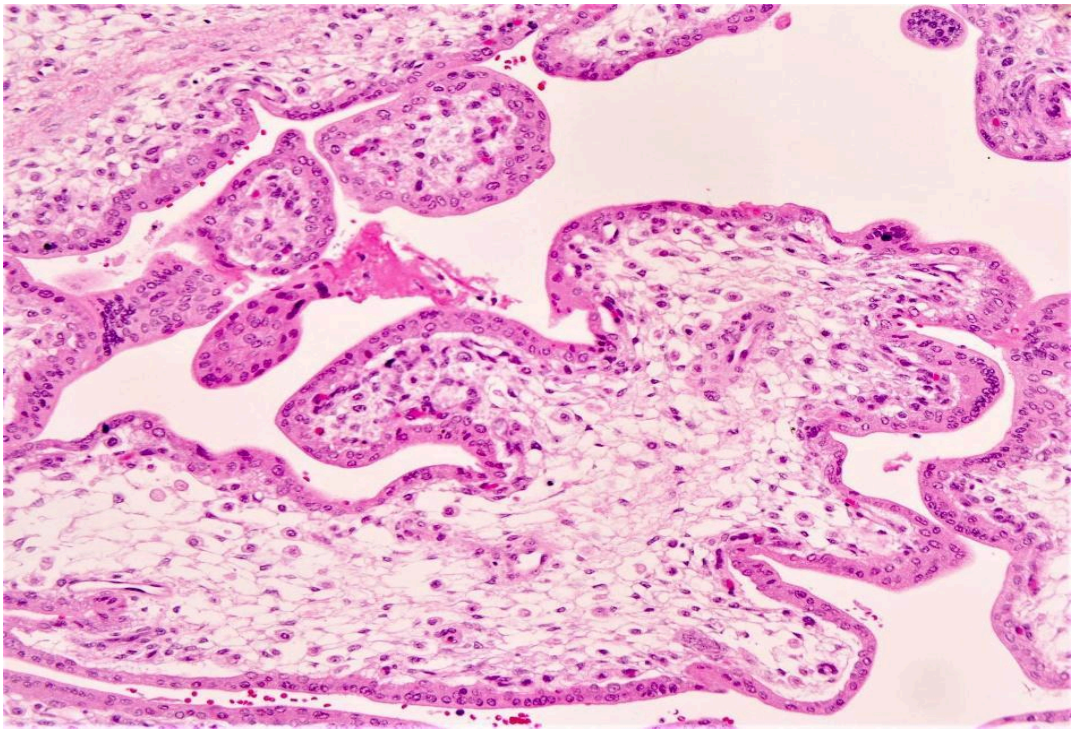
Slide 2 – Amnion

Staining: hematoxylin–eosin.
1 – epithelial cells, 2 – nucleus of cells



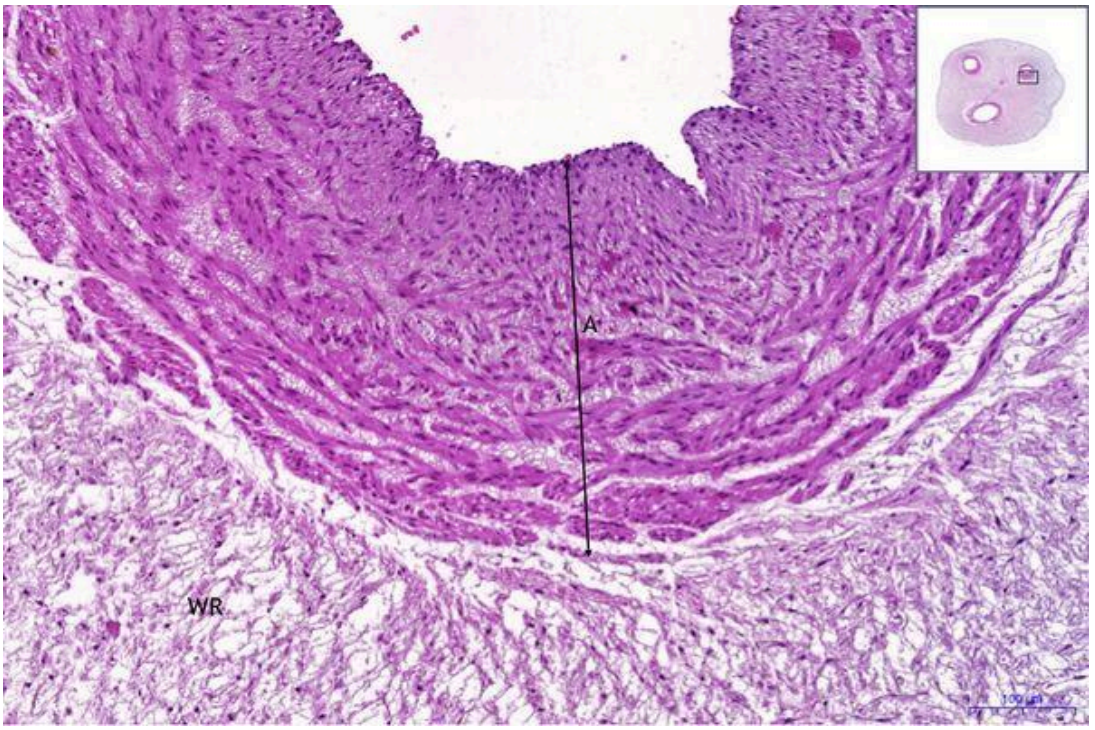
Slide 3 – Placental villi

Staining: hematoxylin–eosin.



Slide 4 - Immature villi

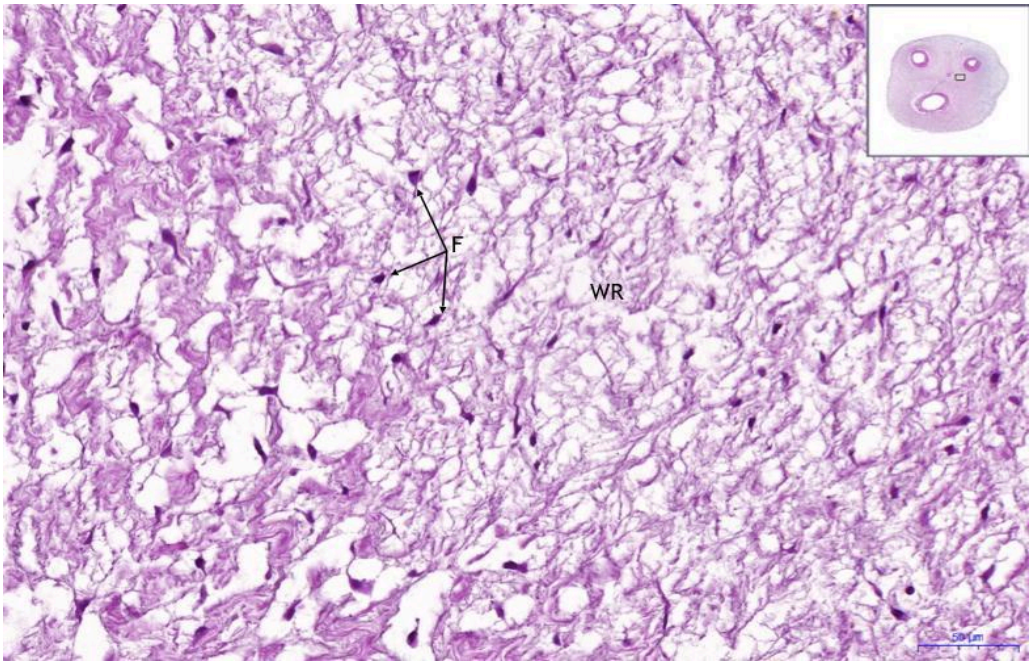
Staining: hematoxylin–eosin.



Slide 5 - Umbilical cord

Staining: hematoxylin–eosin.

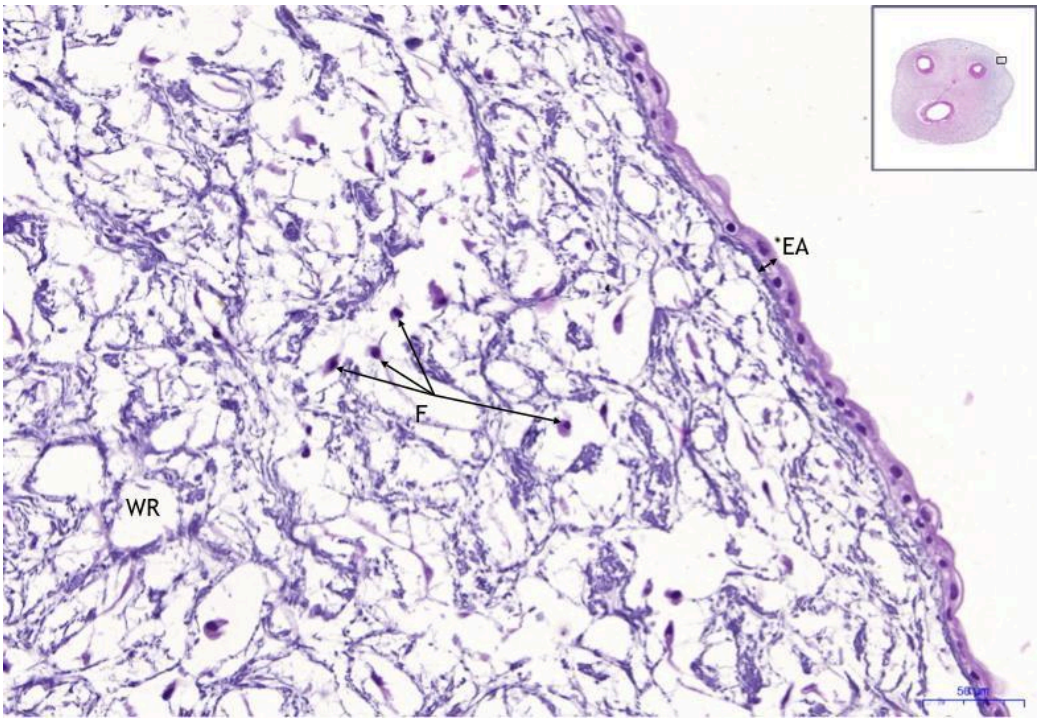
1 – A – artery/arteries, 2 – WR – wharton's jelly / wharton's jelly (substantia gelatinea funiculi umbilicalis)



Slide 6 – Umbilical cord

Staining: hematoxylin–eosin.

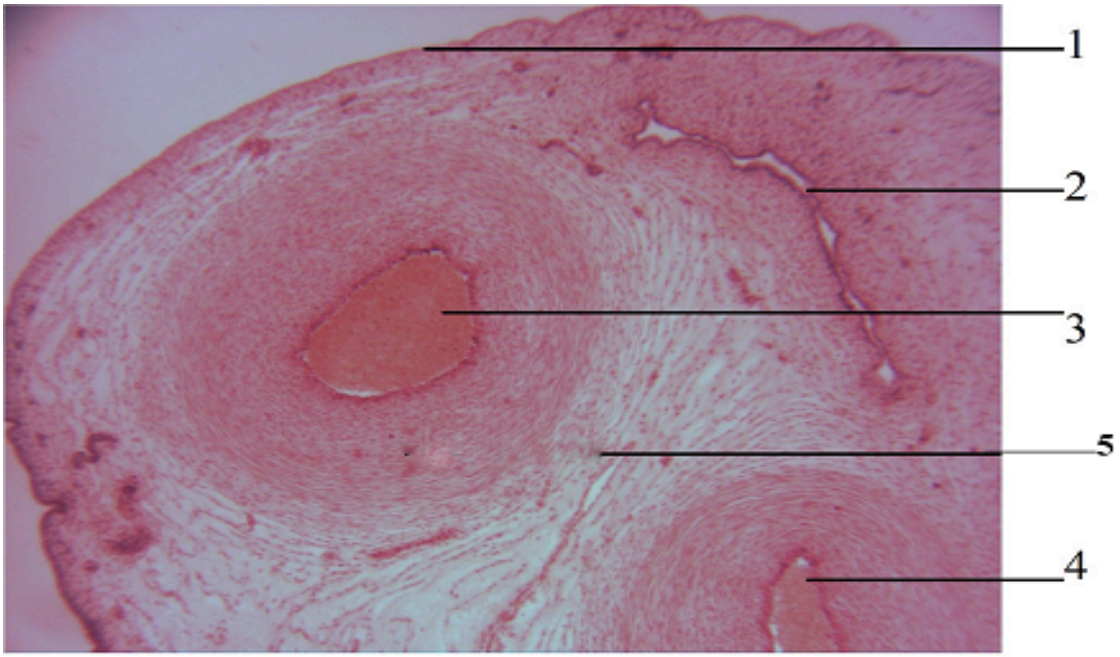
1 – WR – wharton's jelly / wharton's jelly (substantia gelatinea funiculi umbilicalis), 2 – F – fibroblast



Slide 7 – Umbilical cord

Staining: hematoxylin–eosin.

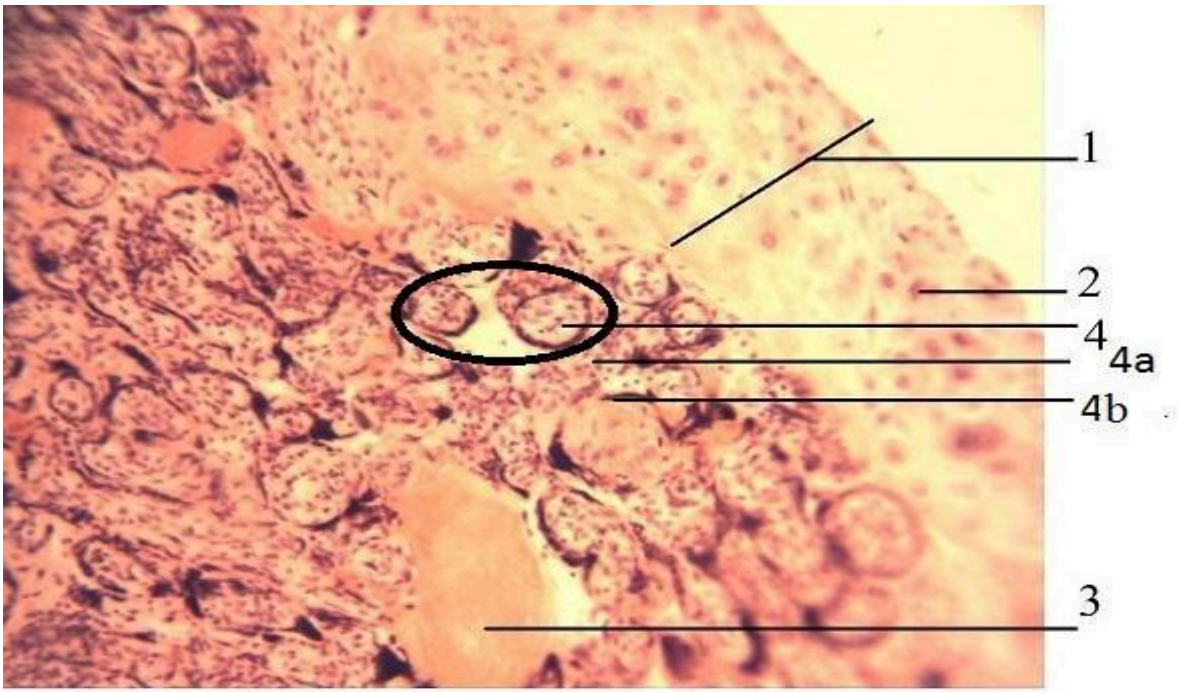
1 – EA – amnion epithelium, 2 – WR – wharton's jelly / wharton's jelly (substantia gelatinea funiculi umbilicalis), 3 – F – fibroblast



Slide 8– Umbilical cord

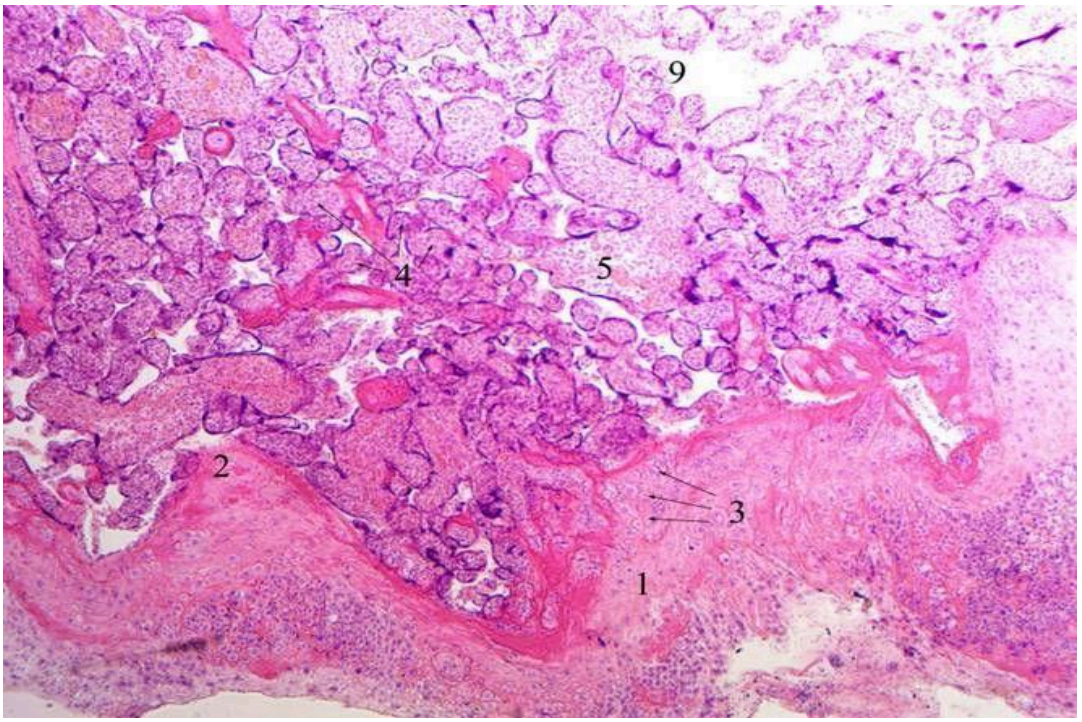
Staining: hematoxylin–eosin.

1 – amniotic epithelium; 2 – vein; 3, 4 – arteries; 5 – mucous tissue (Wharton's jelly).



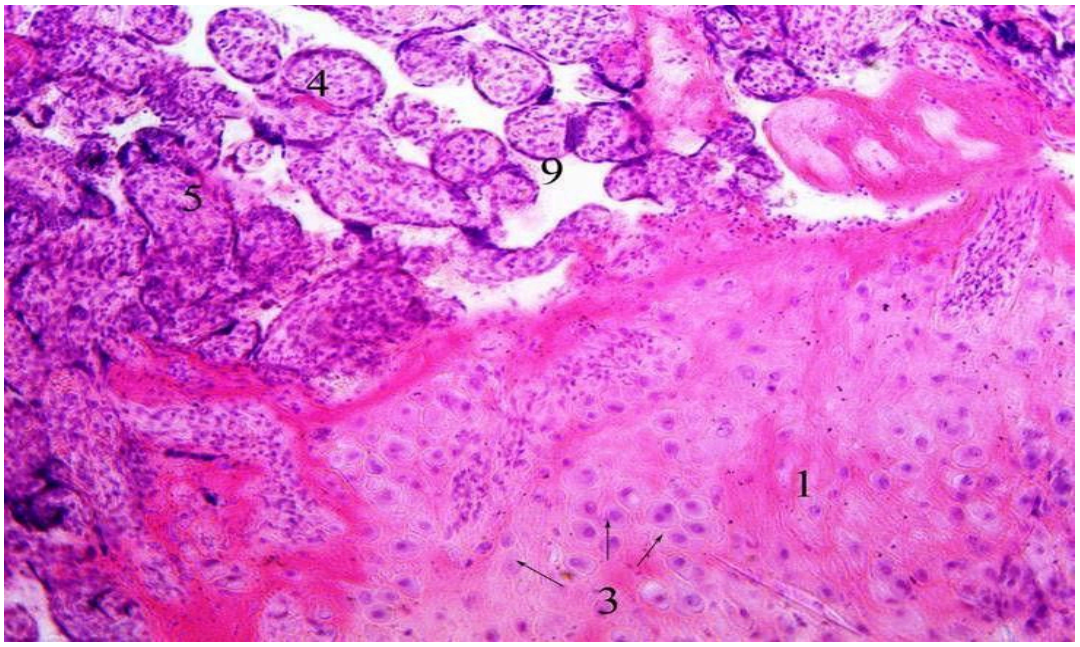
Slide 9 – Maternal part of the placenta

Staining: hematoxylin–eosin.
1 – basal lamina, 2 – deciduous cells, 3 – lacunae filled with maternal blood, 4 – chorion villi: a) connective tissue of the villus, b) synsytiotrophoblast



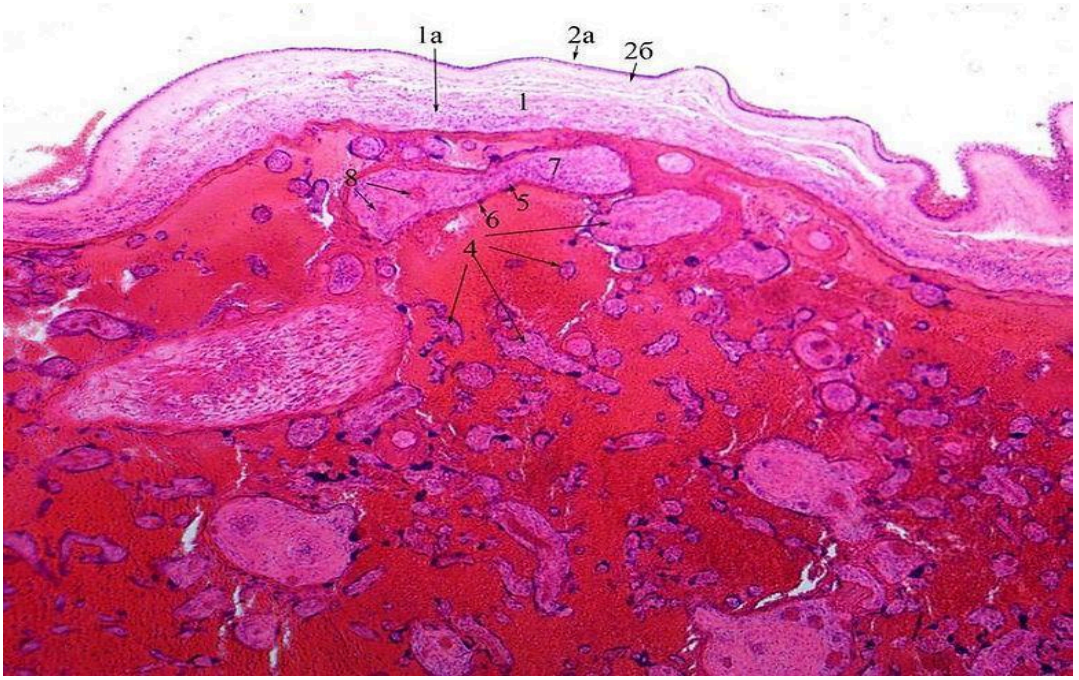
Slide 11 – Maternal part of the placenta

Staining: hematoxylin–eosin.
1 – endometrium, 2 – septum, 3 – decidual cells, 4 – villi, 5 – connective tissue, 9 – lacunae with maternal blood



Slide 12 – Maternal part of the placenta

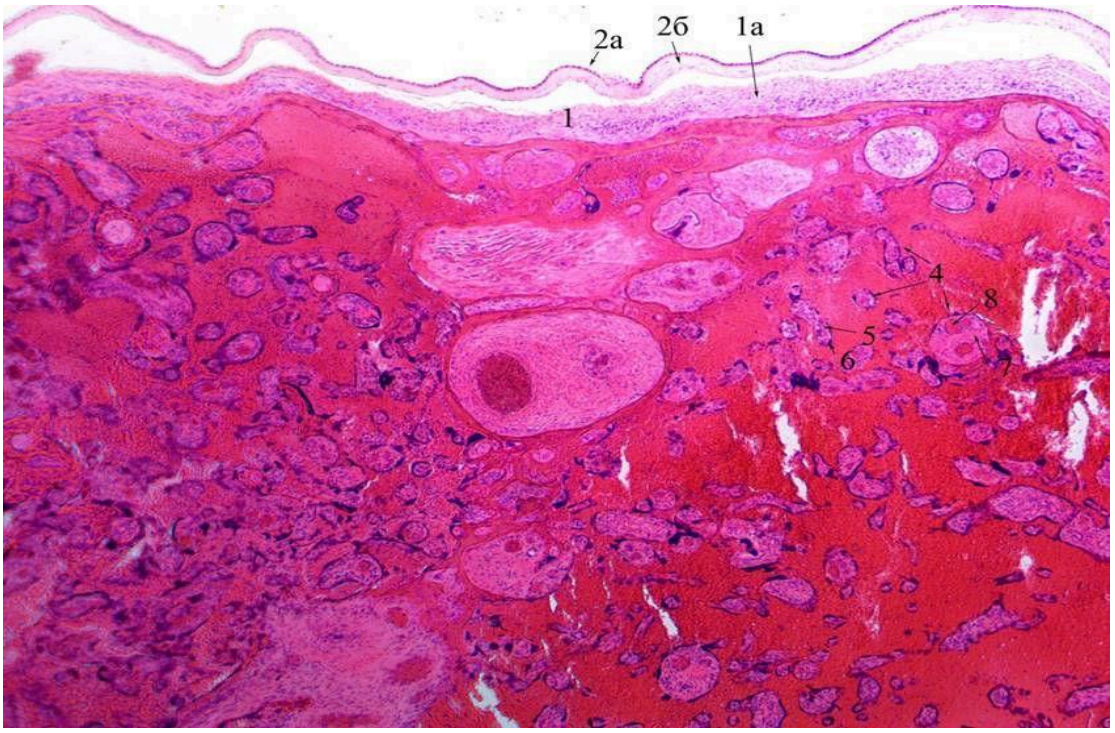
Staining: hematoxylin–eosin.
1 – endometrium, 2 – septum, 3 – decidual cells, 4 – villi, 5 – connective tissue, 9 – lacunae with maternal blood



Slide 13 – Fetal part of the placenta

Staining: hematoxylin–eosin.

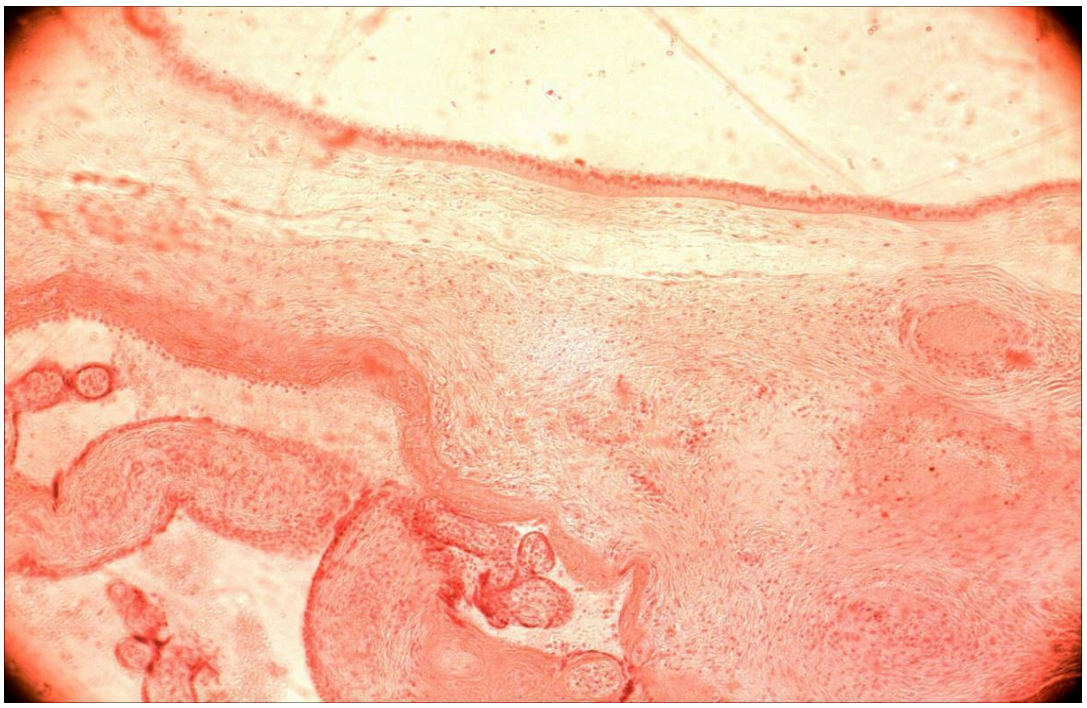
1 – chorion plate, 1a- connective tissue of the chorion, 2a - epithelium of the amnion, 2б - connective tissue of the amnion, 3. lacunae filled with maternal blood, 4- trophic villi, 5- syncytiotrophoblast, 6- cytotrophoblast, 7- connective tissue of the villus, 8- capillary in the villi.



Slide 14 – Fetal part of the placenta

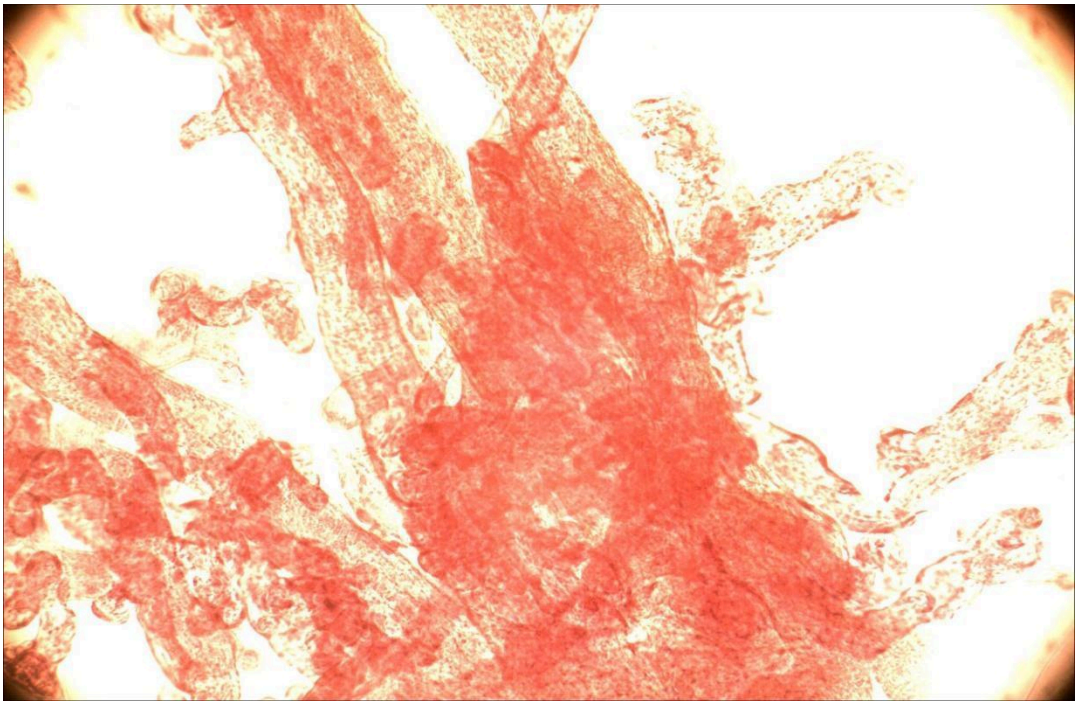
Staining: hematoxylin–eosin.

1 – chorion plate, 1а- connective tissue of the chorion, 2а - epithelium of the amnion, 2б - connective tissue of the amnion



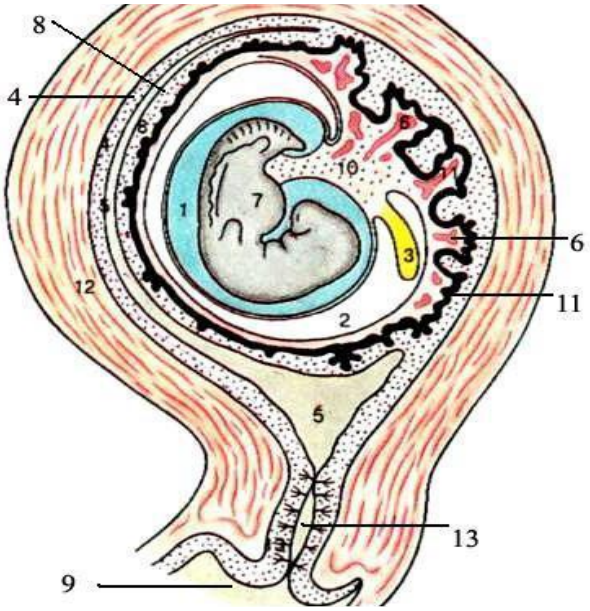
Slide 15 – The fetal part of placenta

Staining: hematoxylin–eosin.



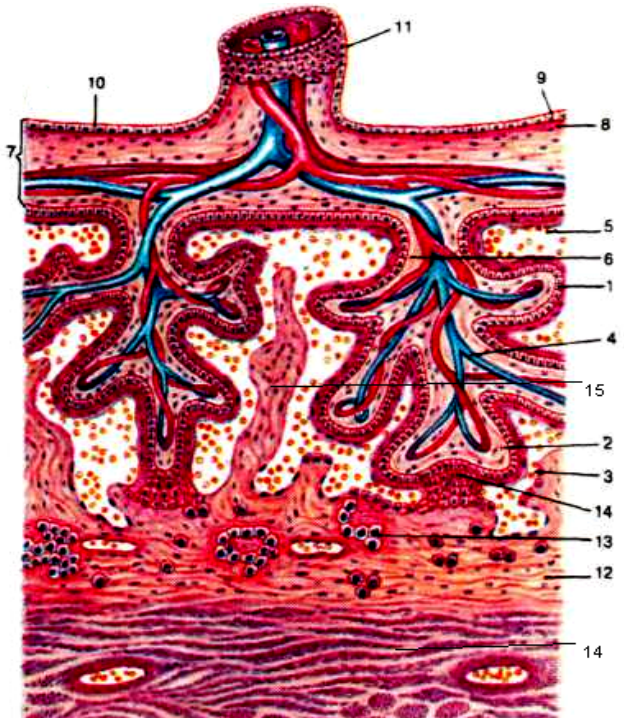
Slide 16 – Chorion villi

Staining: hematoxylin–eosin.



Slide 17 – The relationship of the developing human embryo with the endometrium of the uterus (3–week fetus)

1 – amniotic cavity; 2 – extraembryonic cavity; 3 – yolk sac; 4 – deciduous parietal; 5 – cavity of the uterus; 6 – deciduous basal; 7 – embryo; 8 – deciduous capsular; 9 – vagina; 10 – amniotic stalk; 11 – chorionic villi; 12 – myometrium; 13 – uterine cervix.



Slide 18 – Placenta

1 – cytiotrophoblast; 2 – connective tissue; 3 – syncytiotrophoblast; 4 – capillary; 5 – lacuna; 6 – stem villi of the chorion; 7 – chorion plate; 8 – connective tissue of the amnion; 9 – epithelium of the amnion; 10 – trophic villi; 11 – umbilical cord; 12 – endometrium; 13 – deciduous cells; 14 – myometrium; 15 – septa.

QUESTIONS ON THE TOPIC: PROVISIONAL ORGANS

1. Provisional organs definition.
2. Amniotic tunic, its origin, structural components and functions.
3. The origin, structural components and functions of yolk sac.
4. Allantois origin, its structure and functions.
5. Chorion formation.
6. Structure and functions of primary, secondary and tertiary villi of chorion.
7. Placenta definition.
8. Structure of deciduous tunic.
9. Structure of fetal part of placenta.
10. Structure and functions of placental barrier.
11. Structure and functions of umbilical cord.

QUESTIONS TO THE MODULE

1. The structure of the Plasmalemma.

2. The characteristic of receptive and transport functions of the plasmalemma.

3. The structure of intercellular contacts: Simple contact, Zonular occludentes, Synapse.

4. The structure of intercellular contacts: Desmosome, Zonular adherents, Gap junctions.

5. The characteristic and structure of symplast and sincytium.

6. The structure and functions of Mitochondria.

7. The structure and functions of Lysosomes and Peroxisomes.

8. The structure and functions of Agranular Endoplasmic Reticulum.

9. The structure and functions of Granular Endoplasmic Reticulum and Ribosomes.

10. The structure and functions of Golgi Bodies.

11. The structure and functions of Microfilaments and Microtubules.

12. The structure and functions of Cytocentrum (centrosome).

13. The structure and functions of Cilia and Flagella.

14. Name types of Inclusions and their functions.

15. Reproduction of cells definition.

16. Cell cycle definition.

17. Stages of interphase, characteristic features.

18. Stages of mitosis.

19. The characteristic of polyploidy (endoreduplication).

20. Meiosis peculiarities.

21. Ageing and death of cells. Necrosis and apoptosis.

22. Main features of Female sex cell.

23. Oocytes types.

24. Main features of Male sex cell.

25. Fertilazation, stages and biological significance.

26. Ovarian cycle

27. Follicular development

28. Graafian (mature) follicle

29. Corpus luteum

30. Cleavage definition. Different modes of cleavage. Structure of blastula.

31. The cleavage peculiarities in the human. Chronology of the process. The structure of blastocyst.

32. Implantation site, significance and stages.

33. Vitelotrophic, histiotrophic and haematotrophic embryogenesis periods.

34. Gastrulation definition and attribute. Ways of gastrulation.

35. Human gastrulation early stage. Manners of germ layers and extraembryonal organs formation.

36. Gastrulation later stage.

37. Formation and functions of the primary streak.

38. Differentiation of mesoderm.

39. Amniotic tunic, its origin, structural components and functions.

40. The origin, structural components and functions of yolk sac.

41. Allantois origin, structure and functions.

42. Chorion formation and functions.

43. The structure and functions primary, secondary and tertiary villi of chorion.

44. Placenta definition. The structure of deciduous tunic.

45. Placenta definition. The structure of fetal part of placenta.

46. The structure and functions of placental barrier.

47. The structure and functions of umbilical cord.

QUESTIONS FOR SELF – CONTROL

1. The development of multi – cellular organism begins from?

+ Zigote

– Blastula

– Primary streak

– Chorion

2. What organelles are absence in cytoplasm of Female sex cell?

+ Centrosome

– Mitochondria

– Lysosomes

– Granular (rough) endoplamic reticulum

3. What is the structure of Alecithal oocyte?

+ They don't contain yolk granules in the cytoplasm

– They are contain a little amount of yolk granules in the cytoplasm

– They are contain a large amount of yolk granules in the cytoplasm

4. What is the structure of Telolecithal oocyte?

+ They are contain a large amount of yolk granules in the cytoplasm

– They don't contain yolk granules in the cytoplasm

– They are contain a little amount of yolk granules in the cytoplasm

5. What is the structure of Isolecithal oocyte?

+ They are contain a little amount of yolk granules in the cytoplasm

– They are contain a large amount of yolk granules in the cytoplasm

– They don't contain yolk granules in the cytoplasm

6. Types of the Telolecithal oocyte?

+ Moderately telolecithal, centrolecithal, shaply telolecithal

– Primary, centrolecithal, shaply telolecithal

– Primery, secondary, moderately telolecithal

– Moderately telolecithal, shaply telolecithal, secondary

7. A spermatozoon consists of?

+ Head, neck and tail

– Head, neck, body and tail

– Head, neck and body

– Neck, body and tail

8. Function of acrosome enzymes?

+ Capable to dissolve the ovum membranes at the moment of fertilization

– Erode glycoprotein covering of spermatozoon

– Membrane of fertilization is formed

– They deprive the oocyte ability to move

9. Function of cortical granules of the oocyte?

+ Membrane of fertilization is formed

– Erode glycoprotein covering of spermatozoon

– Capable to dissolve the ovum membranes at the moment of fertilization

– They deprive the oocyte ability to move

10. Function of Androgamones?

+ They deprive the oocyte ability to move

– Erode glycoprotein covering of spermatozoon

– Capable to dissolve the ovum membranes at the moment of fertilization

– Membrane of fertilization is formed

11. What is type cleavage in the human?

+ Complete and asynchronous

– Complete and synchronous

– Incomplete and asynchronous

– Incomplete and synchronous

12. Morula consist of:

+ 12 – 16 blastomeres

– 50 – 60 blastomeres

– 107 – 110 blastomeres

– 160 – 170 blastomeres

13. Blastula consist of:

+ Blastomeres, blastoderm and blastocell

– Morula, blastomeres and blastocell

– Zygote, morula and blastocell

– Zygote, embryoblast and trophoblast

14. On the seventh day blastula consist of:

+ 107 blastomeres, from which 69 trophoblast, 8 embryoblast and 30 inner cell mass

– 107 blastomeres, from which 69 trophoblast, 30 embryoblast and 8 inner cell mass

– 127 blastomeres, from which 79 trophoblast, 18 embryoblast and 30 inner cell mass

– 137 blastomeres, from which 79 trophoblast, 18 embryoblast and 40 inner cell mass

15. What is implantation phases?

+ Adhesion and invasion

– Ashesion and delamination

– Invagination and invasion

– Invagination and delamination

16. What is embryo fed with during vitelotrophic period?

+ Partly by oocyte nutrients, partly by secretion of uterine tube and endometrium glands

– Nutritious substances and gas by mother's blood

– Secretion of uterus glands and erosion products of endometrium tissues

– Nutritious substances and gas by mother's milk

17. What is embryo fed with during histiotrophic period?

+ Secretion of uterus glands and erosion products of endometrium tissues

– Nutritious substances and gas by mother's milk

– Partly by oocyte nutrients, partly by secretion of uterine tube and endometrium glands

– Nutritious substances and gas by mother's blood

18. What is embryo fed with during haematotrophic period?

+ Nutritious substances and gas by mother's blood

– Secretion of uterus glands and erosion products of endometrium tissues

– Partly by oocyte nutrients, partly by secretion of uterine tube and endometrium glands

– Nutritious substances and gas by mother's milk

19. What is invasion?

+ Penetration of blastocyst into uterus mucosa

– Formation of the morula

– Formation of the blastocyste

– Attachment of blastocyst between excretory ducts of uterus glands

20. What is adhesion?

+ Attachment of blastocyst between excretory ducts of uterus glands

– Formation of the blastocyste

– Penetration of blastocyst into uterus mucosa

– Formation of the morula

21. What is formed during delamination?

+ Epiblast and hypoblast

– Ectoderm, mesoderm

– Entoderm, mesoderm

– Ectoderm, mesoderm and entoderm

22. What are the ways of human gastrulation?

+ Delamination and immigration

– Epiboly and delamination

– Invagination and epiboly

– Delamination, immigration and epiboly

23. Embryonic disk consists of:

+ Bottom of amniotic vesicle and roof of yolk sac

– Bottom of yolk sac and roof of amniotic vesicle

– Extraembryonic mesoderm and amniotic vesicle

– Extraembryonic mesoderm and yolk sac

24. What is formed from hypoblast?

+ Exstraembryonic entoderm

– Exstraembryonic mesoderm

– Exstraembryonic ectoderm

– Embryonic ectoderm

25. What is formed from epiblast?

+ Embryonic ectoderm and exstraembryonic ectoderm

– Morula

– Exstraembryonic entoderm

– Cytotrophoblast

26. What is formed from primary stripe?

+ Embryonic entoderm, extraembryonic mesoderm and embryonic mesoderm

– Exstraembryonic entoderm and exstraembryonic mesoderm

– Embryonic ectoderm, extraembryonic mesoderm and embryonic mesoderm

– Extraembryonic mesoderm and yolk sac

27. What is formed from dorsal mesoderm?

+ Dermatome, myotome, sclerotome

– Dermatome, myotome, nephrotome

– Splanchnotome, myotome, sclerotome

– Exstraembryonic entoderm and myotome

28. What is formed from intermediate mesoderm?

+ Nephrotome

– Splanchnotome, myotome, sclerotome

– Dermatome, myotome, sclerotome

– Exstraembryonic entoderm and myotome

29. What is formed from ventral mesoderm?

+ Coelom

– Nephrotome

– Dermatome, myotome, sclerotome

– Exstraembryonic ectoderm and myotome

30. Neural tube is formed from:

+ Embryonic ectoderm

– Exstraembryonic entoderm

– Exstraembryonic ectoderm and embryonic mesoderm

– Exstraembryonic entoderm

31. Amnion wall is composed of:

+ Exstraembryonic mesoderm and exstraembryonic ectoderm

– Exstraembryonic mesoderm and embryonic ectoderm

– Exstraembryonic entoderm and embryonic ectoderm

– Embryonic ectoderm and exstraembryonic ectoderm

32. Yolk sac wall is composed of:

+ Exstraembryonic mesoderm and extraembryonic entoderm

– Embryonic ectoderm and exstraembryonic ectoderm

– Embryonic ectoderm and extraembryonic entoderm

– Extraembryonic ectoderm and exstraembryonic mesoderm

33. Chorion wall is composed of:

+ Syncytiotrophoblast, cytotrophoblast and exstraembryonic mesoderm

– Syncytiotrophoblast, cytotrophoblast and embryonic mesoderm

– Embryonic ectoderm and exstraembryonic ectoderm

– Exstraembryonic mesoderm and embryonic ectoderm

34. Functions of the amnion?

+ Produces fluid, defences the fetus from mechanical injures

– Garticipates in formation of vascular system of placenta

– Gas exchange

– Sourse of primary sex cells

35. Functions of inner layer of the yolk sac?

+ Sourse of primary sex cells

– Participates in formation of vascular system of placenta

– The place of embryonic hemopoiesis

– Gas exchange

36. Functions of external layer of the yolk sac?

+ The place of embryonic hemopoiesis

– Sourse of primary sex cells

– Gas exchange

– Participates in formation of vascular system of placenta

37. Functions of the allantois?

+ Participates in formation of vascular system of placenta, gas exchange

– Produces fluid, defences the fetus from mechanical injures

– The place of embryonic hemopoiesis

– Sourse of primary sex cells

38. Allantois wall is composed of:

+ Exstraembryonic mesoderm and exstraembryonic entoderm

– Exstraembryonic mesoderm and embryonic ectoderm

– Exstraembryonic entoderm and embryonic ectoderm

– Embryonic ectoderm and exstraembryonic ectoderm

39. Primary villi is composed of:

+ Cytotrophoblast and syncytiotrophoblast

– Cytotrophoblast, syncytiotrophoblast and exstraembryonic mesoderm

– Cytotrophoblast, syncytiotrophoblast, exstraembryonic mesoderm and blood vessels

– Cytotrophoblast, syncytiotrophoblast and exstraembryonic entoderm

40. Secondary villi is composed of:

+ Cytotrophoblast, syncytiotrophoblast and exstraembryonic mesoderm

– Cytotrophoblast, syncytiotrophoblast, exstraembryonic mesoderm and blood vessels

– Cytotrophoblast, syncytiotrophoblast and exstraembryonic entoderm

– Cytotrophoblast and syncytiotrophoblast

41. Tertiary villi is composed of:

+ Cytotrophoblast, syncytiotrophoblast, exstraembryonic mesoderm and blood vessels

– Cytotrophoblast, syncytiotrophoblast and exstraembryonic entoderm

– Cytotrophoblast and syncytiotrophoblast

– Cytotrophoblast, syncytiotrophoblast and exstraembryonic mesoderm

42. Deciduous tunic of placenta is consists of:

+ Basal part, capsular part and parietal part

– Chorionic plate and chorionic villi

– Extraembryonic mesoderm and chorionic villi

– Monolayer epithelium, extraembryonic ectoderm and chorionic plate

43. What is separates the fetus from uterus myometrium?

+ Basal part of deciduous tunic

– Parietal part of deciduous tunic

– Capsular part of deciduous tunic

– Chorionic villi

44. What is separates the fetus from uterus cavity?

+ Capsular part of deciduous tunic

– Parietal part of deciduous tunic

– Chorionic villi

– Basal part of deciduous tunic

45. What is separates lacunae from each other?

+ Septa

– Chorionic villi

– Chorionic plate

– Parietal part of deciduous tunic

46. Than is filled lacunae?

+ Maternal blood

– Blood of the fetal

– Loose connective tissue

– Deciduous cells

47. Fetal part of placenta is consists of:

+ Villous chorion

– Deciduous cells

– Extraembryonic entoderm

– Uterus myometrium

48. Villous chorion is consists of:

+ Chorionic plate and chorionic villi

–Basal part, capsular part and parietal part

– Monolayer epithelium, extraembryonic entoderm and chorionic plate

– Lacunae and septa

49. Chorionic plate is consists of:

+ Monolayer epithelium and extraembryonic connective tissue

– Syncytiotrophoblast and cytotrophoblast

– Deciduous cells

– Extraembryonic entoderm

50. Placental barrier NOT includes:

+ Maternal blood

– Syncytiotrophoblast and cytotrophoblast

– Connective tissue of villi

– Wall of capillary

51. Umbilical cord is consists of:

+ Mucous tissue with two arteries and one vein

– Mucous tissue with one artery and two veins

– Epithelial tissue with two arteries and one vein

– Epithelial tissue with one artery and two veins

52. What implants into the nutrient–rich endometrium (i.e. decidua) about 8–9 days after ovulation?

+ Blastocyst

− Morula

− Epiblast

− Hypoblast
− Bilaminar disk

53. What structure has to degenerate so that implantation can occur?

− Syncytiotrophoblast
− Functional layer of the endometrium
− Basal layer of the endometrium
− Cytotrophoblast
+ Zona Pellucida

54. How soon after fertilization does implantation take place?

− By 12 hours
− By 30 hours
− Day 3
− Day 4
+ Day 6

55. A 23–year–old woman presents at the emergency department with moderately severe abdominal pain on her right side. She is showing some signs of internal bleeding. She is sexually active but does not use any form of contraception and missed her last menstrual period. Based on this information, which of the following disorders should be included as an option in the diagnosis?

− Ovarian cancer
− Appendicitis
+ Ectopic pregnancy
− Normal pregnancy
− HIV

56. The second week of development is referred to as the week of two's because…?

− The embryoblast divides into two layers
− Two cavities form, the amniotic cavity and yolk sac

− The trophoblast organizes into two layers, the cytotrophoblast and syncytiotrophoblast

+ All of the above

− A & C

57. Which two embryological structures together form the bilaminar disk?

− Cytotrophoblast and Hypoblast

+ Hypoblast and Epiblast

− Epiblast and Cytotrophoblast

− Syncytiotrophoblast and Inner cell mass

− Epiblast and Embryoblast

58. Chemotherapy treatment often targets mitotically active cells. Although this treatment is beneficial for cancer, it can negatively effect implantation and embryonic growth. Which of the following layers would be most affected by a slowed cell division rate?

+ Cytotrophoblast

− Epiblast

− Amnioblast

− Syncytiotrophoblast

− Hypoblast

59. Which of the following develops from the multinucleated syncytium, the syncytiotrophoblast and serves as the beginnings of gas exchange between mother and embryo?

− Bilaminar disk

− Cytotrophoblast

− Amniotic cavity

+ Lacunae

60. The placenta is part of the chorion. The chorion consists of which of the following?

− Extraembryonic mesoderm

− Cytotrophoblast

− Hypoblast

− All of the above

+ A & B

61. The amniotic cavity forms during the process of implantation of the blastocyst. The amniotic cavity forms within which of the following structures?

+ Epiblast

− Cytotrophoblast

− Syncytiotrophoblast

− Maternal endometrium

− Hypoblast

62. Which of the following cells form endoderm and mesoderm?

+ Migrating epiblast cells

− Migrating hypoblast cells

− Non–migrating epiblast cells

− Non–migrating hypoblast cells

− Neural crest cells

63. The notochord develops from which of the following embryonic germ layers?

− Endoderm

− Ectoderm

+ Mesoderm

− Neuroectoderm

− Neural crest cells

64. Which week of embryonic development usually corresponds to the first missed menstrual period?

− Week one

− Week two

+ Week three

− Week four

− None of the Above

65. Neural crest cells develop during a process known as neurulation. These cells can ultimately form which of the following?

+ Melanocytes

− Lymphocytes

− Somites

− All of the above

66. The neural tube and plate forms from:

− Intermediate mesoderm

− Paraxial mesoderm

− Neural crest cells

+ Neuroectoderm

− Endoderm

67. Somites form from which of the following embryological derivations?

+ Paraxial mesoderm

− Lateral plate mesoderm

− Neural crest cells

− Endoderm

− Ectoderm

68. In a growing embryo, the vertebrae encase notochord and neural tube in a solid bone like structure. Vertebrae are formed from which of the following embryological structures?

− Dermatomes

− Myotomes

+ Sclerotomes

− Primaxial domain

− Abaxial domain

69. Which of the following sets are derived from lateral plate mesoderm?

− Nerves, arteries and connective tissue of limbs

− Nerves, arteries and connective tissue of abdomen

− Nerves, arteries and connective tissue of thorax

+ Bones, joints and connective tissue of limbs

− Bones, joints and connective tissue of thorax

70. Which pathological condition is called placenta increta?

− Placenta is inserted too low, it covers the cervical channel

− Placenta is full of blood clots (trombi), its function drops

− Placenta is splitted to two or more separated lobes

+Placentar villi growth into the myometrium

71. All but one hormones are produced by the placenta? Which one does not?

− Chorionic gonadotropin

+ Triiodthyronine

− Progesteron

− Estrogens

72. Which statement about the blood flowing in the umbilical vein is true?

− The blood is maternal oxygenated

+ The blood is fetal oxygenated

− The blood is maternal with low level of oxygen

− The blood is fetal with low level of oxygen

73. Where takes place the amniotic fluid?

− In the abdominal cavity of the fetus

− In the intervillous space

+ In the amniotic cavity

− In the chorion

74. Which statement about the syncytiotrophoblast is true?

− It covers the chorionic villi

− It covers the chorionic plate

+It covers both chorioic villi and plate

− It disappears before formation of the placenta is completed

75. Which compound can not pass the placental barrier?

+ Hemoglobin

− Aminoacids

− Glucose

− Water

76. Which structure holds maternal and fetal parts of the placenta together?

− Pressuere of surrounging anatomical structures

− Ligaments on the border of the placenta

− Ligament in the center of the placenta

+Anchoring villi

77. Which structures form the placental barrier?

− Fetal capillaries, syncytiotrophoblast, maternal capillaries

+ Fetal capillaries, cytotrophoblast, syncytiotrophoblast

− Chorionic membrane and maternal capillaries

− Chorionic membrane and fetal capillaries

78. Which pathological condition can be caused by Rh incompatibitily

− Twin – to – twin transfusion

+ Fetal erythroblastosis

− Placenta percretta

− Umbilical knots

79. How big is usually the placenta before the birth?

− About 12 cm in diameter and 2 – 2.5 cm in thickness

− About 12 cm in diameter and 5 – 5.5 cm in thickness

+ About 22 cm in diameter and 2 – 2.5 cm in thickness

− About 22 cm in diameter and 5 – 5.5 cm in thickness

80. How long is usually the umbilical cord before the birth?

− About 20 cm

− About 30 cm

− About 40 cm

+ About 50 cm

81. How is called the stage of the labor in which the placenta is expelled?

− Second stage

+ Third stage

− Fourth staga

− It has no name

82. In which direction are transported urea and uric acid through the placenta? Note: both these compounds are common waste products of the metabolism

+ From the fetal blood to the maternal blood

− Form the maternal blood to the fetal blood

− They can not pass the placental barrier

83. Whati is an allantois? (Possible formulation is also: "Allantois:")

− Finger–like protrusion in the site of pharyngeal membrane

− Finger–like protrusion in the site of syncytiotrophoblast

+ Finger–like protrusion in the site of cloak membrane

− Finger–like protrusion in the site of cytotrophoblast

84. Which statement about the amniotic sac is true? (Possible formulation is also: "Amniotic sac:")

− It is lined up by cells of ectoderm from its beginning

− It is lined up by cells of endoderm from its beginning

+ It is composed of cells derived from the epiblast

− It disappears completely during the second week

85. Which structures form the bilaminar germ disk?

− Mesoderm and mesenchyme

+ Epiblast and hypoblast

− Endoderm and ektoderm

− Laurel and Hardy

86. Which embryonic structure gives rise to cells in our bodies? (note: you can assume "the majority of cells" instead of "all cells" as the application of the rule "the best–fitting answer is correct")

− Both epiblast and hypoblast

− Hypoblast

+ Epiblast

87. Chorda dorsalis (dorsal chord) is a source of signaling molecules driving the development of: (note: Instead of "driving", words like "controlling" or "checking" can be used in the same meaning)

+ Axial structures

− Umbilical cord

− Placenta

− Hearth

88. Chorda dorsalis (dorsal chord):

− Completely disappears during prenatal life

− Is fully preserved nearly till the birth

+ Is a solid chord composed of cells

− Is the tubular structure

89. When start differentiation of somites (somitogenesis)?

+ In 3rd week

− In 4th week

− In 5th week

− In 6th week

90. Does the morula change its volume in the Fallopian tube?

− Yes, the volume undergoes three to five cycles of changes

− Yes, the volume decreases

− Yes, the volume increases

+ No, the volume does not change

91. Ductus venosus (Arantii): (note: This short formulation means: "Select correct or best–fitting statement about the structure")

− Originates as the connection of anterior and posterior cardinal veins

+ Connects umbilical vein with inferior caval vein

− Is the venous side of the primitive heart tube

− Gives rise to the portal vein

92. Which statement about 'formation of somites is correct?

+ Formation of somites is gradual: Cranial somites start, caudal somites continue later on

− Formation of somites is gradual: Caudal somites start, cranial somites continue later on

− Timing of formation of somites is less or more chaotic

− All somites are formed at the same time

93. When starts the implantation?

− Immediately after fertilization

− 3rd day after fertilization

+ 6th day after fertilization

− 9th day after fertilization

94. Journey of the morula through the Fallopian tupe takes usually:

− 1 to 2 days

+ 3 to 4 days

− 5 to 7 days

− 8 to 10 days

95. What is a capacitation?

+ Capacitation is a process in which the glycoprotein layer over the acrosome is dissolved

− Capacitation is a process in which sperm penetrates zona pellucida

− Capacitation is a process in which the tail of the sperm is inactivated

− Capacitation is a process in which the tail of the sperm is activated

96. Where the fertilization occurs usually?

− In the infundibular part of the Fallopian tube

+ In the ampullary part of the Fallopian tube

− Horn of the uterus (cornua uteri)

− Cavity of the uterus

97. Where originates the extraembryonic mesoderm?

− It is a result of the migration of cells from the neuroectoderm

+ In a site between trophoblast and embryoblast

− In a site between hypoblast and epiblast

− In a site between endoderm and ectoderm

98. Which statement about the neural plate is true?

− Neural plate forms itself between the node of Hensen and cloacal membrane

+ Neural plate is the basic structure for neural tube and neural crests

− Neural plate originates at the ventral side of the germ disc

− Neural plate is of endodermal origin

99. Which statement about the neural crest is not true?

− Some kind of mesenchyme can develop from the neural crest

− Neural crest give rise to the medula of the suprarenal gland

+ Neural crest gives rise to the cortex of the suprarenal gland

− Melanocytes originate from the neural crest

100. Which statement about the zona pellucida is true?

− Zona pellucida is a membrane surrounding the oocyte, it is composed mainly of glycoproteins

+ Zona pellucida is a membrane surrounding the oocyte, it is composed mainly of glycolipids

− Zona pellucida is on the border between theca folliculi interna and externa

− Zona pellucida is another name for Slavjanski's membrane

101. Which structure does not take place in the late blastocyst?

+ Zona pellucida

− Trophoblast

− Embryoblast

− Cavity

102. What surrounds the yolk sac?

− Chorion

+ Amnion

+ Extraembryonic cavity=chorionic cavity

− Epiblast which then gives rise to all 3 germ layers

103. What does splanchnopleure and somatopleure surround

+ Primitive body cavity

− Secondary body cavity

− Primary yolk sac

− Secondary yolk sac

104. Where is the fetal fluid (Amniotic fluid)?

− Chorion

+ Amnion

− Allantois

− Primitive body cavity

105. In which part of placenta is mother's blood?

− Chorionic plate

+ Intervillous space

− Perimetrium

− Chorionic villi

106. Which is main tissue of tunica albuginea testis?

− Reticular connective tissue

+ Dense connective tissue

− Hyaline cartilage

− Fibrocartilage

107. How many lobules are in one testis?

− About 2500

+ About 250

− About 25

− About 2

108. Tunica vaginalis testis is derived of one distant structure. Which one?

− Muscular layer of abdominal wall

− Skin of abdominal wall

+ Perinoneum

− Mesenter

109. Which cells produce testosterone?

− Sertoli cells

− Myoidal cells

+ Leydig cells

− Sperms

110. Which stage of development of sperm is diploid?

− Secondary spermatocyte

+ Spermatogonia B

− Spermatozoon

− Spermatid

111. Which type of cell adhesion is main adhesion in the blood-testis barries?

+ Tight junction

− Focal adhesion

− Gap junction

− Desmosome

112. During which phase of spermiogenesis are shed resudual bodies?

+ Maturation phase

− Acrosomal phase

− Golgi phase

− Cap phase

113. Which hormone is produced by Sertoli cells?

− Testosterone

+ Inhibin

− FSH

− LH

114. Which structure is site of first occurence of primordial germ cells?

− Gonadal primordia

− Neural crest

+ Yolk sack

− Midgut

115. Which statement about primary oocytes is not true?

+ They are produced in surface epithelium of ovary

− They are surrounded by follicular cells

− They are formed before the birth

− They are arrested in meiosis

116. Tunica albuginea of ovary:

+ It is composed of dense connective tissue

− It is composed of hyaline cartilage

− It is composed of fibrocartilage

− It does not exist

117. Primary follicle:

+ Basal lamina of follicular cells is on the border between follicle and ovarial stroma

− Basal lamina of follicular cells is on the border between oocyte and follicular cells

− Basal lamina of follicular cells surrounds them from all sides

− There is no basal lamina in primary follicle

118. Granulosa cells:

+ Granulosa cells are connected through gap junctions

− Granulosa cells are derived from ovarial stroma

− Granulosa cells produce FSH

− Granulosa cells produce LH

119. Follicular theca interna:

− Theca interna has the same function as theca externa

− Cells of theca interna are part of corona radiata

+ Theca interna is derived from ovarial stroma

− Theca interna is derived from granulosa

120. What is an atresia?

− Physiological process of dying of minor part of oocytes

+ Physiological process of dying of main part of oocytes

− Pathological process of dying of oocytes

− Pathological overproduction of oocytes

121. What is main material of zona pellucida?

− Glycoproteins of a hyaline cartilage

− Reticular epithelium

+ Unique glycoproteins

− Unique lipids

122. Which compound is not present in the follicular fluid?

− Hyaluronic acid

− Heparan sufate

− Plasminogen

+ Glycogen

123. Which cells give rise to the corpus luteum?

− Cells of theca foliculi interna and theca foliculi externa

+ Cells of granulosa and theca foliculi interna

− Cells of theca foliculi interna only

− Cells of granulosa only

QUESTIONS KROK 1

1. An embryo displays disturbed process of dorsal mesoderm segmentation and somite formation. What part of skin will have developmental abnormalities?

+Derma

–Epidermis

–Sudoriferous glands

–Hair

–Sebaceous glands

2. Blue asphyxia of a newborn child has been diagnosed. What vessel carrying oxygenated maternal blood to the fetus has been pinched during delivery?

+Umbilical vein

–Umbilical artery

–Chorionic vein

–Chorionic artery

–Uterine artery

3. Two sacs contacting with each other (amniotic and yolk) can be seen in a 10–day embryo specimen. What is the structure in the place of their contact called?

+Embryonic plate

–Bottom of the amniotic sac

–Roof of the yolk sac

–Amniotic crus

–Extraembryonic mesoderm

4. In a histological specimen is observed an extraembryonic organ that represents a bladder connected with intestinal tube Its wall is covered with epithelium on the inside, on the outside it is formed of embryonic connective tissue. At early stages of embryogenesis it functions as a hematopoietic organ. What organ is this?

+Yolk sac

–Allantois

–Amnion

–Umbilical cord

–Uterine artery

5. At early stages of human embryo–genesis there arises a digitiform outgrowth of the ventral wall of the primitive gut rooting itself in the amniotic crus. What is the name of this extraembryonic organ?

+Allantois

–Yolk sac

–Amnion

–Placenta

–Umbilical cord

6. In the histological specimen of a human fetus there can be seen one of extraembryonic organs – a bladder linked with intestinal tube In its wall there are primary germ cells and primary erythrocytes (megaloblasts). Define what this organ is:

+Yolk sac

–Allantois

–Placenta

–Umbilical cord

–Amnion

7. A histological specimen shows a transverse section of an organ, whose basis is formed of mucous connective tissue, two arteries, and a vein. What organ is it?

+Umbilical cord

–Allantois

–Yolk sac

–Amnion

–Placenta

8. During the third week of embryo–genesis the central part of epiblast cells (ectoderm) sags and neurulation process begins In which direction will the remaining ectodermal cells differentiate?

+Skin

–Gut

–Somites

–Chord

–Yolk sac

9. In the course of the experiment on a frog embryo the external embryonic layer – ectoderm – has been destroyed. Which of the following morphological structures has not developed henceforth?

+Epidermis

–Somites

–Nephrotome

–Splanchnotome

–Myotome

10. In a histological specimen there is a hen embryo in the stage of mesoderm differentiation to somites, nephrotomes, and splanchnotome. Of which material will the axial skeleton develop?

+Sclerotome

–Dermatome

–Nephrotome

–Splanchnotome

–Myotome

11. Zygote cell–division finishes after blastula formation. What type of blastula is specific of a human being?

+Blastocyst

–Celoblastula

–Discoblastula

–Amphiblastula

–Morula

12. In a microscopic specimen of a human embryo, taken after involuntary miscarriage, an embryonic plate has been detected with two cellular layers: endo– and ectoderm. At what stage of embryonal development is this embryo?

+Gastrulation

–Progenesis

–Neurulation

–Histogenesis

–Organogenesis

13. During the process of a human embryo formation one can observe the rise of a cavity, light little blastomeres at the periphery, and dark big blastomeres at one of the poles. How is the embryo called at this stage of development?

+Blastocyst

–Morula

–Zygote

–Gastrula

–Embryonic disk

14. Gonoblasts, sex stem cells, are detected in a 2–3–week–old embryo. Where do these cells differentiate?

+In yolk sac

–In mesenchyme

–In embryonic ectoderm

–In dermatome

–In embryonic endoderm

15. Embryonic implantation into endometrium (uterine mucosa) consists of two phases – adhesion and invasion. The first phase is accompanied by:

+Blastocyst attachment to endometrium surface

–Destruction of endometrium connective tissue

–Destruction of endometrium epithelial cells

–Activation of uterine glands secretion

–Suppression of uterine glands secretion

16. In a specimen an ovocyte at the moment of its fertilization by spermatozoon can be seen. What is the main result of fertilization?

+Formation of zygote

–Determining the child's sex

–Meiosis completion with ovocyte

–Penetration of ovolemma by spermatozoon

–Cortical reaction

17. An anlage of an organ performing endocrine function is formed of a trophoblast during embryogenesis. What organ is this?

+Villous chorion (fetal part of placenta)

–Amnion

–Yolk sac

–Allantois

–Umbilical cord

18. A human embryo is comprised of two blastomeres. Name its location under the condition of normal genesis:

+Uterine tube

–Cavity of uterus

–Abdominal cavity

–Endometrium

–Ovary

19. Some microorganisms being the reason of infectious diseases can pass through the placental barrier. What structures does it consist of?

+All the components of tertiary villi

–Chorion and amnion

–All the components of secondary villi

–Allantois, yolk sac

–Basal lamina of endometrium with decidual cells

20. A fetus' umbilical cord is compressed, but blood circulation between the mother and child is preserved. What structures provided this primarily?

+Mucous connective tissue

–Residue of allantois

–Arteries sheath

–Veins sheath

–Residue of yolk pedicel

21. "To be born with a silver spoon in one's mouth" corresponds to Russian "to be born in a shirt". What "shirt" is meant?

+Amniotic

–Yolk

–Serous

–Chorionic

–Trophoblastic

22. Internal female genital organs were removed in the course of an operation. Microscopic examination of these organs has shown an embryo consisting of two blastomeres. Name the place of its localization in the conditions of normal development

+Ampulla part of uterine tube

–Uterine part of uterine tube

–Cavity of uterus

–Abdominal cavity

–Ovary

CRITICAL THINKING QUESTIONS

1. Darcy and Raul are having difficulty conceiving a child. Darcy ovulates every 28 days, and Raul's sperm count is normal. If we could observe Raul's sperm about an hour after ejaculation, however, we'd see that they appear to be moving only sluggishly. When Raul's sperm eventually encounter Darcy's oocyte, they appear to be incapable of generating an adequate acrosomal reaction. Which process has probably gone wrong?

2. Sherrise is a sexually active college student. On Saturday night, she has unprotected sex with her boyfriend. On Tuesday morning, she experiences the twinge of mid–cycle pain that she typically feels when she is ovulating. This makes Sherrise extremely anxious that she might soon learn she is pregnant. Is Sherrise's concern valid? Why or why not?

3. A 23-year-old woman presents at the emergency department with moderately severe abdominal pain on her right side. She is showing some signs of internal bleeding. She is sexually active but does not use any form of contraception and missed her last menstrual period. Based on this information, which of the following disorders should be included as an option in the diagnosis?

4. Chemotherapy treatment often targets mitotically active cells. Although this treatment is beneficial for cancer, it can negatively effect implantation and embryonic growth. Which of the following layers would be most affected by a slowed cell division rate?

5. Which of the following cells form endoderm and mesoderm?

6. Which week of embryonic development usually corresponds to the first missed menstrual period?

7. What is the embryological remnant of the umbilical veins?

8. Which of the following sets are derived from lateral plate mesoderm?

9. The lateral somatic frontier is a well defined border between each somite and the parietal layer of lateral plate mesoderm, and this creates 2 domains of cells

(the primaxial domain and abaxial domain). In the abaxial domain, the muscle precursor which cells form adult structures in humans?

Answers:

1. The process of capacitation appears to be incomplete. Capacitation increases sperm motility and makes the sperm membrane more fragile. This enables it to release its digestive enzymes during the acrosomal reaction. When capacitation is inadequate, sperm cannot reach the oocyte membrane.

2. Sherrise's concern is valid. Sperm may be viable for up to 4 days; therefore, it is entirely possible that capacitated sperm are still residing in her uterine tubes and could fertilize the oocyte she has just ovulated.

3. Ectopic pregnancy: Ectopic tubal pregnancy must always be an option in the diagnosis when a woman in her reproductive years presents with such symptoms. About ten percent of ectopic implantations occur in the uterine tube. Ectopic tubal pregnancies result in rupture of the uterine tube and internal hemorrhage, which presents a major threat to the woman's life. The uterine tube and embryo must be surgically removed. The symptoms may sometimes be confused with appendicitis.

4. Cytotrophoblast: The trophoblast forms the fetal part of the placenta and is involved with implantation. The cytotrophoblast is the mitotically active inner part of the trophoblast, and provides the cells that migrate into the syncytiotrophoblast to allow it to expand. Thus, chemotherapy may directly affect mitotic activity in the cytotrophoblast possibly hindering implantation.

5. Migrating epiblast cells: Epiblast cells move into the primitive streak and primitive node to form endoderm and mesoderm. Nonmigrating epiblast cells form ectoderm.

6. Week three: High yield fact sheet - "During the third week of development, the process of gastrulation beginning with the formation of the primitive streak and primitive node at the cephalic (head) end of the embryo. Third week usually corresponds to first missed menstrual period."

7. Ligamentum teres hepatis: Umbilical veins bring oxygen-rich blood to the fetus from the placenta and closes after birth forming the ligamentum teres hepatis.

8. Bones, joints and connective tissue of limbs: Bones, joints and connective tissue of limbs come from parietal layer of lateral plate mesoderm.

9. Limb muscles, Abdominal wall: Muscle precursor cells in the primaxial domain give rise to back, shoulder girdle and intercostal muscles. Muscle precursor cells in the abaxial domain give rise to abdominal wall and limb muscles.

REFERENCES

1. https://www.pathologyoutlines.com/topic/placentanormalhistology.html
2. https://courses.lumenlearning.com/suny-ap2/chapter/embryonic-development/
3. https://www.dentaljuce.com/histology-placenta
4. https://www.wikilectures.eu/w/Portal:Histology
5. https://ethw.org/Category:Biological_topics?gad_source=1&gclid=Cj0KCQjwwMqvBhCtARIsAIXsZpYhesXWUfVL3nb5KA6ThVTSa7CAUlAax1Az-iuwRGxFJEPQ_QBEzZMaAk4XEALw_wcB
6. https://www.glowm.com/article/heading/vol-10--common-obstetric-conditions--pathology-of-the-placenta/id/409323
7. https://www.ttuhsc.edu/medicine/medical-education/success-types/documents/unit1embryoqandamodule.pdf
8. https://www.testcentr.org.ua/banks/med/k2-med-f-eng.pdf
9. https://www.britannica.com/science/prenatal-development/Embryonic-acquisition-of-external-form
10. https://medcell.org/histology/female_reproductive_system_lab/chorionic_villi.php
11. https://www.intechopen.com/chapters/63244
12. https://www.invitra.com/en/umbilical-cord-abnormalities/importance-umbilical-cord/
13. https://www.slideserve.com/daniel_millan/neurulation#google_vignette
14. https://jackwestin.com/resources/mcat-content/embryogenesis/neural-crest
15. https://quizlet.com/336048502/neurulation-diagram/
16. https://letstalkacademy.com/gastrulation/
17. https://worms.zoology.wisc.edu/frogs/gast/gast_morph.html#top
18. https://www.dreamstime.com/illustration/gastrula.html
19. https://evolutionunderthemicroscope.com/homology13.html
20. https://redlara.com/images/arq/Cleavage.pdf

Електронне навчальне видання

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Ембріологія

(Англійською мовою)

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Формат 60x84/8. Ум. друк. арк. 14,07. Обл.-вид. арк. 11,94.

Видавець і виготовлювач

Сумський державний університет,

вул. Харківська, 116, м. Суми, 40007

Свідоцтво суб'єкта видавничої справи ДК № 3062 від 17.12.2007.

Видання призначене для студентів медичних закладів вищої освіти, які вивчають гістологію людини англійською мовою.