

Embryology: Images of Man

In the 20 years that I taught at Warmonderhof (the school for biodynamic agriculture and horticulture in the Netherlands), embryology has been one of the subjects I taught. On these pages I will describe the content of the lessons: the development of the embryonic human being. At the beginning I describe the principles of the embryonic development of the plant and the (simple) animal, too, at the basis of phenomenology.

The basis of the classes was formed by a number of books by Blechschmidt and Wilmar. And I was in the fortunate position that I could follow a course on embryology by the embryologist Jaap van der Wal in my first year at the school. His course and later his website were a vital source of information for me.

One may wonder why a subject such as embryology is part of the curriculum of an agricultural training. Primarily the classes are about the development of the embryo itself, from which will - I hope - become clear that we are human beings from the conception, only in a different form than we encounter after birth. This may lead to respect for unborn life: another reason for the lessons. A third reason is that many processes occur simultaneously and that it is an exercise to have them all in our consciousness at the same time. In addition, the development is a three-dimensional process that must be visualised from two-dimensional drawings; an appeal to the imagination. This makes it a difficult subject, stimulating the development of thought.

The embryonic development of man is described and represented in a large number of drawings, too, so that an image of the development can arise. My starting-point for the description is the anthroposophical view of man, which sheds a special light on embryology.

I do not describe the embryonic development in an anatomical or analytical way, but I try to find the inner movement, the coherence and the larger context by observing the changing forms and processes. This is more about understanding the language of the forms of living organisms than about a scientific explanation of these forms. This all aims for awareness for, as Goethe called it the "transcendental" quality of Life, and of man.

These 10 pages and the book have been written for the interested layman. On several occasions I made simplifications. If one wants to delve deeper, there are manuals and an informative website (www.embryology.ch) with drawings and photographs. For more background the website of the embryologist Jaap van der Wal (www.embryo.nl) may be consulted as well as several publications, see: sources. Unless otherwise specified the drawings are based on Moore's "Before we are born".

In the drawings - where appropriate - four colours are used: blue for the ectoderm, red for the mesoderm, green for the entoderm and yellow for the allantois.

Tom van Gelder, June 2011.

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Plant and animal

On this page the embryonic development of a flowering plant and a simple animal (a sea urchin) are described and compared. The fundamental difference between the shape and the essence of a plant and an animal will be explained.

The development of the embryo of the plant

When plants flower, pollen will be carried from the stamens to the stigma of the pistil by wind, insects or other animals. The pollen makes a tube through the style of the pistil to the egg cell in the ovary. Fertilization takes place and then follows the first division (see Fig. 1, stage 2), by which a small apical cell (A) and a large basal cell (B) are formed. The apical cell divides into four cells and forms a small ball. The basal cell ligates cells at the top (stage 3). The apical clump of cells grows and forms a spherical ball. The lower part with the basal cell stops growing and dividing quite soon (stages 4 and 5). This part is called the suspensor (C). This stage (5) is called the globular stage of the embryo.

The apical tissue grows sideward (stage 6), the cotyledons (D) are formed from this. At the same time the tissue between the cotyledons and the suspensor differentiates into the growing point of the root (or apical root meristem, E), the growing point of the shoot (or apical shoot meristem, F) and the connective vascular tissue (G), stages 7 and 8. The cotyledons grow and fold out. The seed (e.g. a peanut) is formed.

The seed grows further and goes into rest. It starts to grow again only when it goes into the ground and the conditions are favourable for germination. One might speak of "a double fertilization". First, the pollen fertilizes the egg, then the seed has to fall or be sown into the earth. The seed (male) is received by Mother Earth.

The following processes are visible:

- right from the first division the embryo is growing;
- immediately there is cell differentiation, the apical and basal cells are different;
- the tissue is solid.

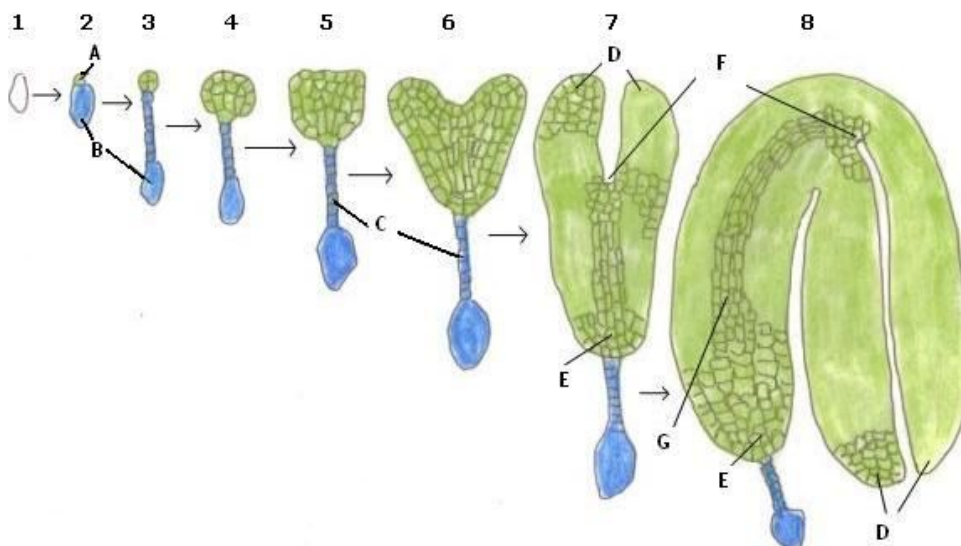


Figure 1. The development of the embryo of the plant

A: top cell; B: basal cell; C: suspensor; D: cotyledons; E: root meristem; F: stem meristem; G: vascular tissue

The development of the embryo of a simple animal (e.g. a sea urchin)

At fertilization an egg cell and a sperm cell fuse and create a zygote* (= fertilized egg). After 24 hours the first division takes place: two equally big cells are created, each being half the size of the zygote. After that the divisions occur approximately every 12 hours. The embryo is and stays spherical and does not grow. The stage of 16 to 64 cells is called a morula (= mulberry) (see Fig. 2, the fifth stage, side view).

Then the cells that lie inside migrate from the centre to the periphery, some cells die in the middle and there a cavity is formed. This cavity is filled with fluid. The embryo is now called a blastula (= small button, Fig. 2, the sixth stage, a cross section) and starts to grow.

The cell divisions in the wall of the blastula continue and then some cells bend inwards to make a tube to the inside. This indentation looks as if a finger is pushed inwards. This happens at the spot that is called the blastopore (= opening of the vesicle)(Fig. 2, stage 7 and 8). The embryo is now called a gastrula (gaster = stomach). This indentation-process continues until the indentation reaches the opposite wall. Then the tissue breaks open. Out of the blastopore the anus is formed and the new breakthrough forms the mouth. Between these two a tube is formed that will become the digestive tract. Between the digestive tract and the outer wall or skin, a body cavity is formed in which clumps of cells (the mesoderm) are formed out of which the organs will develop.

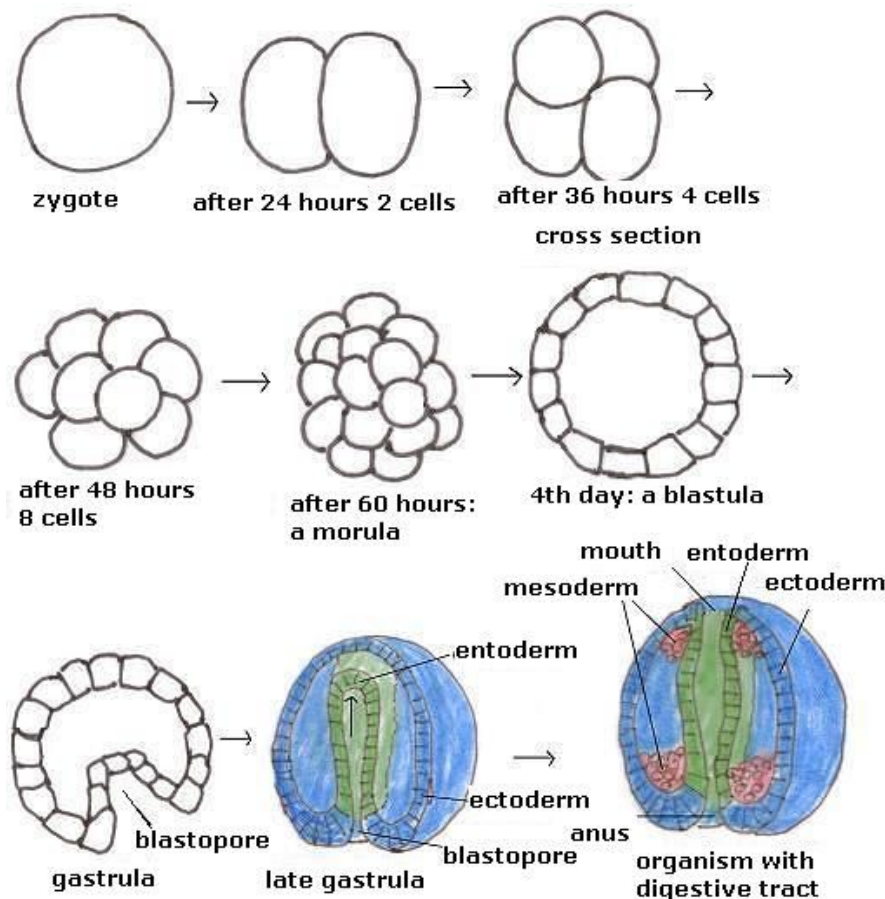


Figure 2: The embryonic development of a sea urchin (schematically)

See text for an explanation. A cluster of cells is formed, in which a cavity is formed on the fourth day. Then an indentation arises, that breaks through on the opposite side. The result is an organism which has a digestive tract and a body cavity with clumps of mesoderm cells. From the blastula on cross sections are given. In the late gastrula and the last drawing, the organism is cut and is half visible. Ectoderm is blue, entoderm green and mesoderm red.

* The first time a technical term appears, the English translation is given in parentheses.

Three types of tissue are formed:

- an outer membrane or outer skin, or ectoderm (ecto = outside and derma = skin, blue)
- an inner membrane or inner skin, or entoderm (also called endoderm; ento = inside, green)
- and between them a cavity in which there is in-between tissue or mesoderm (mesos = middle, red).

These three tissues are called the three germ layers. Later on all tissues and organs will grow out of them.

Two cavities came into being:

- the digestive tract; an external cavity created from the outside a bit of the outside world in the body, which stays in contact with the world outside through the mouth and the anus and
- the body cavity; the cavity between the skin and the digestive tract. This cavity has no connection to the world outside. In this cavity all organs and the centre of the body will develop.

The following processes are visible:

- in the beginning there is no growth,
- in the beginning there is no cell differentiation,
- two different cavities are formed.

Differences between plants and animals

The embryonic development of plants and animals is different. Plants show immediate growth, animals do not at first. The cells of plants differ immediately, whereas this is not the case with animals. Plants are solid and animals have two body cavities. Animals bend inwards and make a body cavity and plants do not form an inner space.

This can also be seen later on. Plants grow on the ends of their twigs, their shoots and roots directed to the surroundings. The growing points are always placed at the ends of twigs, stems and roots, in the periphery. Processes take place on the outside. Growth-rate and size are largely determined by the environment. A plant on poor sandy soil grows less well than a plant on nutrient-rich clay. Plants are in the environment.

Animals grow to a certain (somewhat variable) size and then stop growing. They are not influenced by the environment as much as plants. Plants are fixed in the earth, animals can move. Plants do not have an inner cavity nor a centre, animals do (the heart). Animals have developed an interior space, in which processes take place and they have an inner life. See Fig 3.

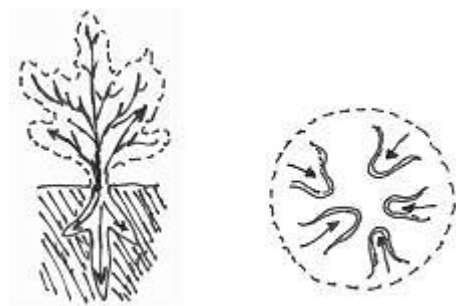


Figure 3. The growth directions of a plant and an animal (from van der Wal (2003): Hartmann)

Hartmann has four drawings of the growth-directions in relationship to the centre and the environment of the mineral, the plant, the animal and man, that are useful in embryology.

The plant grows up and down from a point (the meristem points) and then into the periphery - the air and the soil. The animal grows inwards.

In anthroposophy the inner life of animals is linked to the inner space of the body cavity. The cavity is the basis for the astral body, the non-physical body in which the soul capacities *observing and thinking, feeling and willing and doing* take place. Plants do not have a soul nor body cavities. Plants and animals both have an ether- or vital body. Plants can grow freely, animals cannot, because they are orientated on their centre, as shown by the gastrula. In table 1 the differences between plants and animals are summarized.

	plants	animals
growth	at once, at the first division	not at first, later on
cell differentiation	at once	later on
body cavities	non	digestive tract and body cavity
orientation	environment	the inner centre
centre	non	the heart
levels of being	physical and vital body	physical, vital and astral body

Table 1. Differences between plants and animals

The human egg cell and sperm*

For a conception an egg cell and many sperm are needed. When the cells find each other, they fuse after a while and the chromosomes come together. Then the zygote (= fertilized egg) is formed and can begin to divide. First we will look at the characteristics of the ovum and sperm. There are no cells in humans that are so different and yet belong so much together.

The ovum and sperm

Size and shape

The egg cell (or ovum, or oocyte) is the largest human cell. She measures 0.15 to 0.2 mm and is just visible to the naked eye. She is also the roundest cell, she is almost perfectly round (Fig. 4). She therefore has the largest volume in relation to her surface. The cell consists of a large amount of cytoplasm (= cell fluid) in which the nucleus is dissolved (and therefore invisible) until just before conception.

Sperm cells are the smallest human cells. They are no more than a nucleus with a small amount of cytoplasm, some mitochondria (the energy suppliers of the cell) and a long tail. They have hardly any content and are the straightest cells.

Egg cell and sperm are each others opposite[□]. Large versus small, round versus straight, cytoplasm versus nucleus. The differences are great, at the same time they belong together if we perceive the ovum as a sphere and the straight sperm as the corresponding radius.

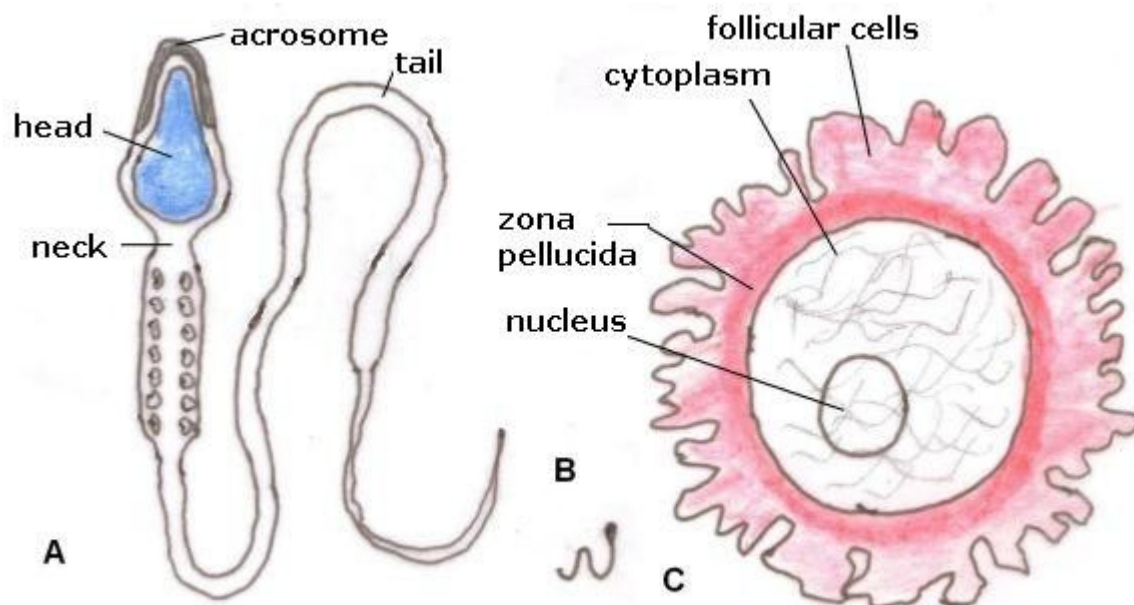


Figure 4. Spermatozoon (A) and ovum (C). B shows the sperm at the same scale as the ovum

* based on:

Van der Wal, J., 2003. Dynamic morphology and embryology. In: Bie, van der G & M. Huber, Foundations of anthroposophical medicine. Floris books, Edinburgh. And: Bie, G van der, 2001. Embryology. Louis Bolk Institute, Driebergen.

□ It is not strictly true that they are the largest and smallest cells. In the spinal cord there are larger cells, in the small brains smaller cells. This does not affect the principle. The difference between ovum and sperm remains enormous.

Mobility

The cytoplasm of a normal body-cell is in movement, the nucleus is not. The two gametes (= germ cells) show different features. The egg cell consists primarily of cytoplasm, she is internally mobile. The nucleus is outspread, the chromosomes are unwound (not folded up). The cell is internally active and mobile. The sperm cells have hardly any cytoplasm and are concentrated in their nuclear DNA. They have a crystalline structure. These cells are internally structured and rigid.

In contrast, the ovum is externally not active. After her release, she is passively moved by the fluid-flow in the oviduct (uterine tube), while the sperm cells are active, using their tails to swim against the stream of fluid in the oviduct. They are externally active and mobile.

The ovum is internally mobile and externally passive, this is a polarity. The sperm shows the opposite: internally passive and externally mobile. Egg cell and sperm have a polarity and are opposite to each other, we see a double polarity.

Metabolism

An egg cell is a metabolically active cell; substances are absorbed and released. E.g. nutrients are absorbed, substances that affect the uterus and substances that attract the sperm are released. An egg cell lives only 12 to 24 hours in her own environment and cannot be preserved*. The egg cell can easily be destroyed. She is an active cell and open to the environment.

Sperm cells do not absorb or release substances. There is no interaction with the environment. They live about 3 to 5 days in the womb and can be preserved and frozen at temperatures below 60 °C. They are not easy to destroy. They are closed off from the environment and metabolically passive.

The open and vulnerable state of the egg cell is polar to the closed and robust state of the sperm cells.

Number

For a conception one ovum and millions of sperm are required. The one ovum is worth as much as all those millions of sperm. A man with less than 20-40 million sperm in an ejaculation is barren. Such great numbers are necessary because most sperm do not reach the ovum. Also, for a conception more than one spermatozoon is necessary. See the page Conception.

The ovum is alone and the sperm are with millions. One sperm cell is nothing, one ovum determines everything. One is polar to millions. One comprises everything, it is all there is, whereas the millions of sperm cells are infinitive, have no importance on their own.

Location

The egg cell develops in one of the two ovaries in the warm abdominal cavity, the sperm develop in the testicles just outside the body in a relatively cold environment.

The ovum develops in warm- and sperm in relative cold conditions.

Development

Egg cells are produced well before birth in a huge number of so called primordial egg cells (primordial oocytes). From the beginning on, there is a continuous process of dying, so that at birth 2 million (!) are left. That process of dying goes on after birth. At the onset of puberty there remain about 40,000 ova. Then every four weeks a number of them begin a process of maturation. Of these, only one (sometimes two or three) ovum matures, the rest dies. In total about 400 ova mature (13 per year for 30 years). At menopause, no primordial egg cells are left.

* Since several years an ovum can be frozen by vitrification, a process whereby water is removed and replaced by a concentrated liquid, leaving no freezing crystals, which can damage the chromosomes.

In men, a very different process is going on. The first sperm cells are formed only from puberty on, before that they are not produced. Then the production goes on and on and never stops, hundreds per second, millions each day. Sperm cells are constantly being newly formed.

Egg cells are old cells that became mature. Primordial oocytes are in a process of dying. Sperm cells are newly formed and are young. The maturation process of ova is an expiring process, it stops. The formation of the sperm is a vital process, it never stops.

Maturation

From a primordial oocyte only one mature egg cell develops. During meiosis the rest of the mass of the nucleus is excreted as polar bodies. The cell grows during maturation, the amount of cytoplasm increases. During ripening the ovum moves from the centre of the ovary to the edge (Fig. 5).

From a primordial sperm cell four sperm cells develop. The cytoplasm is eliminated, the cell is getting smaller. When some cytoplasm stays behind, the sperm cell cannot swim well and cannot reach the egg cell. Sperm cells are produced at the edge of the testis and stored inside.

At egg cell maturation the focus is on one cell, that expands in volume. Sperm cells show concentration of material and expansion of the number. egg cells move from the inside to the outside, sperm cells from the outside to the inside.

Conclusion

In appearance and processes. egg cell and sperm are mutually antagonistic, each others opposite. Large versus small, internally - versus externally active, old versus young, concentration versus expansion, etc. During maturation of these gametes two cells are formed which differ maximally and seem to go to extremes in their individuality. The development and maturation show increasing divergence, a process of polarization.

When they are mature, ovum and sperm can come together and resolve the polarity in a conception, so that a new human being can be born, that has all the cell shapes that lie between the two extremes. If not, there is no viability, and then they die.

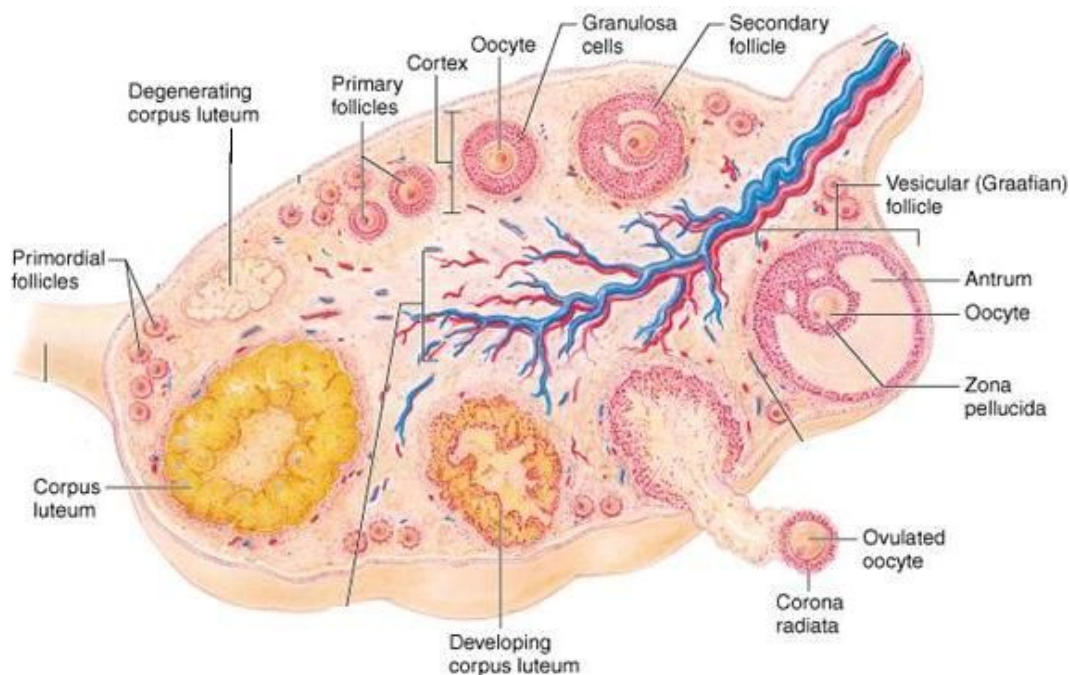


Figure 5. Oogenesis, the development of the egg cell in the ovary (from the Internet)

	egg cell	sperm
size	largest cell	smallest cell
shape	round	straight
inner mobility	mobile cytoplasm	rigid nuclear material
outer mobility	passive	active
metabolism	active	little activity
openness	yes	no
number	one	millions
produced in	the ovary, inside the body	testes, outside the body
temperature	warm	relatively cold
when formed	before birth	from puberty
age	old	young
formed from - until	before birth - menopause	puberty - death
maturation	increasing volume	decreasing volume
life span	short	long
storable	no	yes

Table 2. Differences between an egg cell and sperm

The development of the ovum

Ova are created as primordial oocytes in million copies as early as in the embryonic stage and their number is gradually reduced. They lie separated from each other in follicles and are surrounded by a layer of nutritive, so called follicular cells. In the primordial follicles (= initial vesicles) they lead a passive existence. In Fig. 5 the development of the egg cell can be seen clockwise from the left (primordial follicles)*.

1. The development begins with the thickening of the surrounding layer of nutritive cells, this is called the primary follicle (= first vesicle).
2. This stage leads to the secondary follicle, because in the layer of nutritive cells an antrum (= cave) arises. The ovum grows and gets larger. The follicle produces oestrogen, a hormone that stimulates the wall of the uterus to thicken.

* Konig (1986) gives a similarity between the development of the ovum and the evolution of the earth, as it is described by Rudolf Steiner in Anthroposophy:

1. The egg is surrounded for many years by tissue of the ovary. He compares this to the Warmth Stage of the earth, or the Saturn Stage.
2. The nutritive cells thicken, and the ovum increasingly stands on her own. He compares this to the Air or Sun Stage of the earth.
3. In the layer of nutritive cells the fluid-filled antrum is created. This is compared to the Water or Moon Stage of the earth.
4. The release of the ovum is compared with the (current) solid stage of the earth. The cell is completely on herself and will either develop or die.

3. The antrum grows larger. Around the ovum a layer is formed, called the zona pellucida (= translucent layer). Around it are the nutritive cells in the corona radiata (= radiating wreath). The growth of the ovum continues. The wall of the uterus continues to thicken.
4. Then the ovum is shot away into the abdominal cavity. There is a moment when the ovum floats freely in the abdominal cavity. Then she will be collected by the fimbriae of the oviduct. The interception is an active process, the oviduct moves to the ovum. The remaining cavity in the ovary is called the corpus luteum (= yellow small body) that makes progesterone, which also plays a role in the thickening of the uterine wall, so that the fertilized ovum can implant. When a fertilization does not occur, then the thickened wall comes loose and menstruation occurs.

The development of sperm

From a germ, four equal sperm cells are formed by division. Around the nucleus a hard cap is formed, the acrosome (acros = top, soma = body). Then the cytoplasm is ejected and the cell gets smaller. Mitochondria move to the beginning of the tail, that becomes thicker and longer. The cells are stored for about 60 days, after which they are resorbed. If a small cloud of cytoplasm remains with the nucleus, the sperm is badly damaged and will have trouble moving forward.

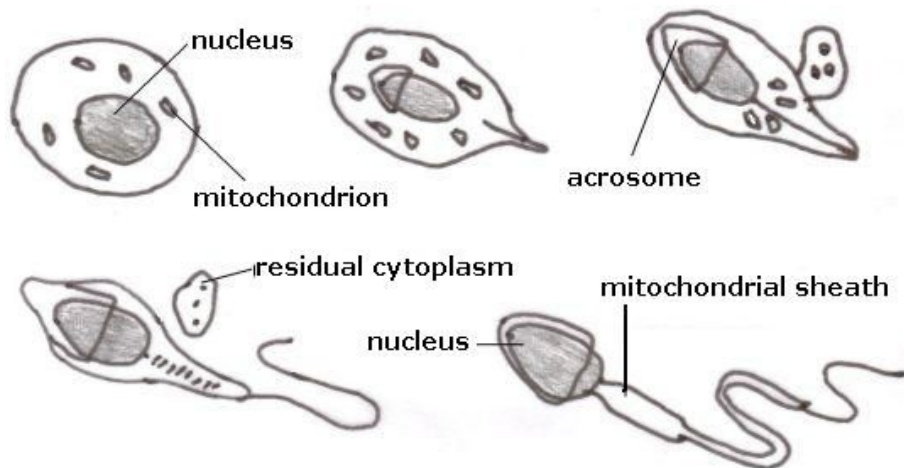


Figure 6. Spermatogenesis, the development of sperm

The conception*

After ovulation and the interception of the egg cell by the fimbriae of the oviduct, the egg cell (or ovum or oocyte) with her surrounding nutritive cells is in the oviduct (or fallopian tube). The egg cell is transported to the uterus by the flow of liquid in the oviduct and by the movement of the cilia in it. Both the egg and the mucus membrane of the fallopian tube produce substances that attract sperm cells. The sperm cells swim against the stream from the vagina through the uterus and oviduct to the egg. Many sperm cells (> 90%) get stuck behind barriers such as cilia or are damaged by antibodies. Only some dozen to a few hundreds of sperm cells reach the egg and surround it with their heads in the direction of the oocyte (Fig. 7).

The pre-conception attraction complex

In *in vitro* (test tube) fertilization it is observed that for a few hours a so called pre-conception attraction complex exists: a state in which the egg is surrounded by several dozens of sperm cells, lying with their heads against the membrane of the egg cell and their tails away from her. It has been observed, too, that this complex starts to rotate. This is caused by the movement of the tails of the sperm cells. After a while they begin to move more or less rhythmically in the same way. Van der Wal calls this a "mating dance".

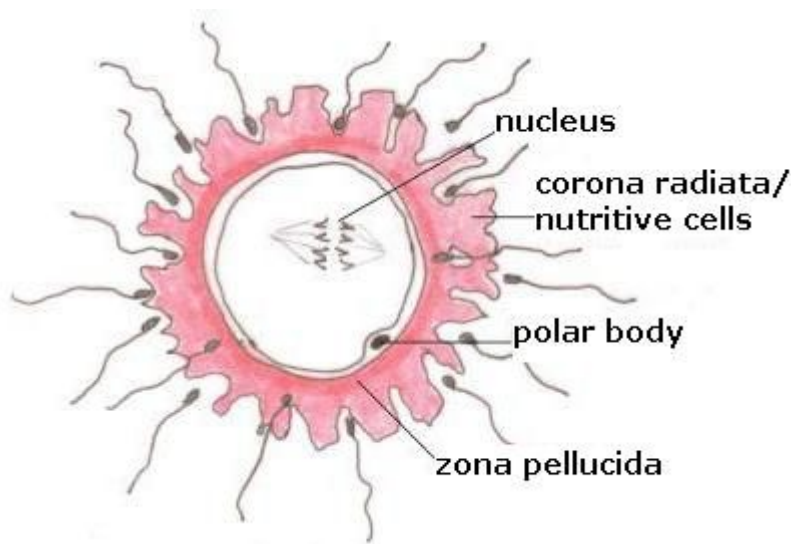


Figure 7. Pre-conception attraction complex

The oocyte with the surrounding zona pellucida and nutritive follicle cells (corona radiata) and around it sperm cells

The conception

During this pre-conception attraction complex the egg secretes substances that alter the sperm. Their cap (the acrosome) dissolves, which enables them to connect themselves to the egg and to fertilize the egg. The sperm cells in turn ensure that the zona pellucida changes, so that it will let one (and only one) sperm cell pass through. So, substances from both sides are required to prepare the fusion of the gametes. Both cells have to be prepared and to change to make them receptive for the other cell. The cells interact and they change each other. Whether the fusion succeeds is uncertain, that depends on the interaction of the two cells.

Then the cell membrane of the egg merges with that of the sperm cell and the contents of the sperm fuses with the contents of the egg. The large egg receives the small sperm. Both cell membranes open up and connect with each other. The cell membrane is continuous, there is not - at any time - an opening or hole in it where the sperm creeps through. The membranes of the egg cell and the sperm cell always form a continuous entity. The question remains, however, how it is determ-

* Based on: Van der Wal, J, 2002. Human conception: how to overcome reproduction? On: www.embryo.nl.

ined which sperm will enter the egg.

After the fusion of the egg with a sperm cell has taken place, the zona pellucida changes again and no sperm cell can fuse with the egg anymore.

The pre-conception attraction complex is a process that takes time. We do not see a race in which one sperm cell arrives first and wins ("survival of the fittest") and it is not true that the sperm enters or penetrates the egg either, since the cell membranes fuse. So, there is no race and no aggression. Both cells are equal, need each other and prepare each other for the fusion and the conception. The conception is a gradual process.

Integration

On the page about the egg cell and the sperm cells it was shown that egg and sperm are polar to each other. Both cells are so far specialized that they are not able to develop further. Only if they meet, the joining of both extremely specialized cells can be the starting point for a new development.

That both cells attract each other is not surprising. What the egg is, the sperm is not and vice versa. When they meet, the one-sidedness of each can be solved by that of the other. What was separated, is being united.

Reversal

During the hours of the pre-conception attraction complex, we see an ovum with her mobile cytoplasm and around it tens or hundreds structured sperm nuclei. The usual picture of a cell in which the nucleus is at the centre and the mobile cytoplasm is around it, is reversed. The nuclei are now at the periphery. At the same time the cytoplasm of the ovum is at rest in the centre around which the movement of the sperm cells' tails induce the rotation. Which is another reversal, since normally the periphery is at rest and the cytoplasm is in motion. And thirdly, normally a cell is in interaction with the environment at the periphery. But now we see there the secluded, non-interactive quality of the sperm cells. The complex is directed inwards. The pre-conception attraction complex is the reversal of the normal conditions and relationships of a cell.

Incarnation

This dance of ovum and sperm-cells and the reversal of the normal relationships during the hours of pre-conception attraction complex, may be necessary to open up the physical for the spiritual. It is possible that an encounter with the soul and spirit of a human being is being prepared. The pre-conception attraction complex may be the moment where the spirit-germ of the new human being is linked with its physical germ. This may be the moment of the incarnation, which is experienced or perceived by some people. They notice not only that there is a pregnancy, but also who will arrive. Sometimes it is a feeling, sometimes this individual makes his being or name known.

Conception and incarnation do not have to become a success. A woman and a man do not make a child, but receive it.

No reproduction

It seems that the conception and embryonic development of humans are inefficient. The probability that a human sperm meets an ovum is small compared to mammals and then there is still the implantation that has to succeed and the embryo that has to develop healthily. There appear to be many more miscarriages in humans (mostly unnoticed) than in mammals. Man is therefore called an inefficient reproducer. When we take into account that an incarnation has to take place, this is not surprising. The conception of humans is then not only a matter of reproduction, but something of a different order, it is about the incarnation of an individual. Every man is a unique individuality. The parents do not repeat themselves in their offspring, but create the conditions for the incarnation of another human being.

The first week: a floating and timeless existence

The first cell divisions

Once the egg and the sperm cell have fused, the nuclei fuse and the chromosomes form pairs. The zona pellucida closes, so that no more sperm cells can connect with the egg. The zygote (= fertilized egg) has come into being. For a few days there is no exchange of nutrients and other substances with the environment.

The unicellular zygote exists for about one day. Then the cell divides itself into two equally big cells. Then they divide again every 16 to 20 hours. First there are four, then eight, then sixteen cells. On the fifth day there are about 32 cells and then about 64, the divisions are no longer synchronized. The stage of 16 to 64 cells is called a morula (= mulberry, the zygote resembles a mulberry or a blackberry).

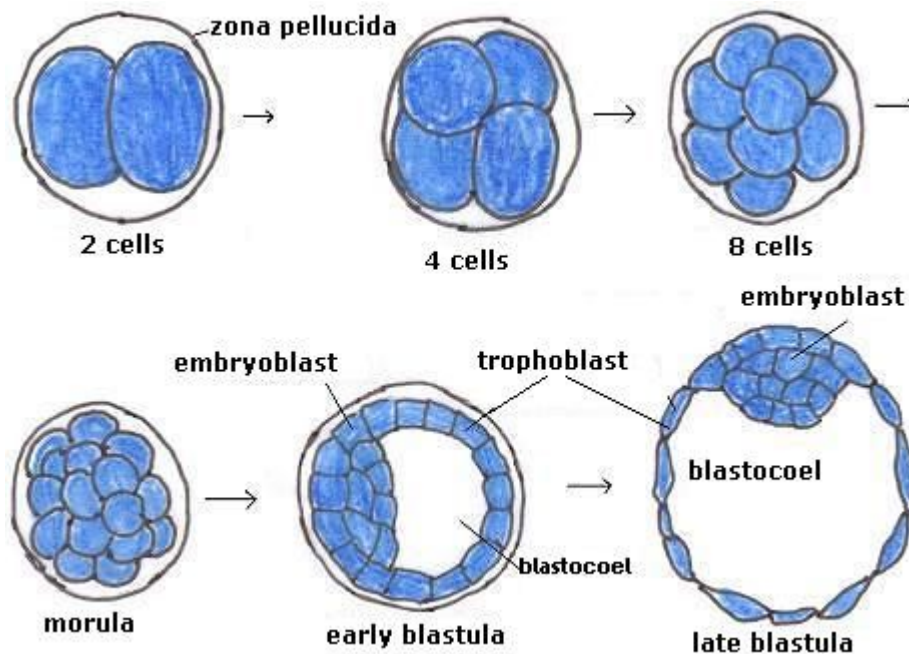


Figure 8. The divisions of day 1 - day 6

1st row: The zygote consists of two cells after 24 hours, these divisions are regular: 4 and 8 cells, around the zygote is the zona pellucida;

Second row: after about 96 hours (5 days) there are 32 cells, the morula has arisen; early blastula with embryoblast and trophoblast on day 6; late blastula on day 7 without zona pellucida.

The last two drawings are cross-sections. The colour has no meaning.

On the sixth day[□], most cells migrate to the periphery (called the trophoblast (= nutritive tissue)) and a clump of cells stays inside (called the embryoblast (= embryonic tissue)). The trophoblast cells move closer to one another which makes the tissue firmer. The divisions continue. On the sixth day, there are approximately 120 cells, of which some 10 form the inner embryonic cell mass and about 110 the outer trophoblast, the ratio is about 1 : 10.

All divisions occur within the shell of the zona pellucida. The embryo does not grow. The cells become smaller after each division and contain relatively less cytoplasm and more nuclear material.

As this happens, the embryo floats passively on the stream of fluid in the oviduct as it is transported to the uterus.

[□] the time is variable, it can be one day earlier or later

Hatching*

On the sixth day when the zygote is in the uterus, the zona pellucida breaks through. This happens because in the trophoblast on the side of the blastocoel enzymes are formed that make the zona pellucida softer. Simultaneously the embryo expands to 2 times its volume, then contracts to 50% and expands again to 3 times its volume. Then the zona pellucida breaks open and the embryo bulges out of its shell. This "first birth" is called hatching and can be compared to the hatching of a chicken (Fig. 9). The embryo is now out of its rigid zona pellucida and can start to grow.

The release of the embryo from its shell is an active process of the embryo itself. The softening of the zona pellucida, together with the expansion, cause a break which enables the embryo to bulge out.

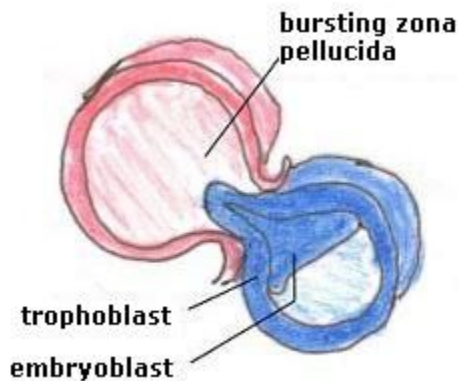


Figure 9. The zona pellucida breaks open on the side of the blastocoel of the blastula and bulges outward

Length of time

Remarkably, the development of the zygote up to the blastula stage is more or less the same in all mammals; it lasts approximately one week. This is not only the case in humans, with their embryonic development of 9 months, but also in mice with a development time till birth of 21 days and the elephant (21 months): the first phase up to the blastula of all of them lasts 6 days. For the rest of the development of mice there are only about 15 days left.

Roe deer have an extended gestation time. The rut takes place in July/August. The zygote develops into a blastula and then rests for approximately 150 days, this is a so-called embryopause. No earlier than in December the development goes on with an implantation. After a further development of 144 days the two fawns are born in May/June. The roe deer is the only ungulate in which this process takes place, but an extended gestation period is also seen with mustelids (including the badger), bears and kangaroos. The embryopause always takes place at the end of the first week in the blastula stage of the embryo, before implantation.

Characteristics

The first day after conception, a human is (or better: we are) a large round cell. That's all we are, there is no more, but no less either. It seems a perfect life: the one-cell human organism is an entity and the one cell includes everything. The zygote is round and floats. We can easily see that the entity is first and the parts come later. A human is not built from cells of organs, a human divided into cells and into organs.

After the first day there are divisions and after 6 days the blastula is formed: a sphere with an interior space. The embryo has no direction: left and right, up and down are not yet concepts to describe it. Directions come later.

Immediately after the conception the zona pellucida closes and there is no interaction with the environment. After 6 days of cell divisions the cells become very small. There is now more nuclear material and less cytoplasm than on the first day, which decreases the inner activity of the cells. The embryo has become more structured compared to the zygote. It has now more the structured quality of the sperm, the inner mobile egg quality from the first day has diminished. Indicative of this is

* See also: www.embryology.ch

that the morula is easier to freeze than the egg (the sperm is also easy to freeze).

This process of dividing, at the same time as the cells are shrinking, cannot continue because the cells would become too small and the embryo would become rigid and die. There must be a reversal. This reversal is brought about by the blastula expanding and contracting and finally bulging out of the zona pellucida. Then it can absorb nutrients and start to grow and the cells can grow too. The embryo will make contact with the uterine wall and its development can continue. Estimates are that this process occurs with only 50 to 70% of the embryos.

In mammals the development of the embryo until the implantation takes 6 days. In the rest of the time of the embryonic development the differences are big: from 15 days to 21 months. The duration of the development of all mammals to the blastula has its own time and is not species-specific. It is not part of the life of the animal, it has its own life. It is as if (species related) time has not yet arrived.

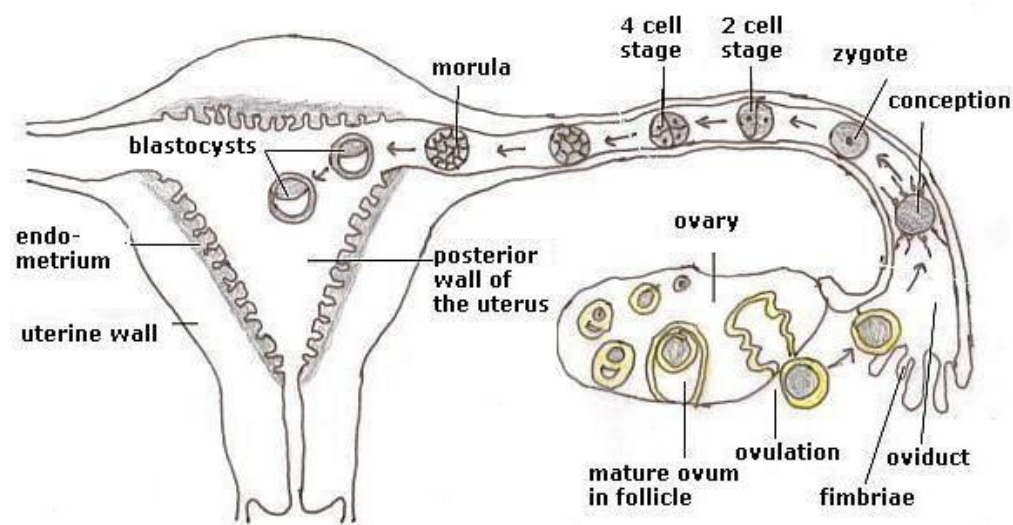


Figure 10. The uterus, fallopian tube and ovary. In the ovary the stages of the maturation of the egg cell are shown. In the fallopian tubes the first cell divisions have been drawn as well as the places where they approximately take place.

Summary of the first week

- The embryo is a sphere, there are no directions.
- The development is set within the seclusion of the zona pellucida.
- Entity or unity comes first, multiplicity comes later.
- The duration of the development in the first week is fixed and equal for all species of mammals.

Characteristics of the mineral are, that it falls apart into the same elements; there is no communication with the environment and there is no time. The first week of the embryo can therefore be called the "mineral human being".

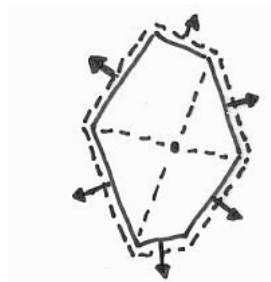


Figure 11. The mineral or a picture for the "mineral human" (from van der Wal (2003): Hartmann)
The mineral is split into equal components, there no communication with the environment and no time.

The second week: growing out in a new shelter

This week the embryo nestles in the wall of the uterus. The tissue on the periphery, the nutritive trophoblast, grows fast. From the inner cell mass, the embryoblast, the embryonic disc will be formed. The embryonic disc becomes largely disconnected from the trophoblast. Differences in growth rate are responsible for this process.

Implantation

The embryo (the blastula) is out of its rigid zona pellucida and has arrived in the uterus. It can now grow and it implants itself on the side of the embryoblast into the wall of the uterus. Enzymes of the embryo digest the maternal uterus tissue. The embryo invades; it eats into the wall of the uterus. The embryo behaves aggressively.

The trophoblast grows fast, so fast that it causes a proliferative tissue with many nuclei and without cell membranes (called syncytiotrophoblast (syn = together, cyto = cell). A layer of 'normal' (cyto)trophoblast cells (= nutritive tissue with cell membranes) remains present between the syncytiotrophoblast and the embryoblast.

In the syncytiotrophoblast gaps arise, called lacunae, through which maternal blood starts to flow. Only one membrane exists between maternal blood and embryonic tissue, and there is just one barrier for the exchange of substances. Embryonic tissue also surrounds capillaries and maternal glands. In this way, the embryo can be supplied with oxygen and nutrients and waste products can be disposed of. However, substances that are bad for the embryo can also get through.

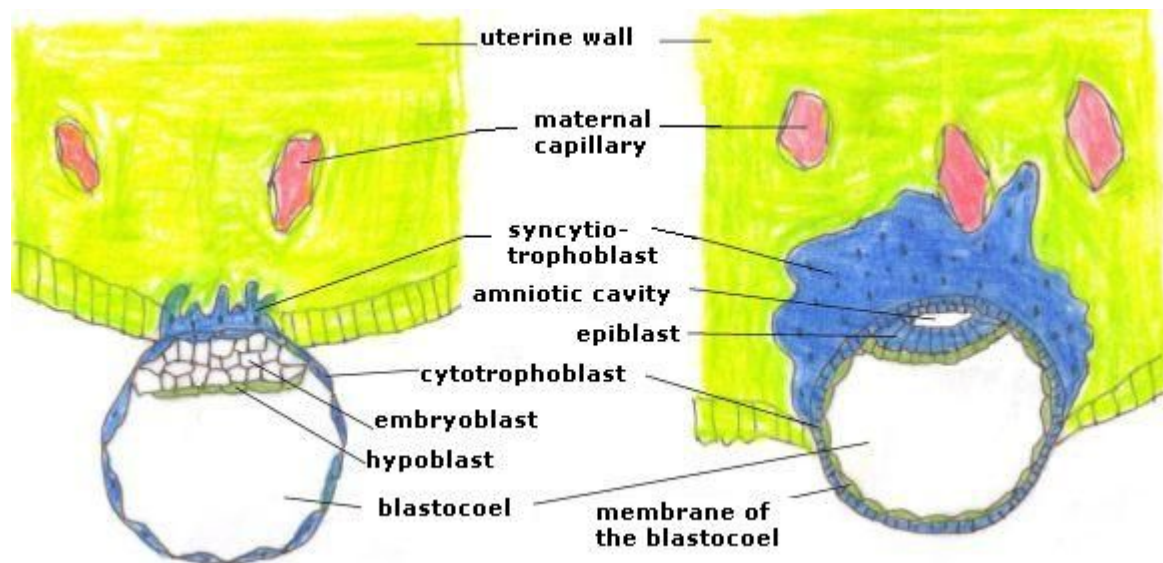


Figure 12. Implantation of the embryo in the uterine wall

Left: on day 7-8. The embryo lies against the uterine wall on the side of the embryoblast. The syncytiotrophoblast expands into the maternal tissue (yellow-green). The hypoblast is ligated from cells of the embryoblast (white).

Right: on day 8-9. The embryo eats further into the uterine wall, the hypoblast (flat cells) has extended all the way down and forms, together with the cytotrophoblast, the membrane of the blastocoele. In the embryoblast the amnion arises. The epiblast (high cells) is located above the hypoblast and the amnion is formed from epiblast and cytotrophoblast cells. The syncytiotrophoblast lies against a maternal blood vessel (capillary).

The embryo eats into the maternal tissue. On the other hand, the mother gives room to the embryo in her own tissue. She allows a strange creature to grow in her own body. This is a wonderful process, because strange creatures (which is what the embryo is to the mother because of the fusion of egg and sperm) normally are fought against. A hormone of the embryo (HCG) ensures that the mother accepts the embryo.

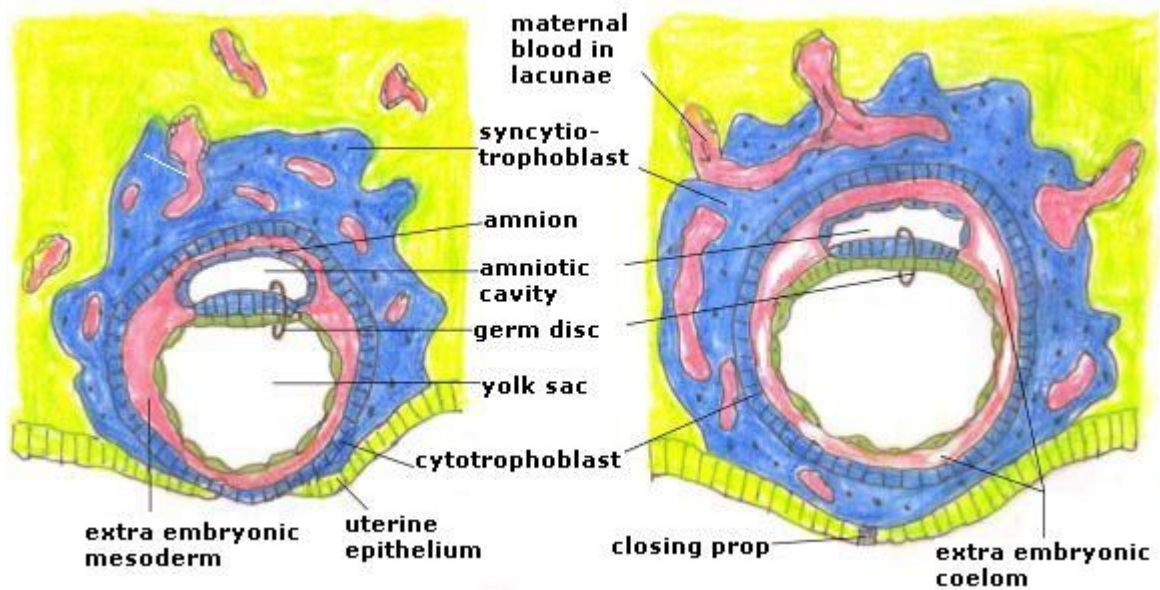


Figure 13. Implantation, continued

Left on day 9. The embryo eats further into the uterine wall. The syncytiotrophoblast proliferates in the maternal tissue and lies around capillaries and makes holes (lacunae) where maternal blood can flow. Maternal blood and tissues remain separated from embryonic tissue. The amniotic cavity develops, by which the two-cells-thick embryonic disc arises. The tissue of the hypoblast covers the blastocoel membrane, now called yolk sac. Between the trophoblast and the membrane of the yolk sac a thick tissue develops: the extra-embryonic mesoderm.

Right on day 12. The embryo is completely enclosed by the tissue of the uterine wall. The syncytiotrophoblast is still rapidly expanding. The extra-embryonic mesoderm is thicker and holes in the extra embryonic coelom are developing.

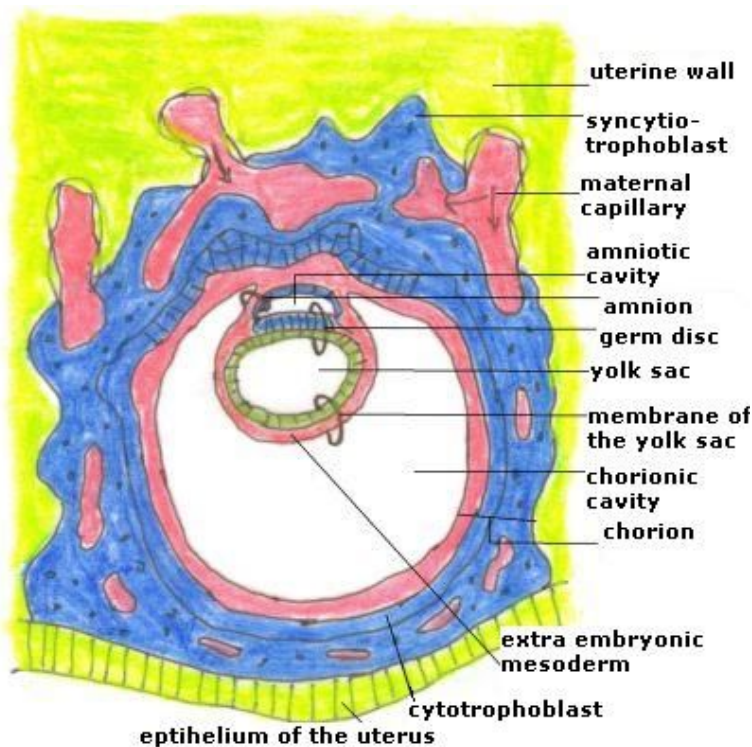


Figure 14. The embryo on day 13 (simplified)

The holes in the extra-embryonic mesoderm have joined together to form the chorionic cavity, its membrane is called chorion. The syncytiotrophoblast is growing all around the embryo, it is thicker on the inside of the uterine tissue than near the epithelium. The embryonic disc is on the backside attached to the chorion. All around the chorion cavity lies the syncytiotrophoblast with the lacunae containing maternal blood. (The primary yolk sac which is now separated from the now called secondary yolk sac has been omitted.)

On day 10 the embryo is completely inside the maternal tissue and a ball or wad is formed to close

the wall of the uterus. Now this wall is completely closed. Around the embryo is the trophoblast, later called chorion (= skin), uterine tissue and the uterine wall.

Development of the embryonic disc

Flat, square cells are ligated from the embryoblast on the side of the blastocoele (Fig. 12 to 15). These cells are called the hypoblast (hypo = under). The hypoblast expands on the inside of the trophoblast, too, and covers it. The blastocoele is now called yolk sac.

In the embryoblast a small cavity develops, called the amniotic cavity, its roof is called the amnion (= sheep skin). The cells adjacent to the hypoblast become cylinder - or elongated cube-shaped; these cells form the epiblast (epi = upper).

Through the formation of the yolk sac and the amniotic cavity a round, flat embryonic - or germ disc is formed, existing of two layers (epi- and hypoblast). At the end of the week the prochordale plate (a spot of different shaped cells) develops in the embryonic disc.

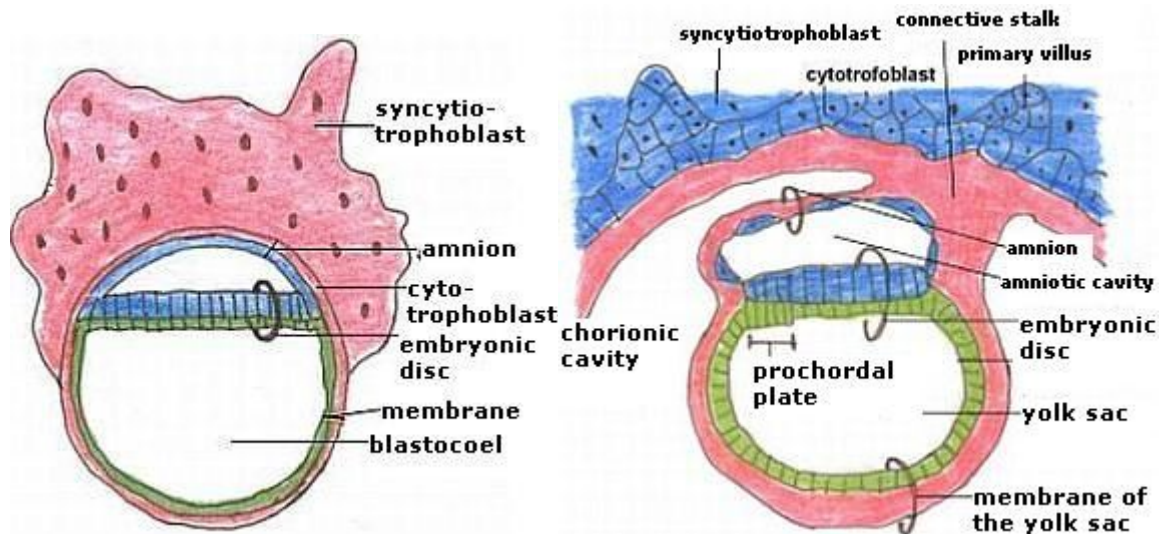


Figure 15. The embryonic disc on day 9 (left) and day 14 (right)

Left: The embryonic disc consists of two cell layers and is round and flat.

Right: at the tail-side the embryo is attached to the chorion and the cyto- and syncytiotrophoblast by the connective stalk. It hangs free in the fluid-filled chorion cavity. The prochordale plate is formed in the embryonic disc at the side where the head will develop. Epiblast cells (up) are high, hypoblast cells (under) are flat.

Origin of the chorion cavity and the connective stalk

From day 9 on, the tissue between trophoblast and embryonic disc, amnion and yolk sac thickens (Fig. 13). This tissue is called extra-embryonic mesoderm (extra = outside). A confusing name, because the tissue lies within the embryo. The name only indicates that the tissue lies outside the embryonic disc. Because the syncytiotrophoblast and the cytotrophoblast grow much faster than the germ disc, in this mesoderm tissue crevices and cavities arise (called the extra-embryonic coelom (= cavity)). From day 12 on they unite and form the chorionic cavity. The trophoblast is now called chorion (= skin or leather).

First, the germ disc with amnion and yolk sac is connected to the chorion (12 days) on the posterior side. This attachment moves to the tail (or better: the place where the tail will develop) and becomes narrower. This attachment is called the connective stalk.

The round, flat germ disc, amniotic cavity and yolk sac are attached to the connective stalk, like two halves of a ball, and they hang freely in a large spherical space (the chorionic cavity) with the chorion as a surrounding wall.

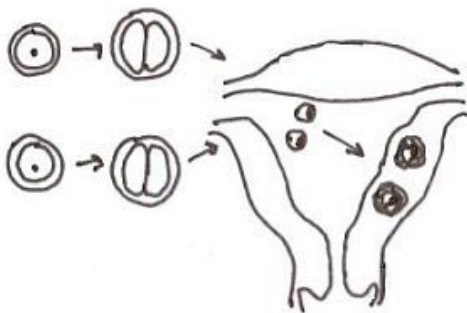
Size

The embryo grows. At the beginning of the second week its size was about 0.3 mm, at the end 3 - to 3.5 mm. In a one week period it grew to 10 times its size. The germ disc is still small: 0.5 mm.

Twins

About one in 90 pregnancies is a twin. Twins may grow from one or two eggs. Dizygotic twins result from two fertilized eggs, do not look the same and can either be of the same - or of different sex. They cover 2/3 of all twins. The two embryos develop as described above and both have their own amnion and chorion (Fig. 16).

Monozygotic twins are born from one fertilized egg, usually because in the first week two embryoblasts develop in the blastula. These embryos have their own amnion and share the chorion and placenta (Fig. 17).



A small number of twins develops in the second week, after the formation of the amnion, by cleavage of the embryonic disc. They are in the same amnion together and also share the same chorion and placenta (Fig. 18).

Figure 16. Dizygotic twins

There are two zygotes, which implant. They both have their own shell (amnion, chorion) and trophoblast.

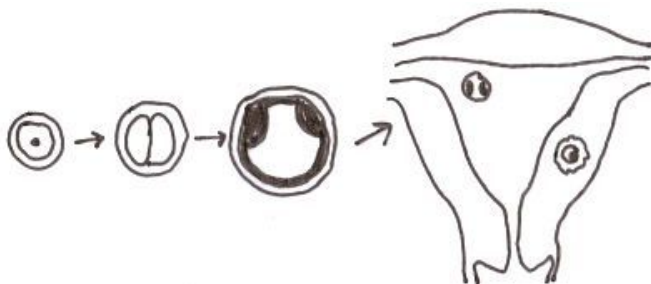


Figure 17. Monozygotic twins

There is one zygote with two embryoblasts that implant. Both embryos have their own amnion, and share the same chorion.

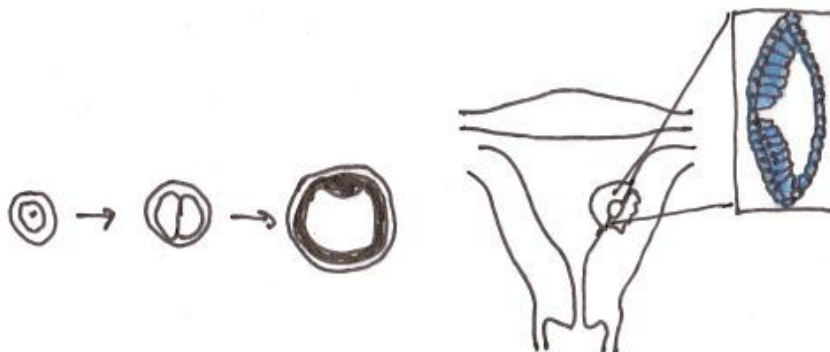


Figure 18. Monozygotic twins from the second week The embryonic disc divides. The embryos are together in the same amnion and chorion.

Characteristics

In the first week the embryo developed in the shell of the zona pellucida. The single-celled zygote was divided into many small and similar cells, creating the morula and blastula. At the end, the trophoblast and the embryoblast arose. Because the embryo breaks out of the zona pellucida at the end of the week, we see a reversal in the second week: the embryo starts to grow. The cells are not getting any smaller, they can grow now. In particular, the trophoblast is growing very fast, so fast

that no cell membranes are made in the syncytiotrophoblast.

The focus of growth lies at the periphery, the trophoblast. The growth of the centre, of the embryoblast, stays behind, as is shown by the tearing of the extra-embryonic mesoderm and the development of the chorionic cavity. In the centre we see a differentiation in amnion and yolk sac, in epiblast and hypoblast.

There is now interaction with the environment, the isolation through the zona pellucida of the first week is gone. The embryo gives off hormones and enzymes, takes up nutrients, etc. Therefore it can grow and gain a place in the uterine wall. The shelter of the zona pellucida is replaced by the shelter of the nourishing uterine wall.

The centre, the embryonic disc, is a flat round disc of two cell layers, which has an upper and a bottom side, but no left and right. The disc has no content, as the two layers are both on the outside. An early orientation of directions occurs only at the end of the week with the formation of the connective stalk.

Monozygotic twins can develop in the first week, and at the beginning of the second week. Thereafter the embryonic disc is no longer divisible. The embryo has then become individual (= not-divisible).

The development of the first week is similar in shape and time in all mammals. Now that's no longer the case, both form and duration are species-dependent.

The characteristics of this week are a reversal of the characteristics of the first week and are that of the plant:

- There is a huge growth on the outside.
- As the embryonic disc is flat and round, there is no left and right in the centre and there is no content.

Therefore, it can be said that the embryo of the second week has the characteristics of the plant and can be called the "plant-man". Rudolf Steiner said that in the second week man is not in the embryo yet, but floats around it. The spirit lives in the periphery, in the tissue of the trophoblast.

	first week	second week
development	divisions	growth and proliferation
communication with the environment	no	intensive
duration	species independent	species dependent
tissues	no differentiation	differentiation
shell	zona pellucida	uterine wall

Table 3. Differences of the embryological processes of the first and the second week



Figure 19. The plant or a picture for the "plant-man" (from van der Wal (2003): Hartmann) With its growth the plant is committed to the periphery; it grows from its seasonal sprout in all directions into space.

The third week: the embryo gets direction

In the second week the embryo grew explosively in the periphery. The tissue between the outer trophoblast and the inner embryoblast tore away and resulted in the chorion cavity. If the process of strong growth in the periphery and little growth inside would continue, a growing and ultimately unbridgeable distance would arise between the nutritive trophoblast and the embryonic disc. To stop that process a reversal takes place in the third week. The periphery will develop further, but the focus of the development will now be on the embryonic disc.

Several developments occur more or less simultaneously. For easy reference, they will be discussed separately in the order in which they occur.

Gastrulation: the formation of mesoderm tissue

The first process that takes place in the third week is called gastrulation (gaster = stomach). For simple animals gastrulation means the formation of a stomach and a digestive tract (see the page: *plant and animal*). At the same time the body cavity is formed in which the mesoderm develops. For humans, gastrulation is the process whereby only the mesoderm is formed. The digestive tract develops later in a process in which the amnion is involved.

At the beginning of the third week the tissue of the epiblast thickens and a small indentation is formed in the embryonic disc near the connective stalk. This occurs at the caudal end of the embryonic disc (cauda = tail, caudal = at the tail end; Fig. 20 and 21A). This formation is called the primitive streak. The primitive streak grows in cranial direction (= side of the head), i.e. away from the connective stalk. From the primitive streak mesoderm cells are ligated, which migrate to the space between the epiblast and the hypoblast. In this process the cells of the hypoblast are replaced by these newly formed cells, too.

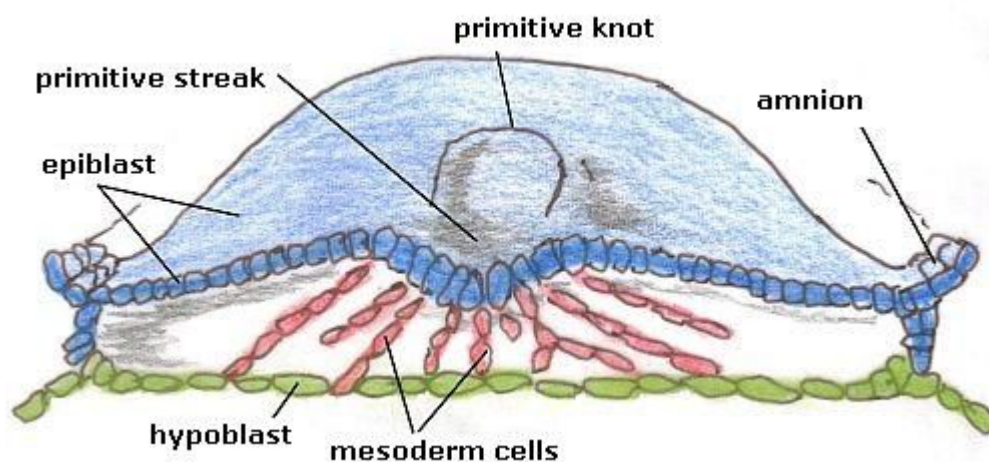


Figure 20. Gastrulation in humans (similar to Fig. 21-A1)

Cross-section through the embryonic disc in which the ligation of mesoderm cells from the primitive streak in the epiblast (cubic cells) is visible. The mesoderm cells migrate to the space between the epiblast and the hypoblast and replace the flat cells of the hypoblast, too.

The primitive streak grows to the middle of the embryo (Fig. 21B). There it makes the primitive knot. This is the place where most mesoderm cells are ligated. These cells migrate to any place between the epi- and hypoblast, except for the prochordale plate and the places where the mouth and anus will arise, because epi- and hypoblast stick together at these places. The epiblast is now called ectoderm and the hypoblast entoderm.

Then a tube is formed that grows from the primitive knot between the epi- and hypoblast to the prochordale plate. This tube is called the notochord (= chorda dorsalis; Fig. 21C). This flexible rod

gives the embryonic disc solidity and creates a symmetry-axis in the embryo. The notochord also forms the directions *left and right*; the mesoderm gives the embryonic disc content and thickness. The notochord* is the formation around which the vertebrae will grow. In an adult small remnants are visible in the intervertebral discs.

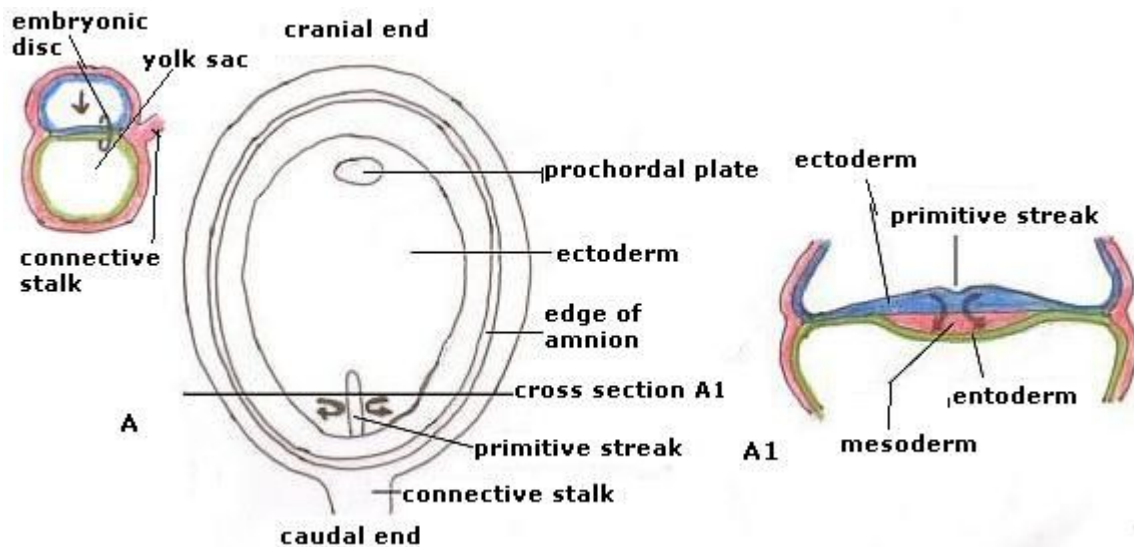
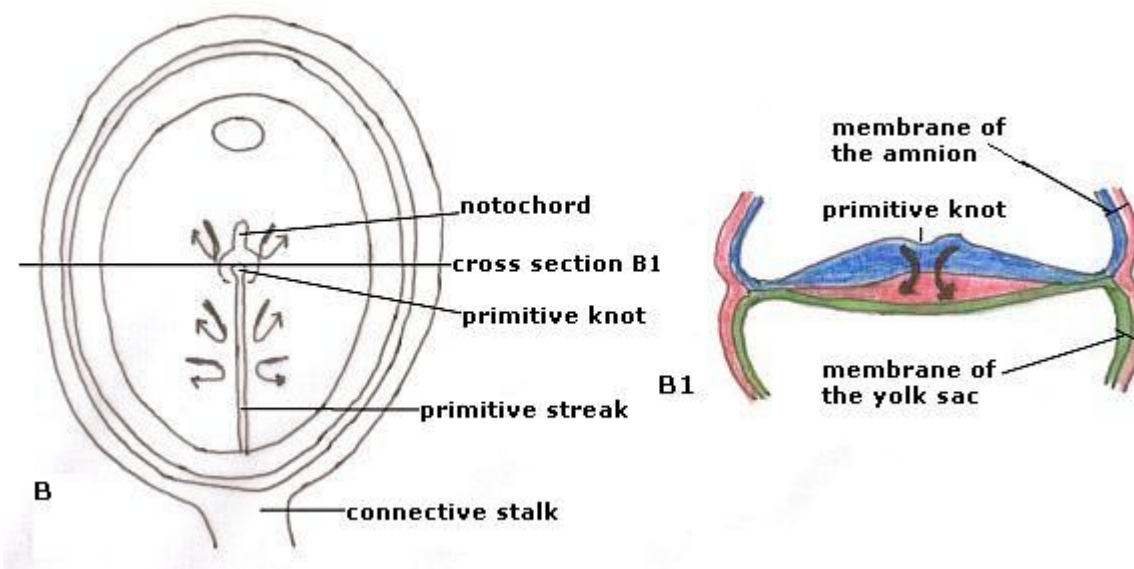


Figure 21. Gastrulation or the formation of the mesoderm (simplified)

A, B and C Dorsal view

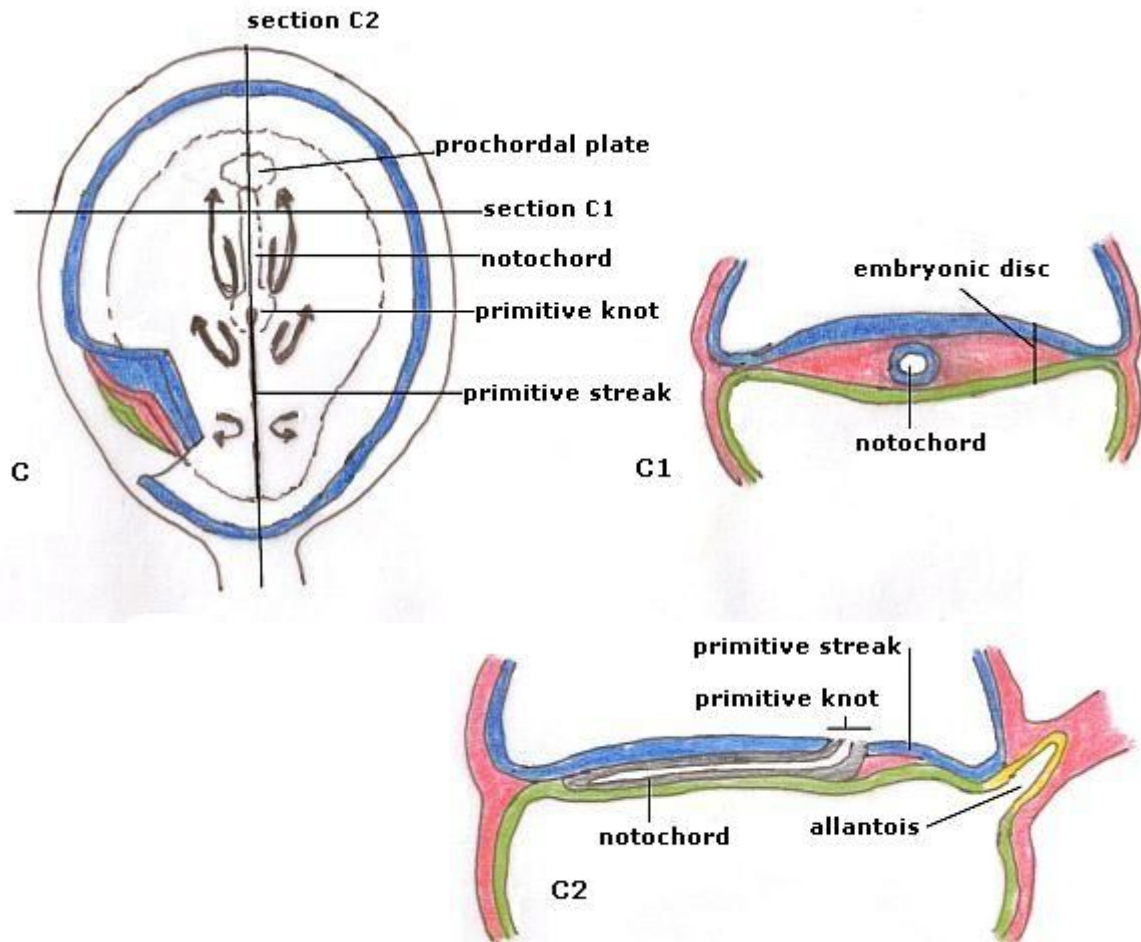
A1, B1 and C1 are the corresponding cross-sections C2 is a longitudinal section of C

A: at the caudal end the primitive streak grows toward the centre of the embryonic disc. From the ectoderm mesoderm cells are ligated to the space between the epi- and the hypoblast.



B: In the middle of the embryonic disc at the end of the primitive streak arises the primitive knot. This is the place where most mesoderm cells arise, that migrate to all parts between the ecto- and the entoderm. From the primitive knot the notochord is created, a tube that runs between ecto- and entoderm.

* The formation of the notochord is here only given in outlines. The actual process is more complicated. See: www.embryology.ch



C: The notochord runs until the prochordale plate. Between ecto- and entoderm is everywhere mesoderm.

C2: a longitudinal section showing how the notochord runs. At the same time as the notochord the allantois is formed. This is a protrusion from the yolk sac into the connective stalk.

At the same time, the embryo grows rapidly in length and not so much in width, and faster at the cranial side than at the caudal side. Thereby the form changes from round to oval. Because the embryo grows faster at the cranial end, the importance of the primitive streak diminishes and it disappears eventually.

The neural tube and the somites

The genesis of the neural tube is related to the growth and development of the notochord. From the 19th day, the ectoderm above the notochord gets thicker (Fig. 22). This formation, about half of the ectoderm, is called the neural plate. The central nervous system will develop from this tissue. The rest of the ectoderm does not thicken and will become the skin.

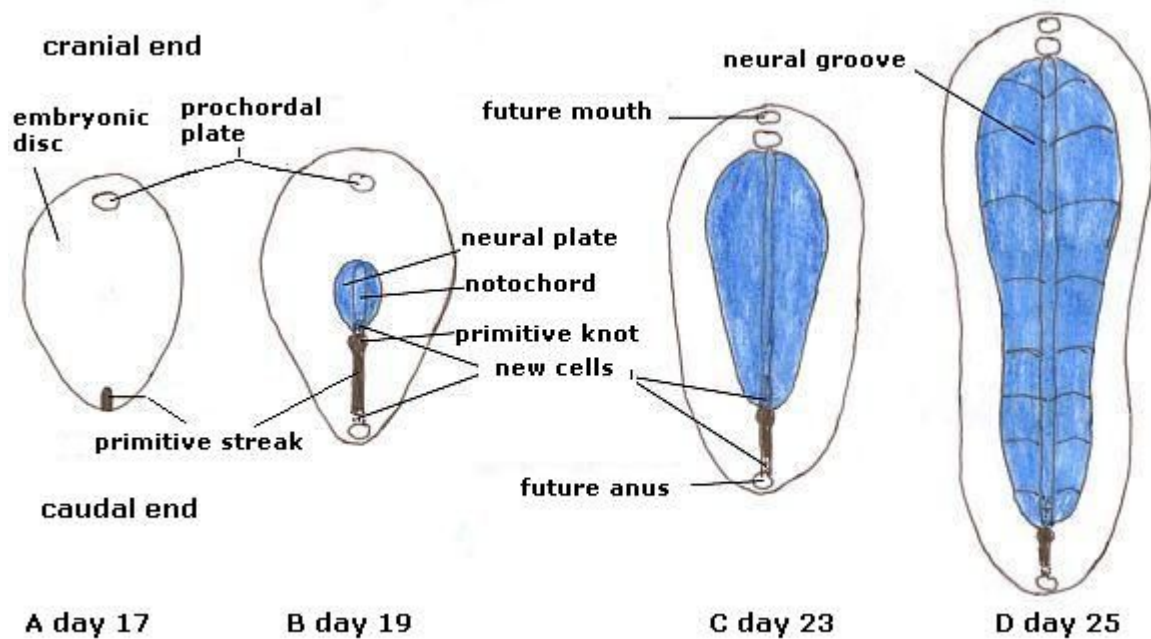


Figure 22. Dorsal view of the embryonic disc. Development of the notochord and neural plate (dating and interpretation prochordale plate: www.embryology.ch)

Only ectoderm is shown, the uncoloured tissue would be blue, too. For clarity, only the neural plate is coloured. The uncoloured ectoderm becomes the skin.

A. On day 17 caudally the primitive streak appears, that grows to the centre of the embryo and ends in the primitive knot.

B. Here one can see that the notochord grows from primitive knot to the prochordale plate. Above the notochord the ectoderm tissue thickens and constitutes the neural plate. The primitive streak and notochord grow from the caudal to the cranial side.

In C. the embryonic disc becomes elongated as growth occurs mainly at the cranial side. The notochord has grown until the prochordale plate.

D. The neural plate folds itself from the middle into the neural groove. The primitive streak barely grows, the notochord does.

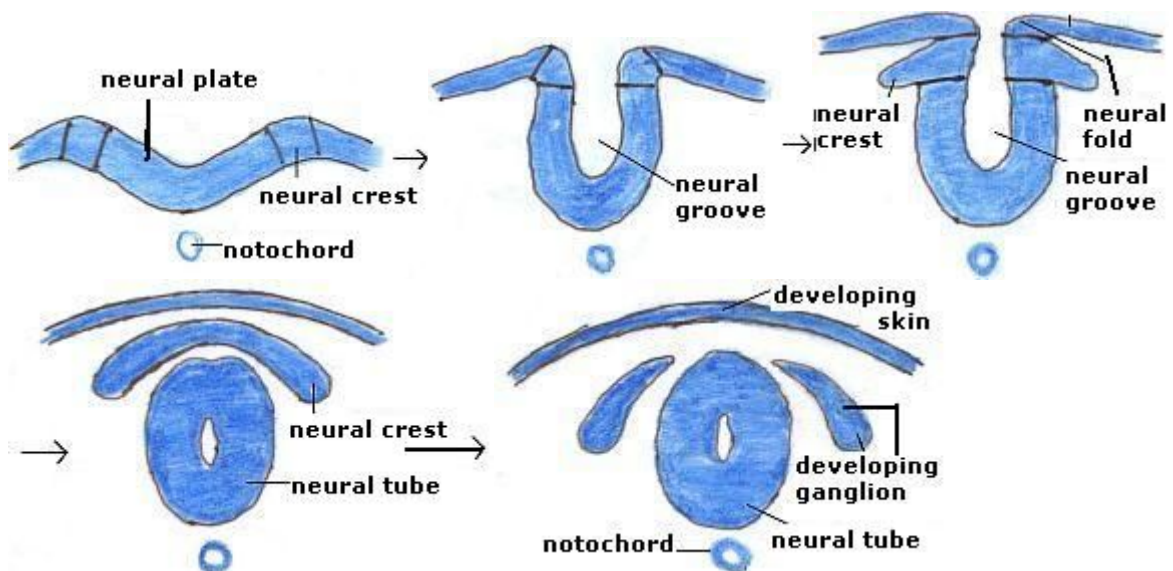


Figure 23. The development of the neural tube (cross-sections)

The thickened ectoderm bends into the neural groove. At the ends is the neural crest. The neural groove deepens and the neural crest expands (third image). On the second row the neural tube is visible. From the neural crest ganglia arise. The neural tube is located between the skin and the notochord and will develop into the spinal cord.

The embryonic disc is growing fast: in five days it doubles its length. On the cranial side it grows much faster than on the caudal side. This makes the neural plate at the head longer and wider than at the side of the tail. The thick neural plate (Fig. 23 and 24) bends in, first in the middle and from there to the cranial and caudal ends. The indentation becomes deeper and the neural groove is formed (Fig. 23 and 24). The connection with the ectoderm is broken and the neural groove and the ectoderm close. The neural tube is created. From the middle of the embryonic disc, this process goes to both ends. The neural tube closes at the cranial end on the 29th day, one day earlier than at the caudal end (30th day).

In the neural tube there is amniotic fluid. From the neural crest ganglia will arise, that lie next to the spinal cord and spread out over the body. Left and right of the neural tube paired clusters of mesoderm cells develop, called somites (soma = body; Fig. 24), about 40 pairs in total. The vertebrae and muscles will eventually develop from these.

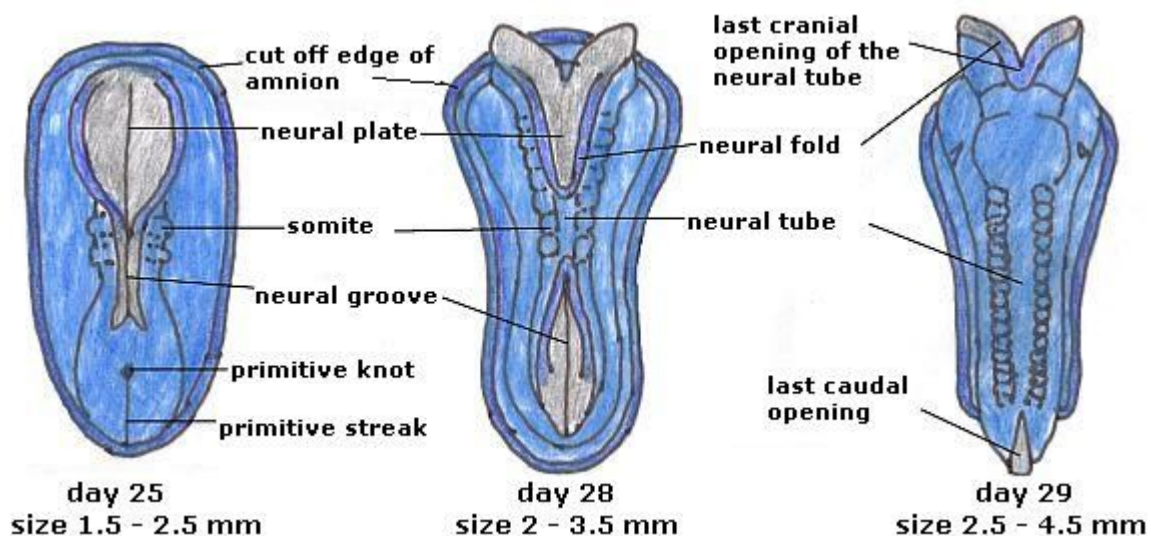


Figure 24. The development of the neural tube; dorsal view (www.embryology.ch). All tissue is ectoderm, the neural plate is coloured gray.

From left to right days 25, 28 and 29.

The closure of the neural tube begins in the middle. Next to the neural tube the somites develop, they are visible as bulges under the ectoderm.

The embryonic disc grows from about 2 to 3.5 mm in five days.

The allantois

At the beginning of the third week the yolk sac grows out finger-like into the connective stalk (Fig. 21 C2). This small organ is called the allantois (allantos = sausage). It plays a role in the development of blood and the circulatory system. Later it participates in the formation of the bladder. In humans it remains small, in embryonic birds the allantois is the organ for breathing.

The blood and its circulation

In the second week, the embryonic disc is so small that nutrition and oxygen from the mother can reach the cells by diffusion in the intercellular liquid. Disposal of waste products takes place in the same way. The growth of the embryonic disc in the third week causes this to be no longer sufficient and a new transport-system is needed. This is created from the middle of the third week on.

At first, the blood vessels and the blood develop in the mesoderm on the outside of the yolk sac and the allantois. There, clusters of cells are formed, called blood islands (Fig. 25). In the blood islands cavities arise. The blood islands grow and several blood islands connect with each other. Then the cavities merge, so that capillaries are formed. The capillaries become longer and find their way to the embryonic disc. Some cells in the wall are transformed into blood cells that will flow in the liquid in the capillaries.

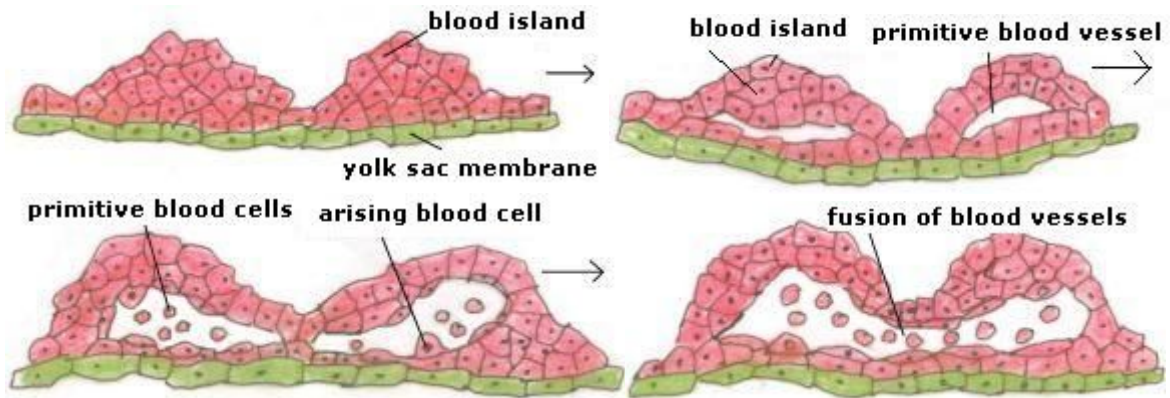


Figure 25. The development of blood vessels
 First clusters of cells arise, blood islands, in which cavities occur. These cavities grow together and capillaries arise. From the same primitive tissue cells blood cells emerge simultaneously, which will flow in the stream of liquid.

Blood is first formed outside the embryonic disc. In the embryo itself it is not formed until the fifth week.

The blood starts to flow because in the embryonic disc some substances are required and others are expelled. The blood flows in capillaries in the embryo on the ventral side towards the head, where its flow is stopped by firmer tissue. The blood must turn around to be able to flow back on the dorsal side of the embryonic disc to the connective stalk and the trophoblast. In this movement, congestion occurs and the stream of blood is stopped for a short while. This is why the blood starts to pulsate. In this place (i.e. on the head side of the neural tube; above the tissues that will become the head) the heart is created (Fig. 26). Around the 20th day it starts to beat.

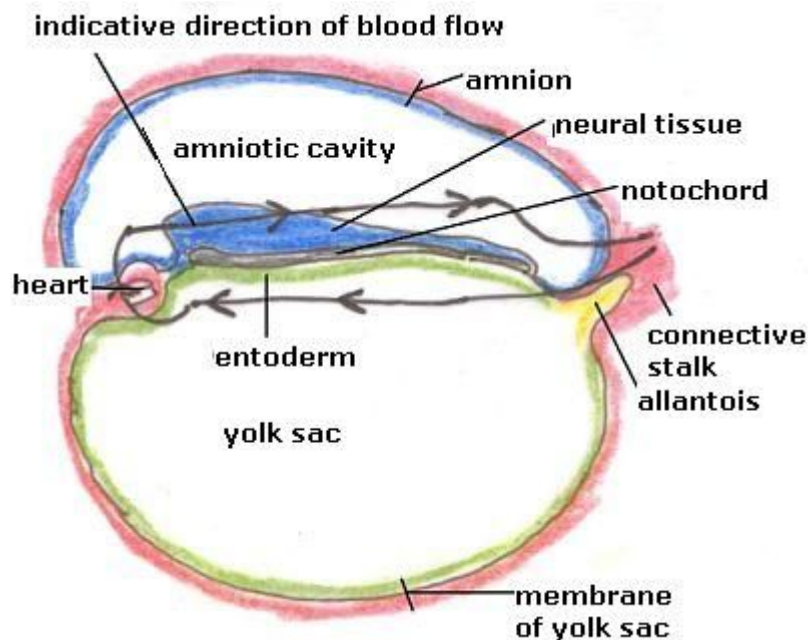


Figure 26. Position of the heart and the circulation at the end of the third week
 The heart lies cranially of the neural tissue and the mouth-membrane (the thin spot behind the heart). The blood flows ventrally (on the side of the stomach) to the head and dorsally (the back side) back to the connective stalk (the arrows are drawn outside the embryonic disc, however, the blood flows in it).

In the beginning we see a flow of liquid, and because the stream meets with firmer tissue, causing congestion and stagnation, the beating heart comes into being. This phenomenon is also seen when a stream collides with a hard material, like waves breaking on the coast, water meeting stones in streams and flow-forms.

The heart arises from flow and stagnation, it is not the cause of the flow of blood. The heart is the only place where the flowing blood comes to a standstill for a short time.

The circulatory system is the first organ in operation.

The chorion and the trophoblast

The rampant growth of the trophoblast decreases towards the end of the third week. The syncytiotrophoblast develops cell membranes and will now be called cytotrophoblast. It constitutes the binding layer between the chorion and the uterine tissue. Blood vessels develop in the chorion which run from the connective stalk to the villi (= flakes), where the exchange of substances with the blood of the mother takes place from the end of this week.

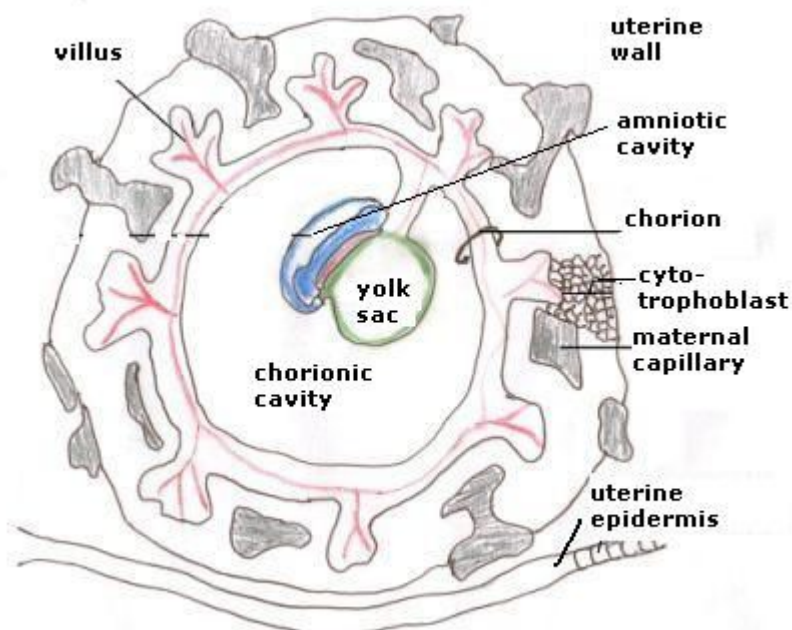


Figure 27. The development of the chorion and the placenta

The embryonic disc with amnion and yolk sac is attached to the connective stalk in the chorionic cavity. In the chorion the blood vessels are indicated that run from the connective stalk to the villi. The syncytiotrophoblast has become cell membranes and is now called cytotrophoblast.

Characteristics

The focus of the development of the embryo in the third week is on the embryonic disc. There is still much growth in the periphery, but it is no longer a proliferating growth and the tissue gets cell membranes. There is now a relative calmness in the periphery. If the growth-movement of the second week would continue, man would stay in the periphery (or his enclosing organs) and would not develop a body.

From the periphery (yolk sac, connective stalk) blood circulation arises, finding its centre in the heart. The heart arises from the flow of blood. Pulsation of the heart arises from standstill and flow.

Simultaneously, thickness is created in the embryonic disc by the ligation of mesoderm cells from the primitive streak and -knot. This gives the embryonic disc content. Left and right are created by the formation of the notochord, later reinforced by the formation of the neural tube. The embryonic disc has become a spatial, three-dimensional structure.

An important point in the embryonic development of man is around the 17th day, when circulation and heart are created. If not, the development cannot go any further and stops.

The fourth week: the form emerges

In the fourth week the embryo (the embryonic disc) will grow from about 2 to about 6 mm. The processes of the third week (neural tube formation, development of blood circulation) continue in the fourth week. At the same time, the amnion increases enormously in size, while the yolk sac does not. This is the cause of a great change in the form.

The growth of the amnion

In the third week, the embryonic disc got thickness and a symmetry-axis. The tissues of the embryonic disc extend into the tissues of the peripheral organs: ectoderm into the amnion membrane, entoderm into the wall of the yolk sac and mesoderm into the extra-embryonic mesoderm and the connective stalk. The embryo is still an open disc on all sides, with ectoderm on the backside and entoderm on the breastside.

In order to let an independent body come into being, a skin has be formed around the entire embryo. This happens by a dramatic growth of the amnion, that is pushed to the outside through the pressure of the amniotic fluid. The yolk sac is not growing and its liquid does not give pressure, which results in a yolk sac that hangs loose. By these growth-movements, the amnion enfolds around the embryonic disc. This happens all around: at the head, the tail and on both lateral sides. It happens faster at the head side than at the tail side.

In figures 28 to 31 this enfolding process is shown. It is difficult to imagine this three-dimensional process. It is advisable to compare the drawn sections, copy them and draw other cross-sections (eg. through the heart) in order to understand the process better.

What happens?

- With the growth of the amnion the relatively large heart is moved from its cranial position above the head to its destination in the chest (Fig. 28 to 30).
- A little later the connective stalk is pushed towards the belly, to a place somewhat caudal from the heart. The umbilical cord will eventually develop around it.
- The neural tube thickens quickly on the cranial end, causing the cranial end to fold inside.
- The amnion pushes the yolk sac to the inside on the cranial and caudal as well as the lateral sides. The solidity that the notochord gives to the embryonic disc causes the embryonic disc to stay more or less straight. Ectoderm and entoderm are joined together at the mouth membrane and at the cloacal membrane by hinging points. This leads to the formation of the digestive tract (Fig. 29, 30).
- The formation of the digestive tract goes from the tips to the centre.
- The umbilical cord is created in the centre. It attaches the embryo to the chorion and it transports nutrients and waste products.
- In the umbilical cord the connective stalk, the yolk sac and allantois are found (Fig. 31).
- In the enclosing of the embryonic disc by the amnion, a part of the chorion is included in the embryo as the body cavity (the intra-embryonic coelom; Fig. 29 and 30).
- The embryo becomes more or less cylindrical, and later it makes a wrapping movement in longitudinal direction (Fig. 31).
- Once it is formed, the digestive tract grows rapidly (Fig. 31).

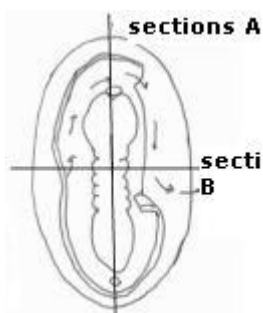
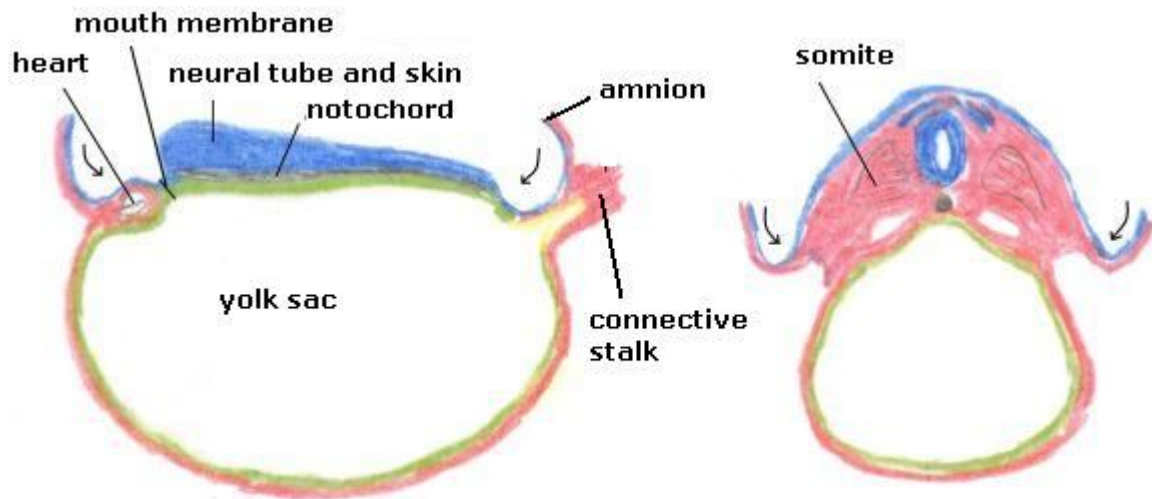


Figure 28. Dorsal view (above) and longitudinal- (A) and cross-section (B) through an embryo of 22 days
 The amnion grows and bulges cranially and caudally in length and laterally at the sides around the embryo. In this movement the heart will be pushed to its place in the chest. The embryo is still more or less flat.

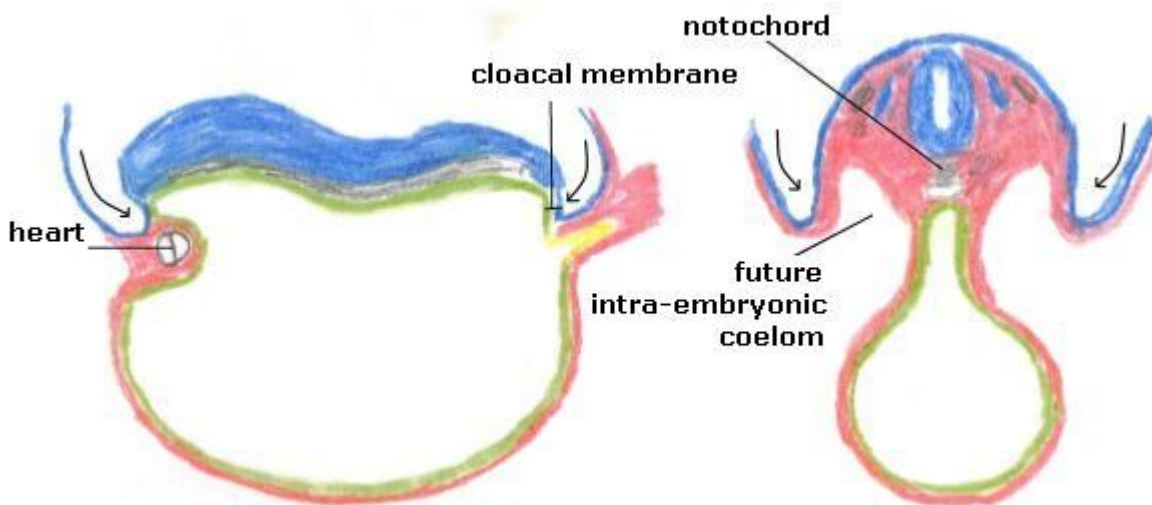


Figure 29. Side view (above) and longitudinal- and cross-section through an embryo of 24 days
 The enclosure of the embryo by the amnion is further than in Fig. 28. The heart no longer lies cranial of the mouth membrane, but more inwardly. The embryo is slightly curved. The mouth and cloacal membrane are places where no mesoderm is formed between ecto- and entoderm.

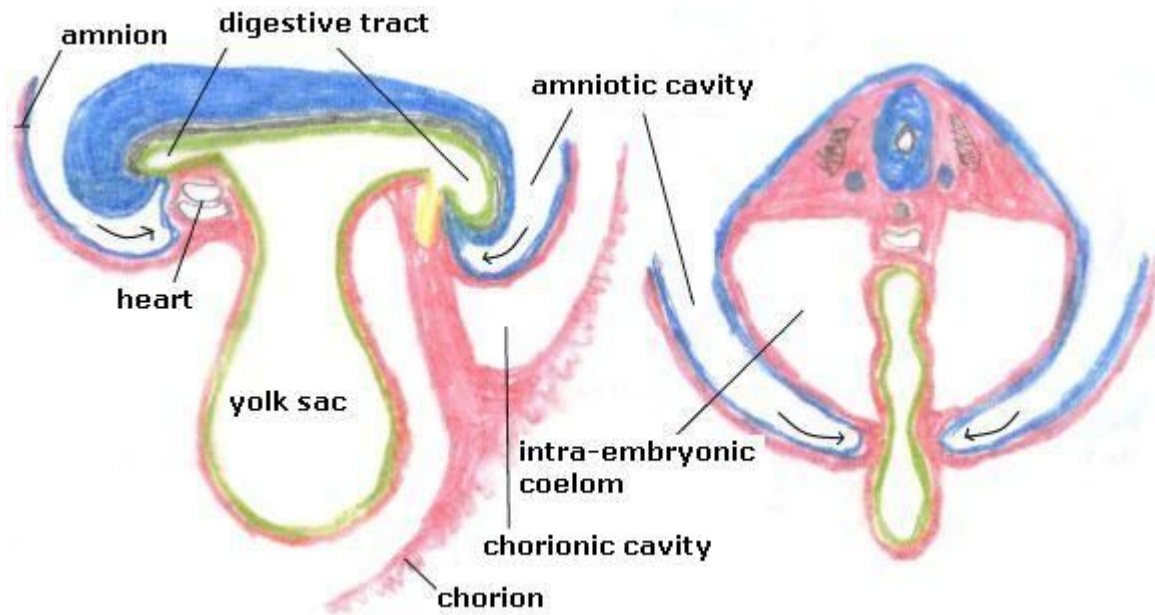


Figure 30. Side view (above) and longitudinal- and cross-section of an embryo of 26 days
 The heart is pushed further inward and is more or less in its final position. Because the amnion wraps around the embryo, the entoderm is folded to the centre and creates a tube, the digestive tract. See the following figure, too. The cross-section shows that a part of the chorionic cavity now lies in the body as the intra-embryonic coelom.

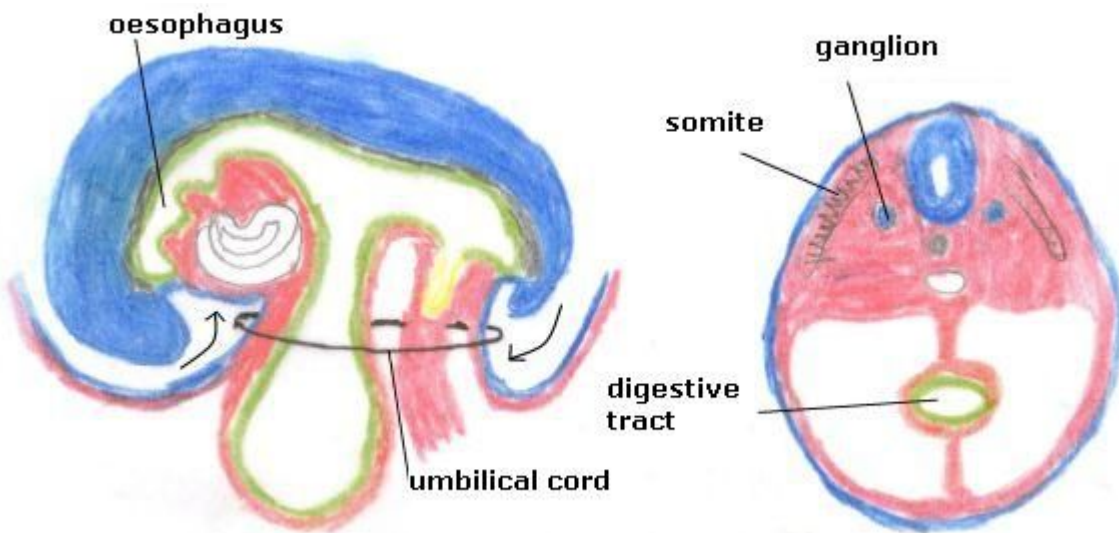


Figure 31. Side view (above) and longitudinal- and cross-section of an embryo of 28 days
 The embryo is almost entirely enveloped in the amnion. The digestive tract is created. The umbilical cord is visible. In it are the connective stalk, the yolk sac and the allantois. The embryo lies in the amniotic cavity, which is in the chorionic cavity.

Fig. 32 shows two side views of the embryo in the fourth week. In the drawing from the middle of the fourth week, the 24th day (Fig. 32 left, corresponds with Fig. 29), the amnion surrounds the embryonic disc and the cylindrical embryo is created. Visible is the large hump of the heart that has been pushed from its cranial position above the head to a location in the chest. The neural tube is still open on both sides. The connective stalk and the yolk sac are visible.

At the end of the fourth week, the 28th day (Fig. 32 right, corresponds with Fig. 31), the complete enclosure of the amnion and the umbilical cord (containing blood vessels, connective stalk, yolk sac and allantois) are visible. The heart has grown and descended a bit more and now lies on its final place adjacent to the umbilical cord. The embryo has a short tail and has become rounder. The head and tail are bent to the inside. The head is large; the headside develops faster than the tailside. At the head folds have appeared, caused by the fast thickening of the tissue of the neural tube that thereby bends the head downward. The first arch is the mandibular arch, from which the upper jaw grows. The last two folds are called branchial (gill) arches, similar to the folds in fish. The beginning of an eye and an ear are visible. The limbs grow, the first beginnings of an arm and a leg can be seen (see the next page for the development of the limbs).

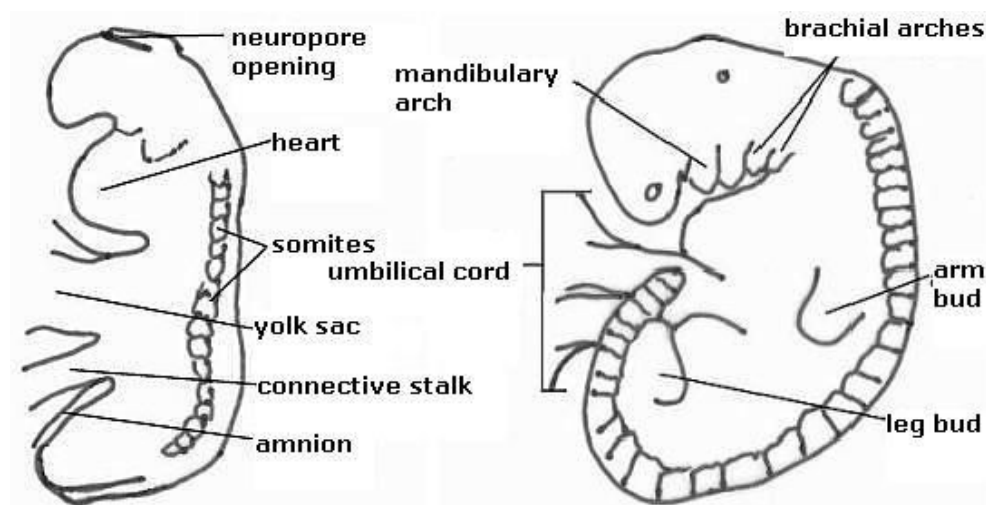


Figure 32. Left: an embryo on day 24, right on 28 days, respectively. 2 and 5 mm long.

Neural tube and digestive tract

The neural tube arises from the centre, the digestive tract from the extremities. In the neural tube there is clear amniotic fluid, which exerts pressure on the wall. In the digestive tract is turbid yolk liquid, which does not. The neural tube is mainly a straight tube, the digestive tract is a tube that winds in and out (the intestines). The neural tube consists of ectoderm, the digestive tract of entoderm. Ectoderm comes from the back, which may be called the antipathy-side of the body (to turn your back on someone). Entoderm comes from the front side, the sympathy-side of our body. With ectoderm we demarcate ourselves and create distance (observing), with entoderm we create connections (digestion of food).

	neural tube	digestive tract
arises from	the middle	the extremities
fluid	clear amniotic fluid, exerts pressure	turbid yolk fluid, no pressure
tissue	ectoderm	entoderm
form	straight	winding
where	backside = antipathy-side	frontside = sympathy-side

Table 4. Differences between the neural tube and the digestive tract

Characteristics

The processes of the third week gave the embryo volume, but did not give the embryonic disc a boundary. At the beginning of the fourth week, the embryonic disc extends into the enclosing tissues of amnion, chorion and yolk sac. The enclosing movement of the amnion separates the embryo from the enclosing tissues and emancipates the embryonic disc. It still takes a long time before the embryo is independent, but the beginning is there, now that the body gets its first form and is connected to the nourishing tissues by the umbilical cord. Steiner called this stage "Paradise Man", by which he meant to say that this is the first separation of man from his environment.

Now the body is apart and three-dimensional. The body bends and is directed towards a centre (Fig. 32). Hartmann uses the name "Animal Man".

The enveloping movement of the amnion has as a result, that the back-side is now on the outside and what was on the ventral side now lies within. It is an enveloping gesture.

The umbilical cord is on the ventral side of the embryo. It started as the connective stalk at the backside, then it moved to the tail and now it shifts to the abdomen. The nourishment came from behind in the stage of the "Plant Man"; from the front in the stage of the "Animal Man".



*Figure 33. Animal Man (from Van der Wal, by Hartmann)
Indicated is that an animal is an organism with content or volume. It is focused inwardly on a centre.*

The three tissues of the embryonic disc and what arises from them

The embryonic disc consists of three germ layers:

- Ectoderm
- Entoderm
- Mesoderm

From the ectoderm arise:

- The skin
- The nervous system
- The senses

From the entoderm arise:

- The digestive tract and digestive organs (liver, pancreas)
- The lungs
- The bladder (from the allantois)

The mesoderm can create three types of tissues:

- It can concentrate and grow inward to form muscles, tendons, ligaments and bones;
- And the kidneys, spleen and reproductive organs.
- It can go to the periphery to form body cavities, such as the pericardium, the lung cavity, the abdominal cavity, etc.
- It can do both at once and form blood cells, blood vessels and the heart.

The fifth to eighth week: the un-folding

In the fourth week a body was formed in the centre of the embryo, clearly demarcated from the nourishing periphery.

On this page you will find:

- how the body changes until the end of the eighth week;
- the development of the limbs;
- the development of twins (as a sequel to the description of the second week);
- the development of the fetal membranes.

Changes in the embryo

In the figures 34 and 35 four side views are drawn of the embryo from the fifth to the eighth week.

On the 32nd day (Fig. 34 left) the embryo is yet more enfolded inward than at the end of the fourth week. Head and tail are bent inward and face each other. The back is round and curved. The head is large, especially the brain is large, and lies over the big heart. The limbs are like small paddles. The umbilical cord has become compact: connective stalk, yolk sac and allantois are lying close to each other.

On the 41st day (Fig. 34 right), the spine has partially stretched and the embryo is less rounded. The head has been pushed upwards by the large heart. In the umbilical cord a bump can be seen, caused by a part of the digestive tract for which there is no place in the abdomen so that it bulges out of the body. The short tail is still present. The limbs have grown and fingers and toes are becoming visible.

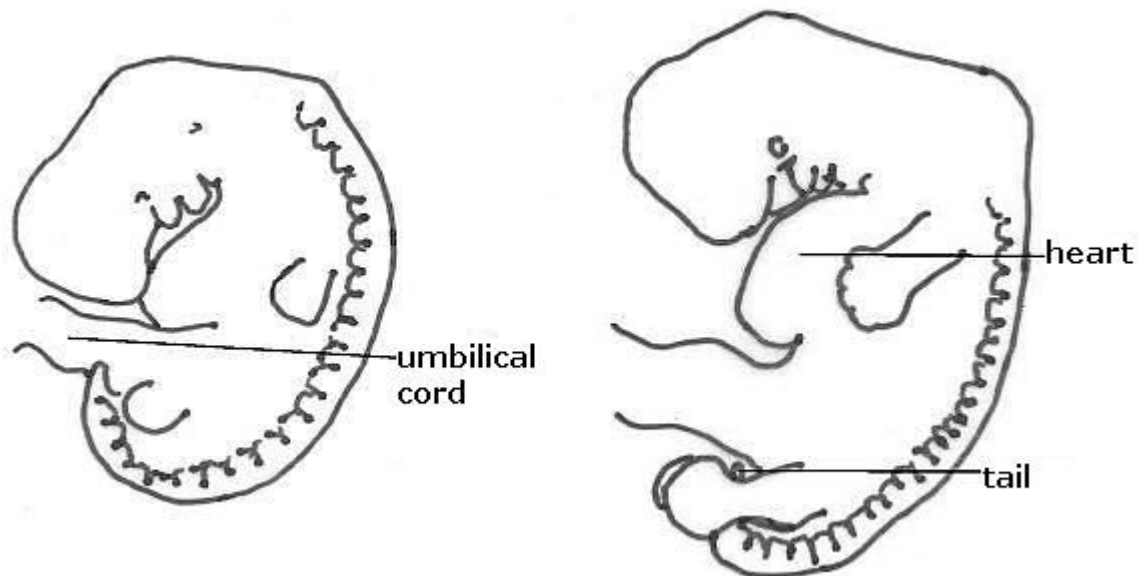


Figure 34. Left: the embryo on day 32, right: on day 41; 7 and 12 mm long.

On the 51st day (Fig. 35 left), the head is bent forward in relation to the unfolded back. The neck is visible as a slight curve. The head is rounder and eyes and ears are visible. The heart has been taken up into the torso, the intestines still protrude and make the abdomen big and round. Arms and legs stick out of the body and are longer. The tail has gone.

On the 56th day (Fig. 35 right), the body is a little human being. Only 3 cm long, he looks just like us. The large round head with the big forehead, eyes and ears is straight on the body. The neck has been formed. There is a convex belly, in the umbilical cord the bulging hump of the digestive tract is still visible. The hips and waist have been formed. The legs are placed under the torso.

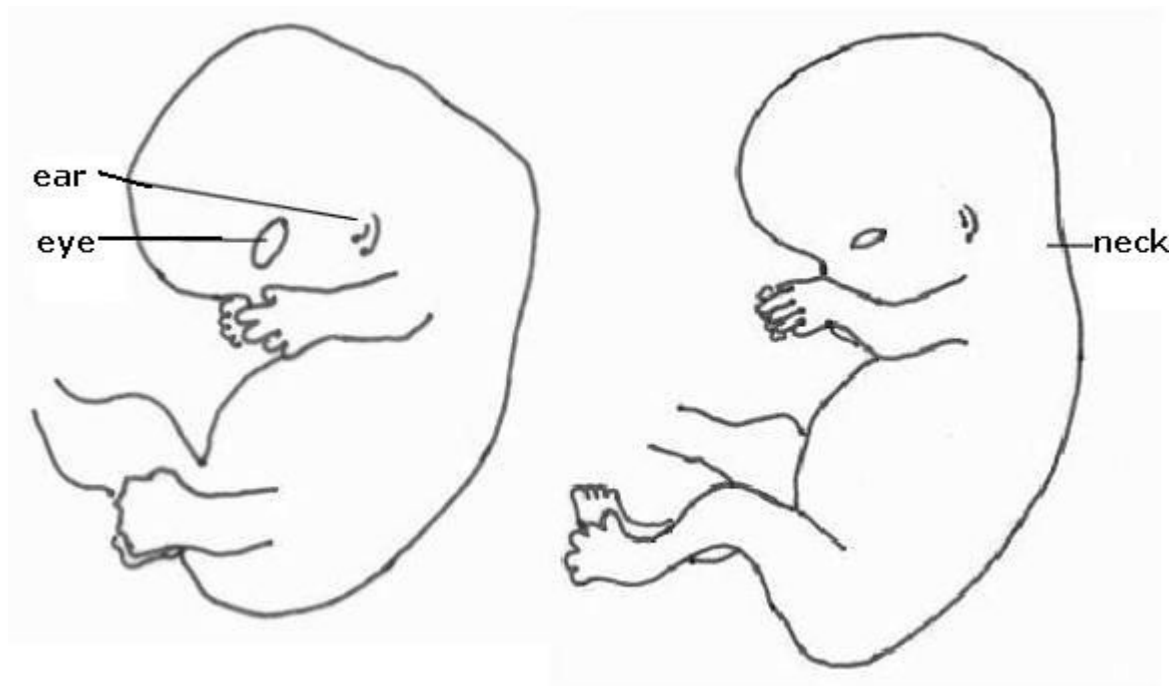


Figure 35. Left: the embryo on day 51, right: on day 56; 22 and 30 mm long.

Characteristics

In the fifth until the eighth week, the body gets its final form. First, the enfolding movement of the fourth week is continued and the embryo gets rounder. Then an unfolding movement can be seen: the spine and the back stretch and the neck and later the waist and the hips appear. Head and limbs become apart from the torso. This process goes from top to bottom: first the neck, then the waist. It is this unfolding process that makes man human. He is centred, and acts from this centre.

Neck and waist ensure that head, chest and limbs become separate areas. The threefoldness of the human body is there.

Man is the only organism that stands and goes upright: all joints (neck, shoulder, hip, knee, ankle) are in one vertical plane. When man stands, he is in balance. Standing and locomotion take little energy. Because he stands on his feet, his hands are free to use at his discretion.

Apes also go through the process of unfolding their back and the development of a neck and a waist, but they lose the erect posture again, the chimpanzee not until after birth (Verhulst).

The polarity between the closed, spherical head and the radiated, elongated limbs is visible. In many ways they are opposites with the trunk in between.

Head, trunk and limbs each have their own task: the head is for observing and thinking, the torso, with heart and lungs, for feeling and the limbs are for action.



Figure 36. Human Man (from Van der Wal, by Hartmann)
Like an animal, man is a centred organism with an inner world. The difference between them is that man not only has a physical centre, but also a spiritual centre, his self-consciousness. Man has a position from which he can look at the world and at himself and he can act freely out of his centre.

The limbs (including characteristics)

At the end of the fourth week the buds of the arms appear and two days later the buds of the legs (Fig. 33). Fig. 37 shows the development of the limbs. Of the arm the ends appear first, i.e. the bud grows into fingers. After that, the hand and then the forearm appear, followed by the upper arm and finally the shoulders. Fingers and toes appear first as flat, paddles-like forms that develop radially and after a phase in which they look like flippers, individual fingers and toes appear. On the 52nd day, the arms and fingers are fully formed, on the 56th day the legs and toes.

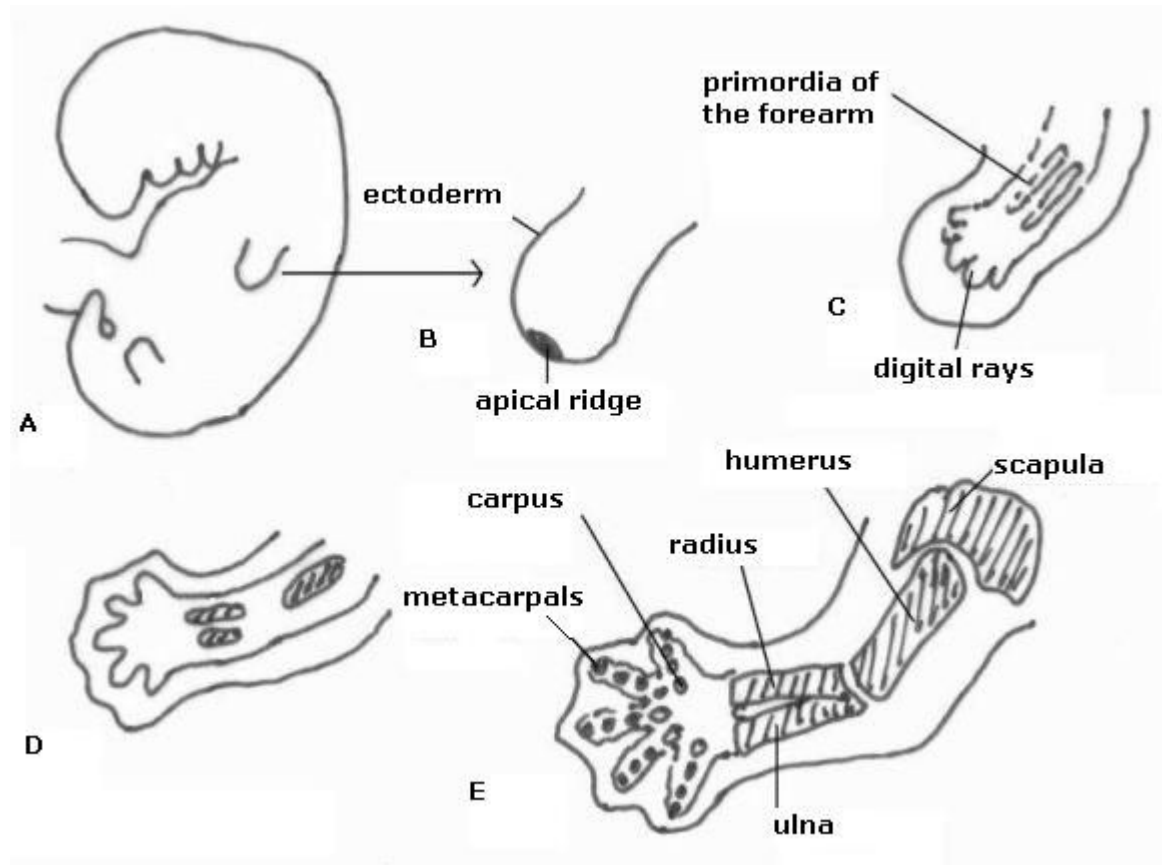


Figure 37. Development of the arm

First the bud of the hands and a day later of the feet appear (A and B). In C the forearms are also visible, the upper arm at D, and E shows the shoulder blades too. Mesoderm slowly hardens, at first the bones are still cartilage.

The arms and legs grow lateral of the body. In the 8th week the arms turn outward (external rotation) and the legs inward (internal rotation), leaving the hands with the palms upward and the feet downward (Fig. 35). The hands are oriented to the sky, to heaven, the feet are earth-oriented.

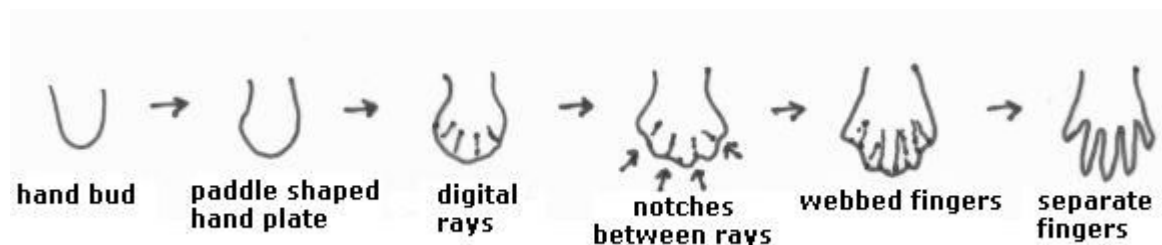


Figure 38. The development of the fingers and toes First there are paddle-shaped plates in which the fingers and toes arise like rays. In the rays, the tissue gets thicker, in between the tissue gets thinner. The thin tissue disappears and the individual fingers and toes are formed.

Fig. 35 shows that the arms lie on the heart and legs lie along the umbilical cord. The arms move with the rhythm of the embryo's own (fast) heartbeat; the legs move with the rhythm of the blood in the umbilical cord, which is determined by the heartbeat of the mother. The arms move with the rhythm of the embryo, the legs with that of the mother. The arms belong more to the embryo, the legs more to the surroundings, to the mother. From the beginning the arms are focused more on the embryo itself, the legs more on the world outside.

Man stands between heaven and earth, he is focused on the earth through his feet on the ground and focused on heaven through his hands. His feet are earthbound, his hands are free.

	arms	legs
rotation	outward (external rotation)	inward (internal rotation)
direction	hands are up	feet are down
place	on the heart	along the umbilical cord

Table 5. Differences between arms and legs

On the side of the head the embryo develops faster than on the side of the tail. The neural tube closes earlier at that side, it is at the head that the digestive tract is formed earlier; the arms develop earlier and faster than the legs. This is called the cranio-caudal (= head-tail) growth movement. This is in contrast with the limbs, where the fingers and toes appear first and the shoulders and pelvis appear last. What is closest to the centre comes last and what is furthest away comes first. This is a reversal of the cranio-caudal development movement. This second growth movement can be called the centre-periphery (or disto-proximal) growth movement (Fig. 39). This growth movement is important for humans: this long embryonic development-time, gives more time to develop what arises late. As a consequence, the legs grow longer than the arms and the upper legs longer than the under legs (Verhulst). This growth movement largely determines the upright posture of man.

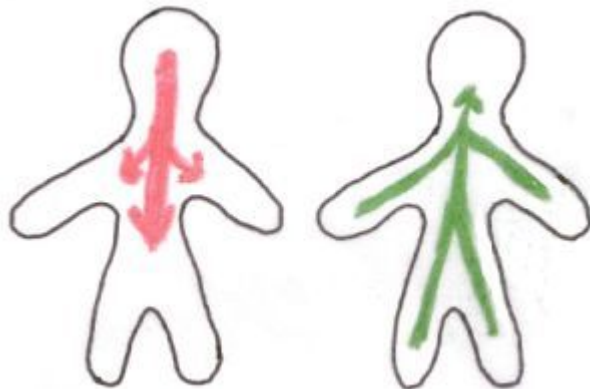


Figure 39. Left: cranio-caudal growth movement and right: centre-periphery growth movement (Verhulst)

Twins

In addition to what has been said in "The second week" and shown in Fig. 5, Fig. 40 shows drawings of the three possible types of twins. From left to right:

- Both embryos of non-identical twins each grow in their own chorion and amnion, the placentas can be separated or connated.
- The fraternal twins of the first week developed from two embryoblasts within one trophoblast. The embryos share the chorion and the placenta and each grow in their own amnion.
- The fraternal twins of the second week arose from a division of the embryonic disc. These embryos share amnion, chorion and placenta. There is considerable danger of the umbilical cords winding around each other, which may cause that the blood supply of either to be cut off.



Figure 40. Twins, from left to right: non-identical twins, fraternal twins in the first week, fraternal twins in the second week. Explanation in the text.

The fetal membranes

The embryo is - from inside to outside - enveloped in the amnion, the chorion and the uterine wall. The embryo grows and is called a fetus after the eighth week. In the drawing of an embryo of the fourth week in Fig. 41A, the amnion is still small and the embryonic disc with the amnion and yolk sac hangs freely in the chorionic cavity. In Fig. 41B, the amniotic cavity has grown and fills almost the whole space of the chorionic cavity. The uterine cavity is almost entirely occupied by both. Fig. 41C. shows that the uterine cavity is entirely occupied by the fetus. The chorionic cavity is almost entirely filled by the amniotic cavity. Eventually, chorion and amnion coalesce (Fig. 41D). The embryo thus floats in amniotic fluid.

Images of man

When is the embryo human? Is it always human, or is it only human from a certain point or a certain appearance? An embryo of 8 weeks certainly looks human. A single-cell zygote is more like other single-celled organisms and does not look like a human. The embryonic stages of the fourth week look strange and not very human.

An answer can be found by looking back at the embryonic development. An adult looks different from a teenager and behaves differently. A teenager looks different from a child and a child looks different from a baby. There is a continuous line to be seen and although a child and a baby look different from- and behave differently than adults, we see them as a young humans.

What about the fetus? It looks like a baby but shows different behaviour in a different environment. When a baby is born prematurely, every effort is made to keep it alive.

The fetus developed from the embryo, which developed from the embryonic disc, which developed from the blastula and finally from the zygote. All are manifestations of a human being. All manifestations have their own appearance and behaviour, appropriate for their stage in life and the environment they are in. So, just as the baby differs from the adult, the zygote is different from the baby. This leads to my conclusion that the zygote and the embryo are human, in a different form. Hence: embryology: images of man.

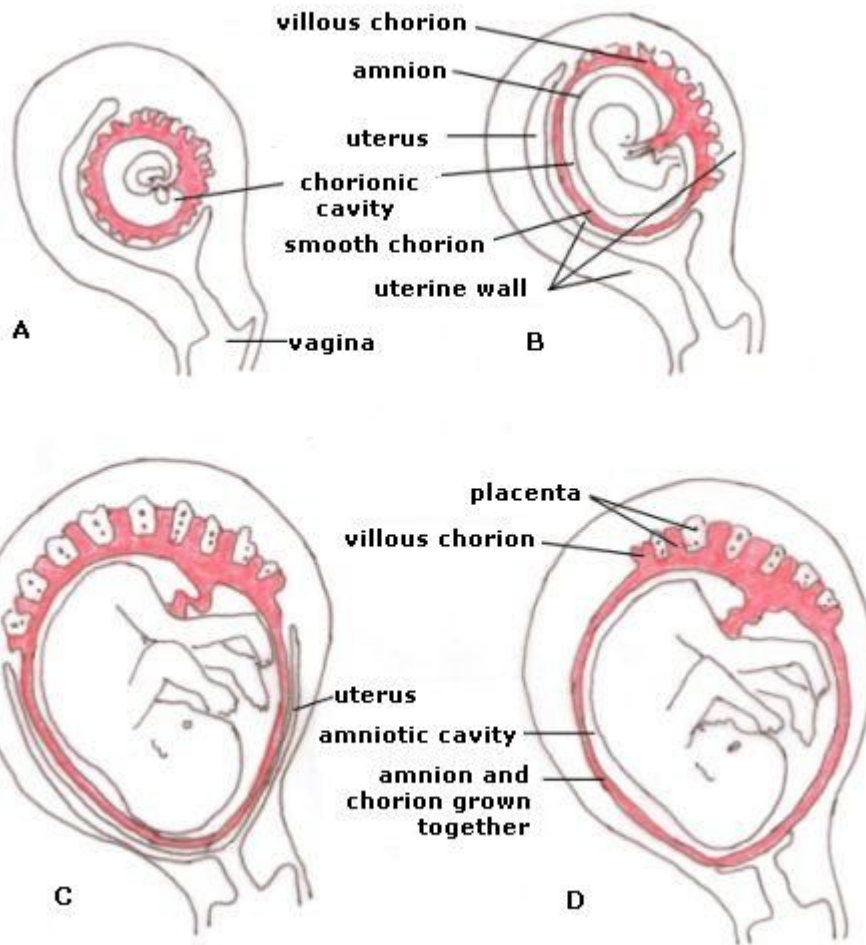


Figure 41. The development of the fetal membranes and the placenta. A: 4th week, B: 8th week, C: 16th week, D: 22nd week. See text for a description.

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