The Digestive system. Embryogenesis and congenital abnormalities.

The Particularities of the child's digestion.

Embryogenesis and congenital abnormalities.

- **The shaping of the digestive organs occurs at early stage of the embryonic development. The organization of the primary gut begins from endoderm in the manner of tube formation already at 7-8-th days.**

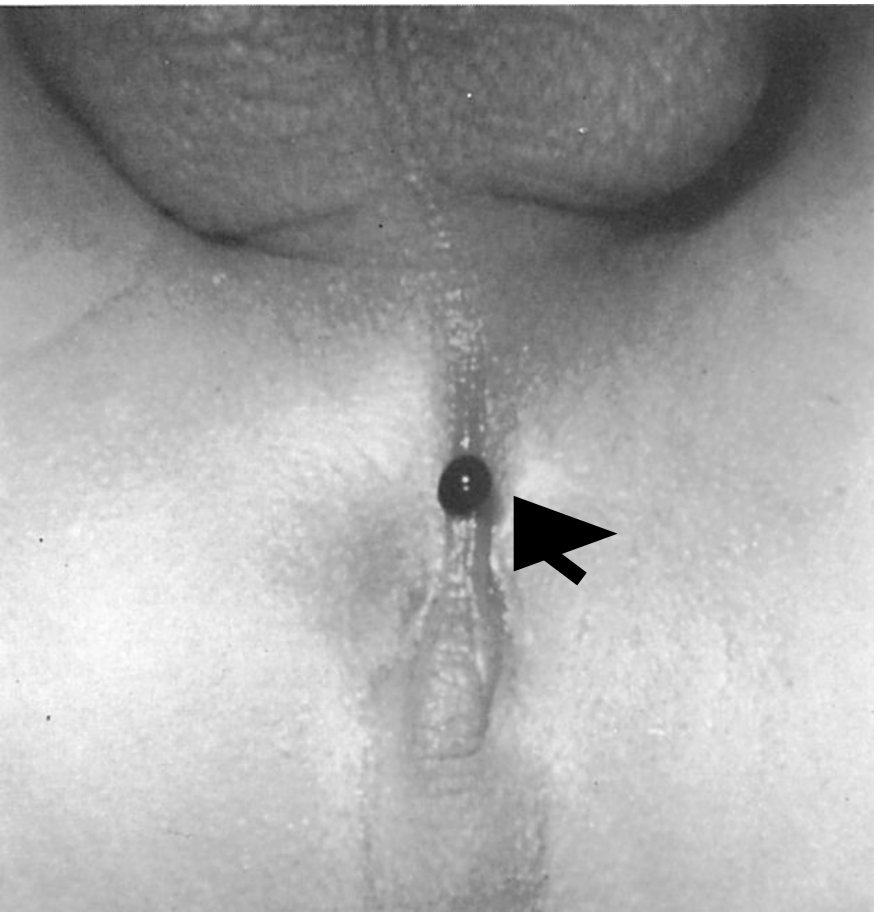
Primary gut

- At 12- th day the primary gut divides on two parts. The first part (intraembrionic) is localized inside embrio. The second part is exstraembryonic being localized in the vitelline bag.
- The vitelline bag is early embrional formation, in which some nutritive material accumulates and the embryo uses them as a feeding as well as for hemopoiesis. The transport of vitelline trophoblastic materials to the embrio is realized by blood circularity and through lymphatic vessels. The vitelline bag formally communicates with middle part of embriotic gut by means of trophycal vitelline stem. The part of middle gut is found directly inwardly bag.

Oropharingeal and cloecal membranes

- **The primary gut of embryo as a tube starts and finishes blindly in consequence of the oropharingeal and cloacal membranes presence. The melting of the oropharingeal membrane occurs on 3-th week of embryo development and the cloecal membrane on 3-th month. The breach of this process causes the congenital anomalies. They are a various vices of oral cavity and of anorectal zone (like atresia of the anus and additional paraanal leads).**

Cleft lip



Anocutaneous fistula. The bead of meconium became visible only at 36 hours of life.

(From Wyllie R, Hyams JS (eds): Pediatric Gastrointestinal Disease. Philadelphia, WB Saunders, 1993, p 708.)

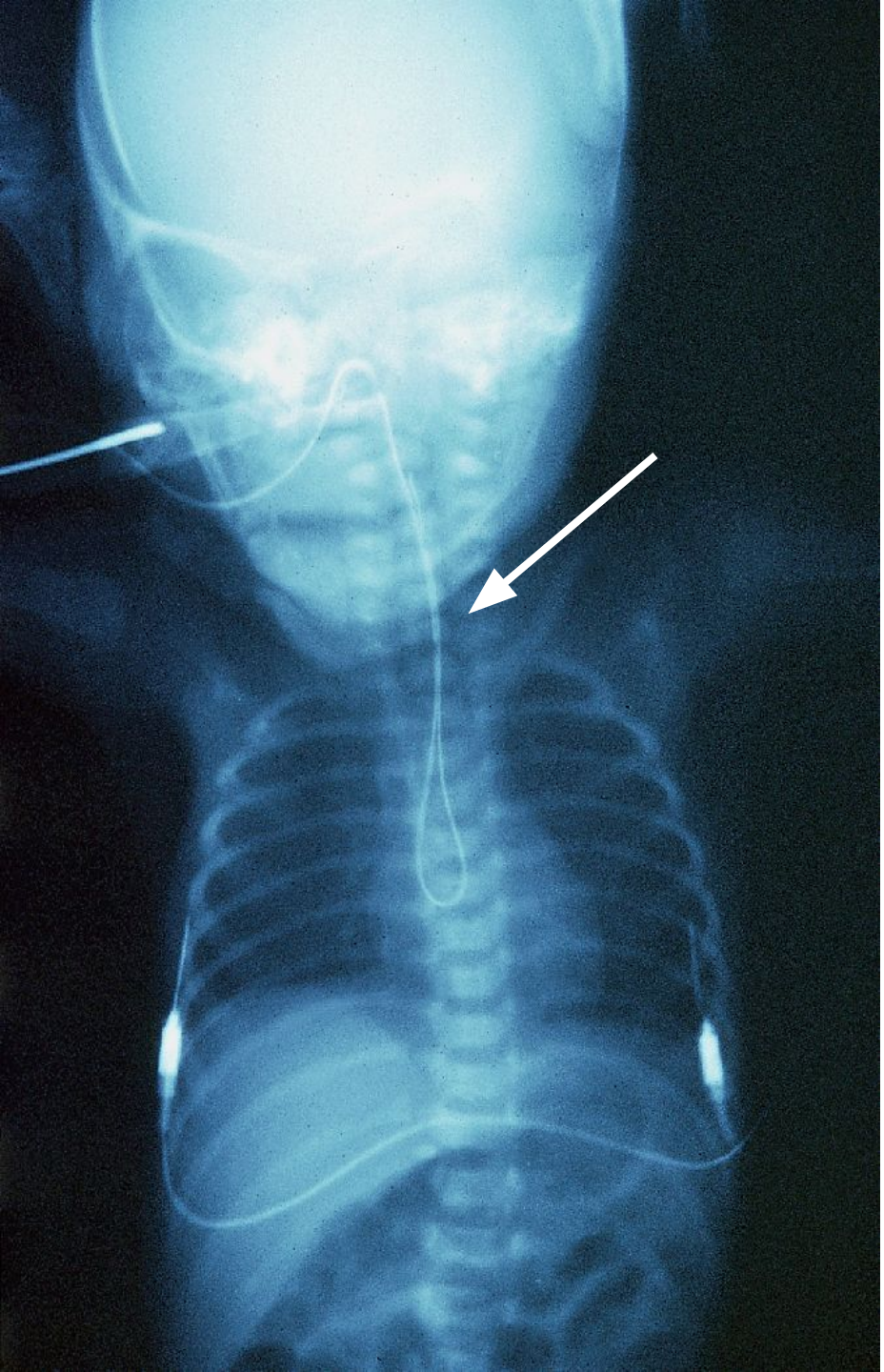
1 mo old embryo

- **The formation of differential divisions of the digestive tract begins after 4 weeks of embryogenesis.**
- **The salivary glands, pharynx, esophagus, stomach and a part of duodenum with pancreas and liver buds (premordiums) develop from the anterior gut. The other part of duodenum and ileum are formed from the middle gut. All divisions of the intestinum develop from the posterior gut.**

The embryonic and postnatal features of digestive system organs.

The esophagus.

- **The normally formed esophagus serves for transport of the food wad from oral cavity into stomach.**
- **The esophagus is shaping like a tube in the beginning of a 4-th week of embryonal development but its bright spot is filled in consequence of cellular mass proliferation. The laying of esophagal glands appears in 3- 4-th months and beguines of the active secretion. This secretion promotes the forming of esophagal cavity. The various breaches of esophagal canalization can lead to innate narrowing (or strictures) and even to esophagal atresia. Also the esophagus can abnormally communicate with trachea.**



Esophagal atresia. Folded feeding tube in the esophagus.

The stomach.

- The orderly formed stomach serves as reservoir for food and for its primary fermentation.
- The stomach appears at 3-th week of gestation as a local fusiform expansion of the anterior gut. This is a future body of the stomach. Its grows up more intensively then other divisions of the stomach. The pyloric sphincter as anatomical division appears at 12-th week of gestation and the cardiac one can be found much later (on 16-th week).

The further intensive development of the stomach occurs in period after child birth.

The stomach.

- **It is a rule that the stomach physiological volume is smaller than its anatomical capacity to intake the food. For instance the newborn has a stomach volume about 7 ml. The stomach ability to contain a foot is increasing very quickly after birth but even infant aged 1 yr can ingest only 250 ml of food.**

The stomach.

- **The anatomical parts of the stomach develop unevenly after birth. The stomach bottom and cardiac division are immature in newborns and infants. There is the functional insufficiency of cardiac sphincter closing function. It predisposes small children to very easy vomiting. This phenomenon can be explain by following facts. The efferent part of esophagus is situated over the diaphragm in the chest. In small children it communicates with stomach through the wide hole in the diaphragm (hiatus esophagus). Also the esophagus is short in infants and opens on a top of the gastric bag and it exaggerates the functional insufficiency of cardiac sphincter closing function in early children.**

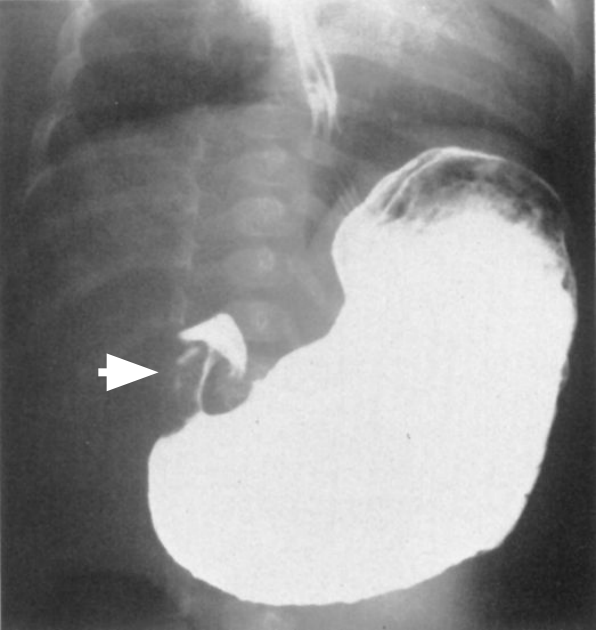
In infancy, regurgitation is most commonly secondary to developmental gastroesophageal reflux and resolves spontaneously. This infant is otherwise healthy and acts well despite large volumes of emesis.

The stomach.

- **The pyloric sphincter of stomach is developed well since child`s delivery. The condition when the pyloric sphincter is strong and cardiac is weak can allow to compare the stomach in small children with "open bottle". It means that the change of baby`s position from standing to lying can provoke easy vomiting and food regurgitations. That is way it is recommended to keep children on elevated position several minutes after nursing for vomiting protection. The total maturation of the cardiac sphincter is terminated in children aged 8 years.**

The stomach.

- **The hypertrophic condition of pyloric sphincter (pylorostenosis) is the most common innate anomaly of the stomach, is being the frequent indication for laparotomia in children aged 2-4 months.**



Pyloric stenosis.

a) b) c)

a) Excessive residual barium following examination. This is the final film that accompanied a transferred infant with projectile vomiting. The attenuated pyloric canal is typical of congenital hypertrophic pyloric stenosis. The stomach is distended with barium, and gastroesophageal reflux has occurred.

b) Infant with pyloric stenosis. Alimentary marasmus and dehydration state. The IV fluids infusion is the most important line of treatment before the child will be operated on. The diuresis is controlling by urine collection in a plastic bag.

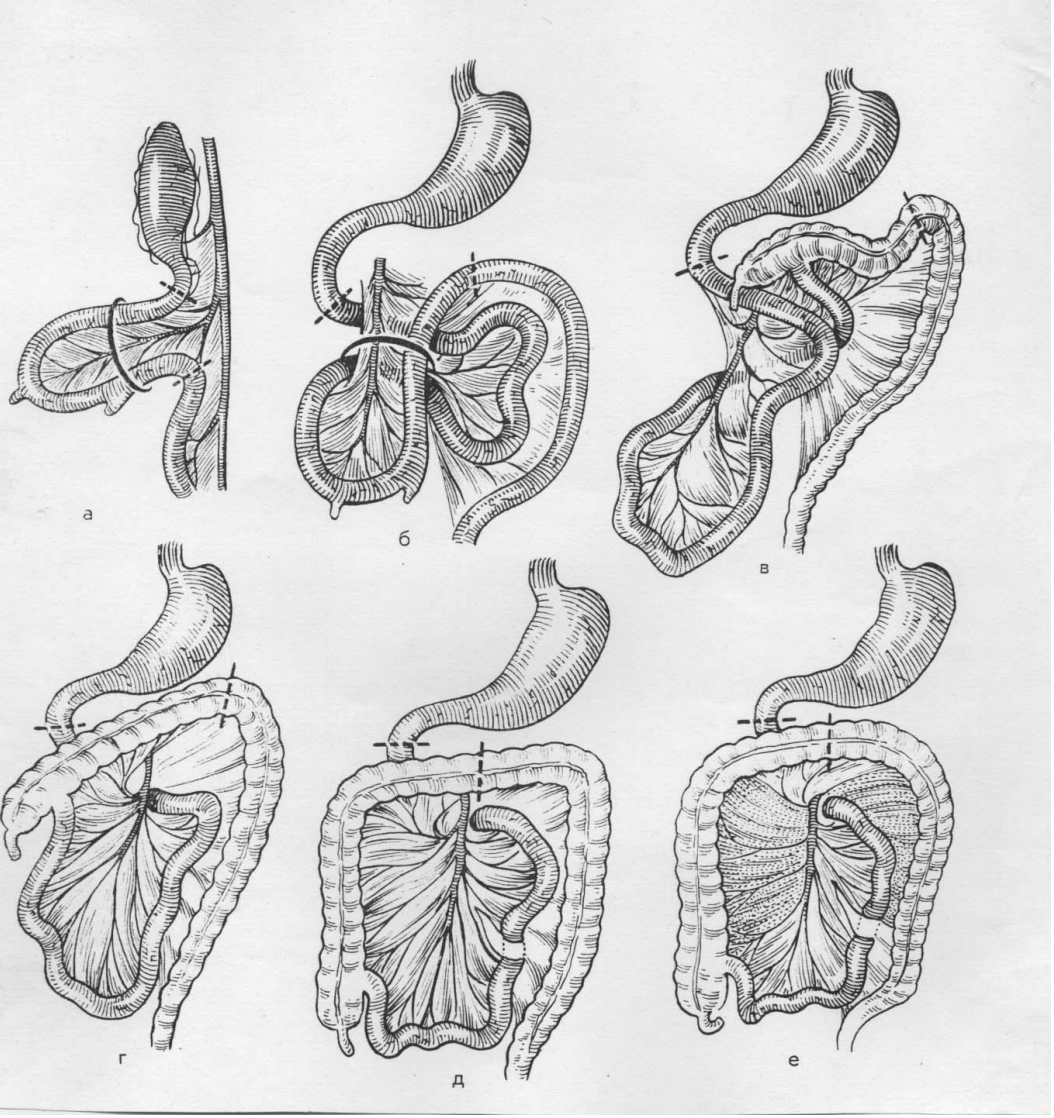
c) Gastric peristaltic wave in an infant with pyloric stenosis.

GUT

- **The Bowel is an organ in which the main processes of digestion occur. The bowel develops enough quickly within the gestation period. A part of embryo's gut between stomach and vitelline stem is identified as an anterior gut knee. Then up to the cloaca it is a posterior gut knee. From the anterior embryonic gut knee the duodenum and jeunal intestines sharp. The other part of ileal intestine and all colon up to the rectum forms from the posterior embryonic gut knee.**

Tumbling of the bowel

- The anterior knee develops most intensively and forms many flexures. At early embryonic stage the top of anterior gut knee (U-figurative loop of primitive gut) is set out of the embryo's body protruding through umbilical cord into vitalline bag. A little bit later (at 3-th month of gestation) this gut loop turns round to the right. Simultaneously U-figurative loop returns back from the vitelline bag into abdominal cavity of embryo. After that the so called tumbling of the bowel proceeds during the rest of in uteri period and even small time after baby delivery. The whole process of jeunoileal displacement (tumbling) in abdomen cavity proceeds from right to left direction around the root setting by mesenterial artery. At the same time the large intestine tumbles round from left to right having the same point of rotation.



a) In embryo the bowel hungs in saggital plane before to begin a tumbling; it must be noted that big part of intestinum is set out of the body in vitelline bag ;

b) the tumbling is beginning: the loop of embryonic middle gut residing in umbilical cord turns round on 90˚ from saggital to horizontal plane;

c) - the continuation of tumbling on following 180˚ and simultaneous spontaneous setting in of the embryonic umbilical hernia;

d) – the caecum turns out to set in right upper abdomen quadrant; at this moment the bowel is tumbled on 270˚ following by further intraabdomenal rotation;

e) – the caecum lowers into its usual position in right iliac region; the large intestine has committed all intraabdomenal rotation (360˚), but the mesentery is not yet fixed on a back abdominal wall;

f) – the tumbling is finished by fixation of the mesentery on a back wall of abdominal cavity.

A. The abnormality of the first period of intestinal tumbling.

1. Hernia of the umbilical cord.

Omphalocele

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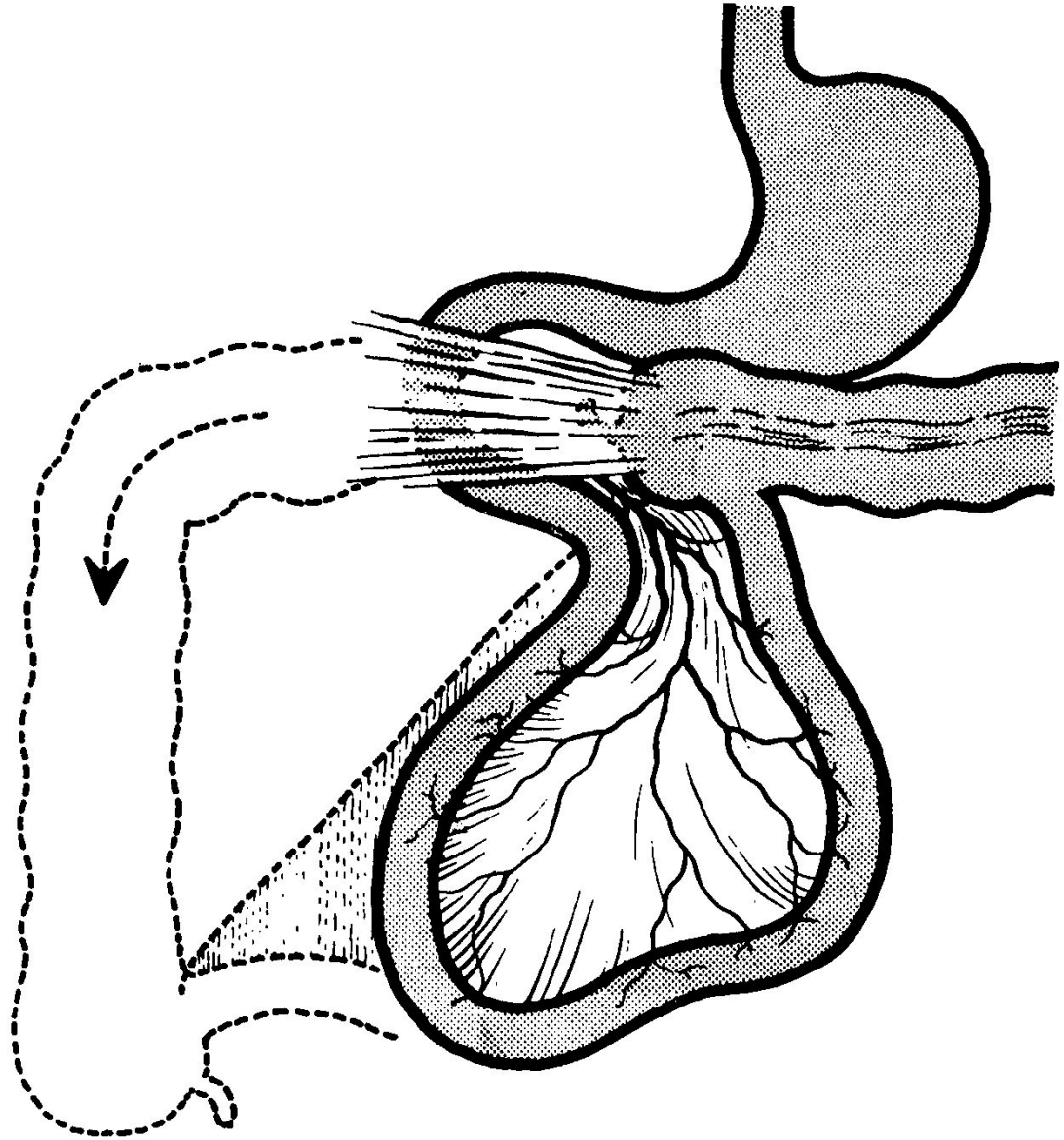
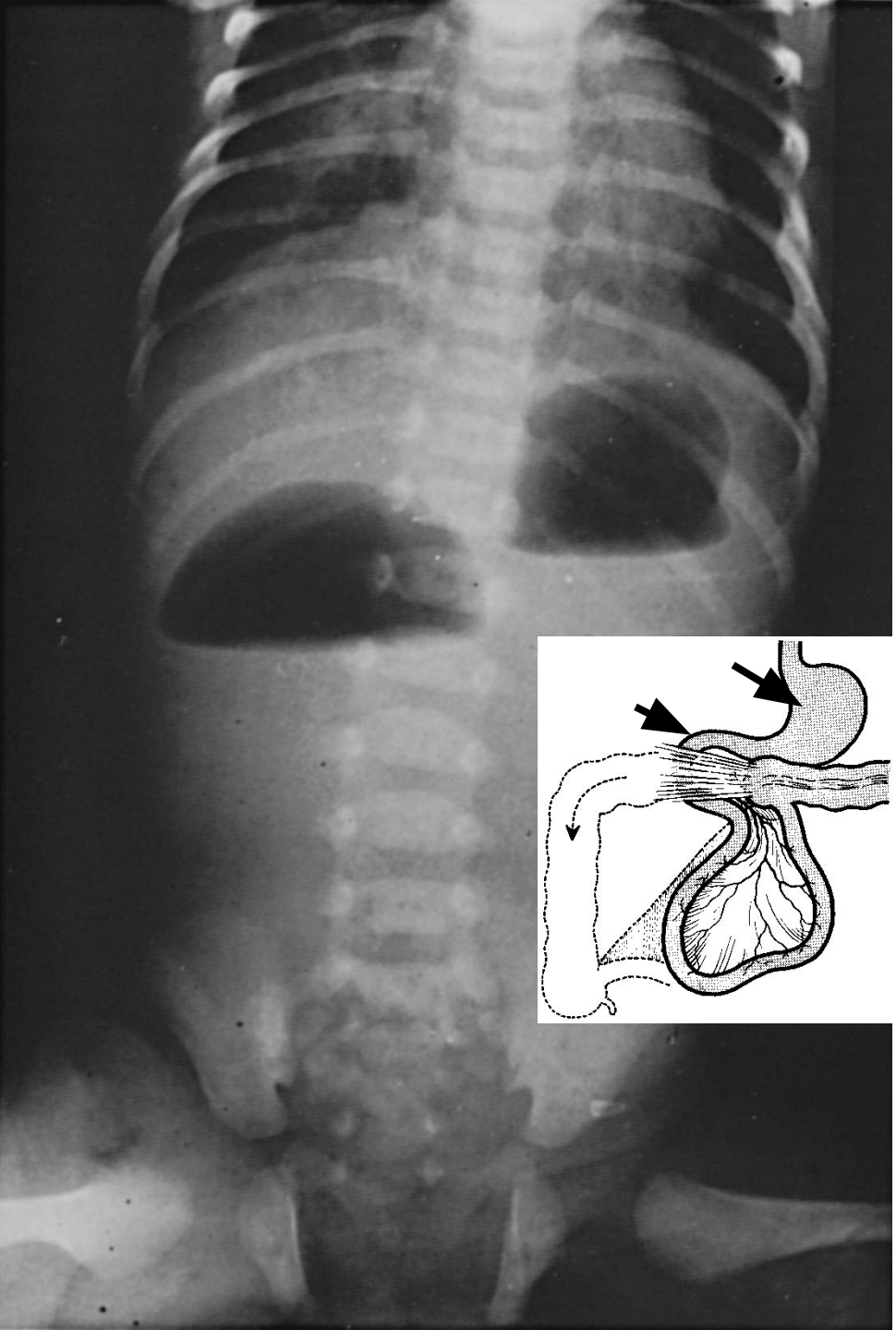
B. The abnormality of the second period of intestinal tumbling.

- 1. Abnormal insufficient tumbling of the bowel.
- 2. The Innate valve of the middle gut.
- 3. The obstruction of the duodenum, caused by outside pressure from:
- a) the miss rotated caecum;
- b) the innate mesenteric cords compressing the caecum.



The mechanism of intestinal obstruction with incomplete rotation of the midgut (malrotation). The dotted lines show the course the cecum should have taken. Failure to rotate has left obstructing bands across the duodenum, and a narrow pedicle for the midgut loop, making it susceptible to volvulus.

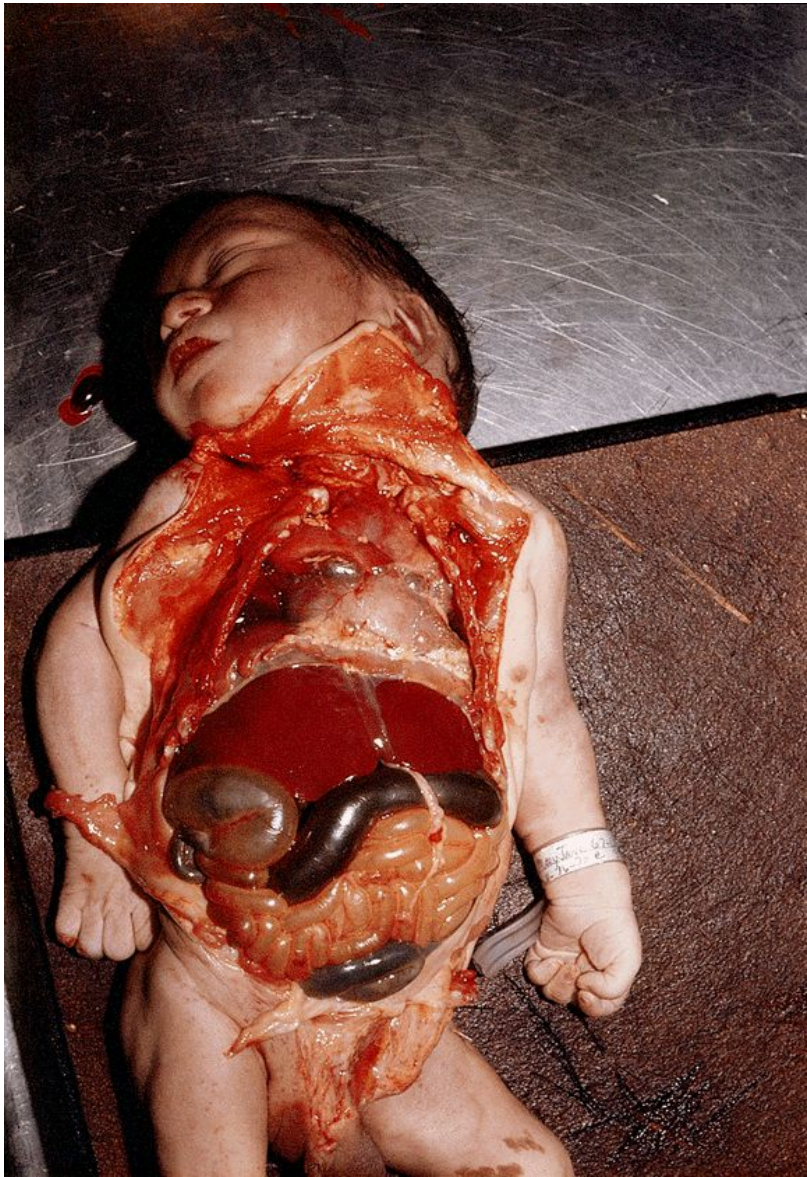
(From Nixon HH, O'Donnell B: The Essentials of Pediatric Surgery. Philadelphia, JB Lippincott, 1961.)

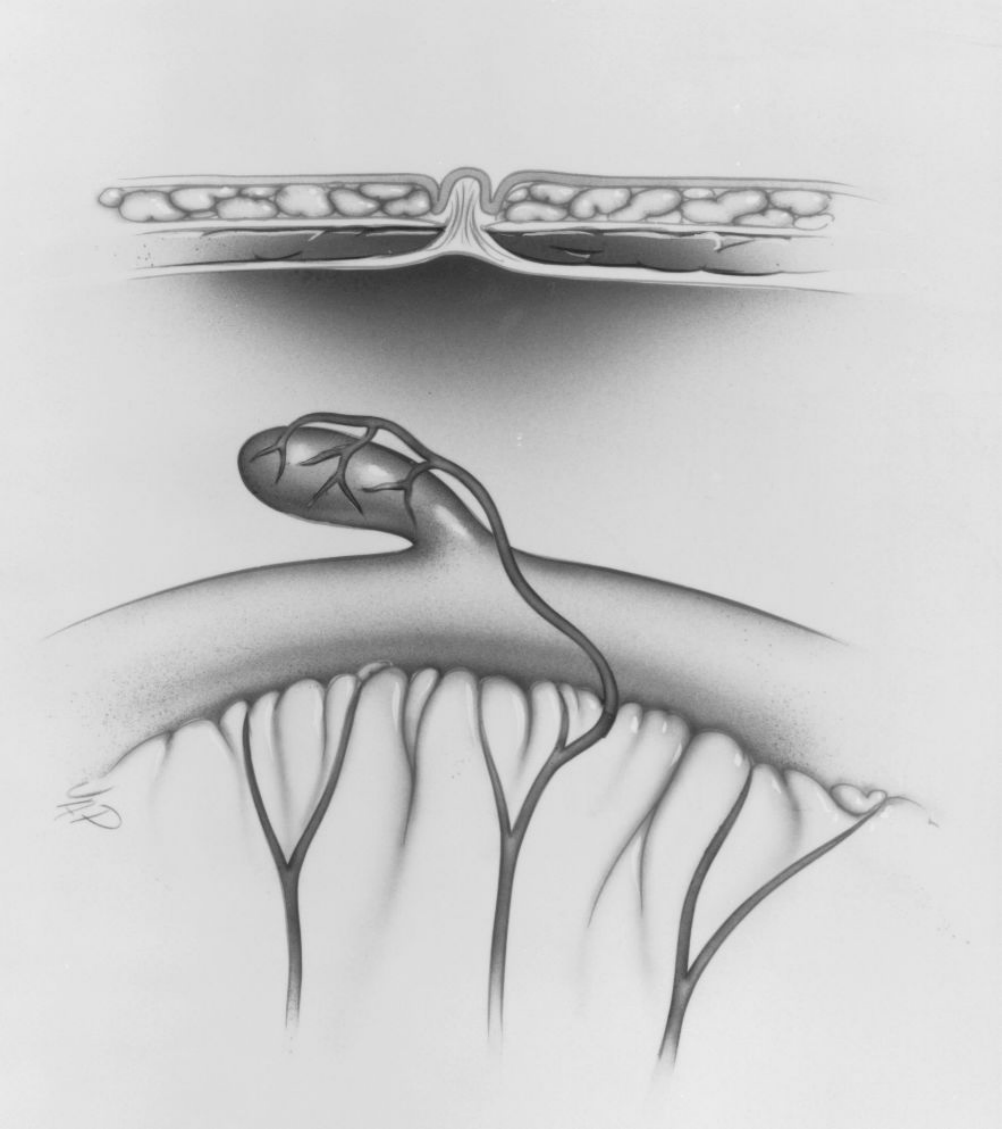


Abdominal roentgenogram of a newborn infant held upright. Note the "double bubble" gas shadow above and the absence of gas in the distal bowel in this case of congenital duodenal atresia.

B. The abnormality of the third period of intestinal tumbling:

- 1. The High location of the caecum.
- 2. The wandering caecum.
- 3. The Location of vermiform appendix behind the caecum.





Mekkel's diverticulum

The relationship between the embryonic vitelline bag, vitelline stem and Mekkel's diverticulum.

The degree of vitelline bag and especially vitelline stem reductions can be different in embryo that explains the different variants of the Mekkel's diverticulum on a wall of small intestine. The inflammation of Mekkel's diverticulum if it is presented like congenital abnormality can appear in a child, and even adult at any time, as well as bleeding from its vessels in ulceration. All this conditions are an indication for emergency treatment.

The small intestine

- **The small intestine** has 3 parts in proximal-distal direction: duodenum, jejunum and ileum.
- The jejunum and ileum form the small intestine**.** The clear border between jejunum and ileum is absent. It is accepted consideration that jejunum occupies approximately 2\5 whole lengths of the gut between duodenum and ileo-caecalis valve (so called the Bauginy's damper). The ileum is a little bit longer (the 3/5 from small intestinal length).
- The small intestine has comparatively greater length in calculation on body growth in early children (aged less then 3 years) in comparison with adult persons. This big length of intestine reflects the low caloric and liquid type of early children meals – mainly breast or cow milk. The intestinal loops lies more portably because comparatively big liver occupies big volume of abdominal cavity in infants and at the same time the pelvis is not developed yet. The location of intestinal loops becomes constant only in children in their second year of life.

Colon

- **The large intestine (Colon)**. The development of large intestine (intestinum grassum) does not end with child delivery. The tapes (teniae coli) are marked in newborns hardly and gaustres are absent until age of 6 months. The maturation of large intestine became similarly with an adults only in children aged 3-4 years. The uneven growing of the different division of large intestine can be accompanied by the different breaches.

Hirschsprung disease (megacolon). Roentgenogram showing extension into the ileum. Lesion at operation.

The Caecum.

- **The caecum of newborn has a cone-shaped or cratered form and is situated higher then in adults. Often it is located so upper that the ascending part of colon is underdeveloped or even absente. The bowel mesentery is very movable (mobile) and is strictly fixed only in 2% of newborns. The final maturation of the caecum is finished at the end of the first life year. The appendix has also conical form in newborns. The length of appendix is about 5 cm in newborns. The entry in appendix is broadly open. This primitive appearance exists for the first year of life. On this age the length of appendix increases up to 7 cm. Then the velocity of appendix`s growing up sharply slows. The age dependent mobility of the caecum mesentery predisposes young children to intestinal intussusceptions.**

Intussusception in an infant. The obstruction is evident in the proximal transverse colon. Contrast material between the intussusceptum and the intussuscipiens is responsible for the coil-spring appearance.

The Colon.

- **The Colon surrounds the intestine loops in the manner of rim. The ascendant part of colon (colon ascendens) is very short in newborn. It will increase in size little bit after leading the large intestine occupies its final position in abdominal cavity. As a rule it happens in children after 1 year of life.**

The Colon.

- **The Transverse part** of colon (colon transversum) takes its horizontal position only in 2 year aged children. Top-down part of colon (colon descendens) in children has smaller diameter than colon ascendens and colon transverse.

The Colon.

- **S-figurative colon** (colon sigmoid) in newborns is comparatively longer than other divisions of bowel and can be rolled up. Moreover the process of its growing lasts all the persons` life notwithstanding the usual growth rate reduction with age. Also the sigmoid colon in early children is situated usually in abdominal cavity instead a pelvis. This fact can be explained by relatively underdeveloped in volume small pelvis cavity in small children. In normal conditions the sigmoid colon occupies its usual position in 5 years old children.

The rectum.

- Rectum is also comparatively long and can occupy all the small pelvis in infants. The ampoule of rectum is nearly undeveloped in newborns. The fatty cellular masses surrounded the rectum are seemed absent. It leads to high mobility of the rectum and predisposes to easy organs` prolapses. The rectum gets a good fixation only in children older than 2 years.

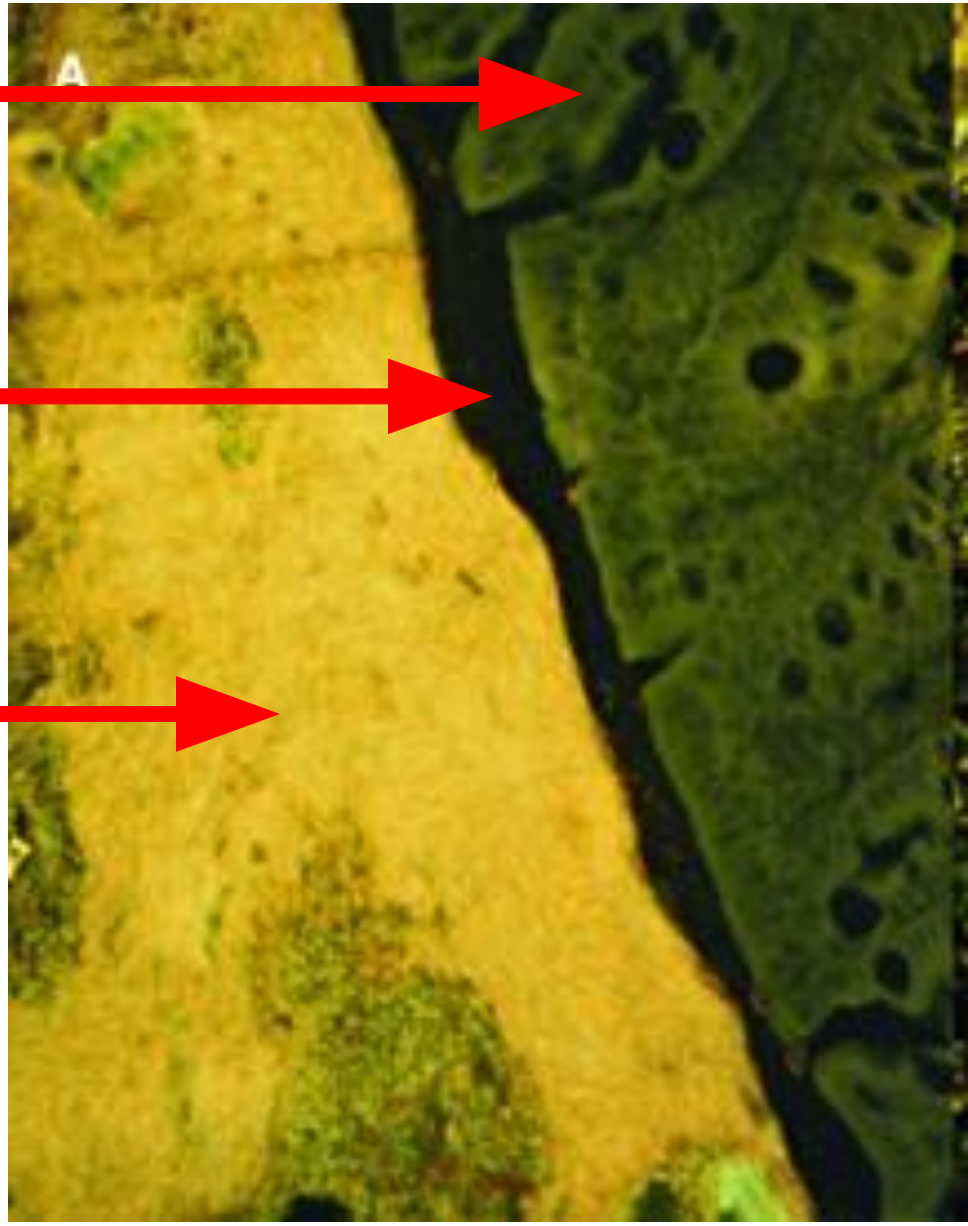
Intestinal microbiota as a "personal digestive additional organ.

- The bowel of embryo is sterile in uteri. The colonization by necessary microbiota starts immediately after birth and lasts about one week in infants in breast feeding. Now it is well known that Lactobacillus microorganisms appear on the skin of expectant mother within last weeks of gestation. The definitive infants` microbiological pattern in bowel establishes in well children aged about 1-2 mo. The majority of microorganisms are Eubacterium rectale (Roseburia spp.), Faecalbacterium prausnitzi и Bacteroides group (70% of total mass) and seems execute digestive and vitamin-synthesizing functions. Also they protect bowel from uncontrolled side pathogenic microbial contamination.
- The Lactobacillus and Bifidobacteriaceae play the most comprehensible role in bowel because they help to accept milk.
- It is necessary to help to the baby to create his or her own desirable bowel microbiota immediately after birth making all the best for accurate nursing and colostrum intake. The baby mouth has to contact only with mothers` breast skin.

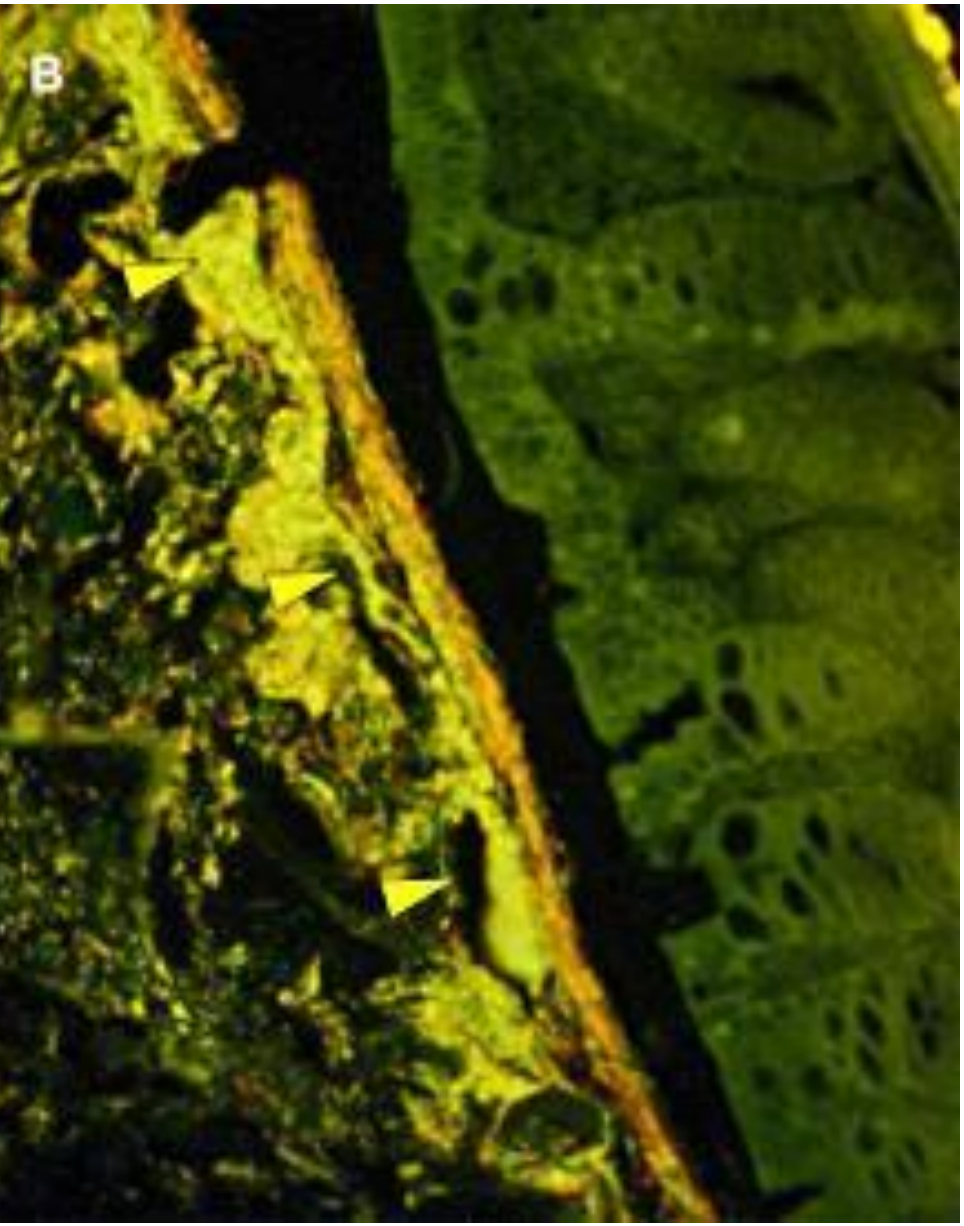
The wall of colon

Slime barrier

Lumen and bioreactor of microbiota

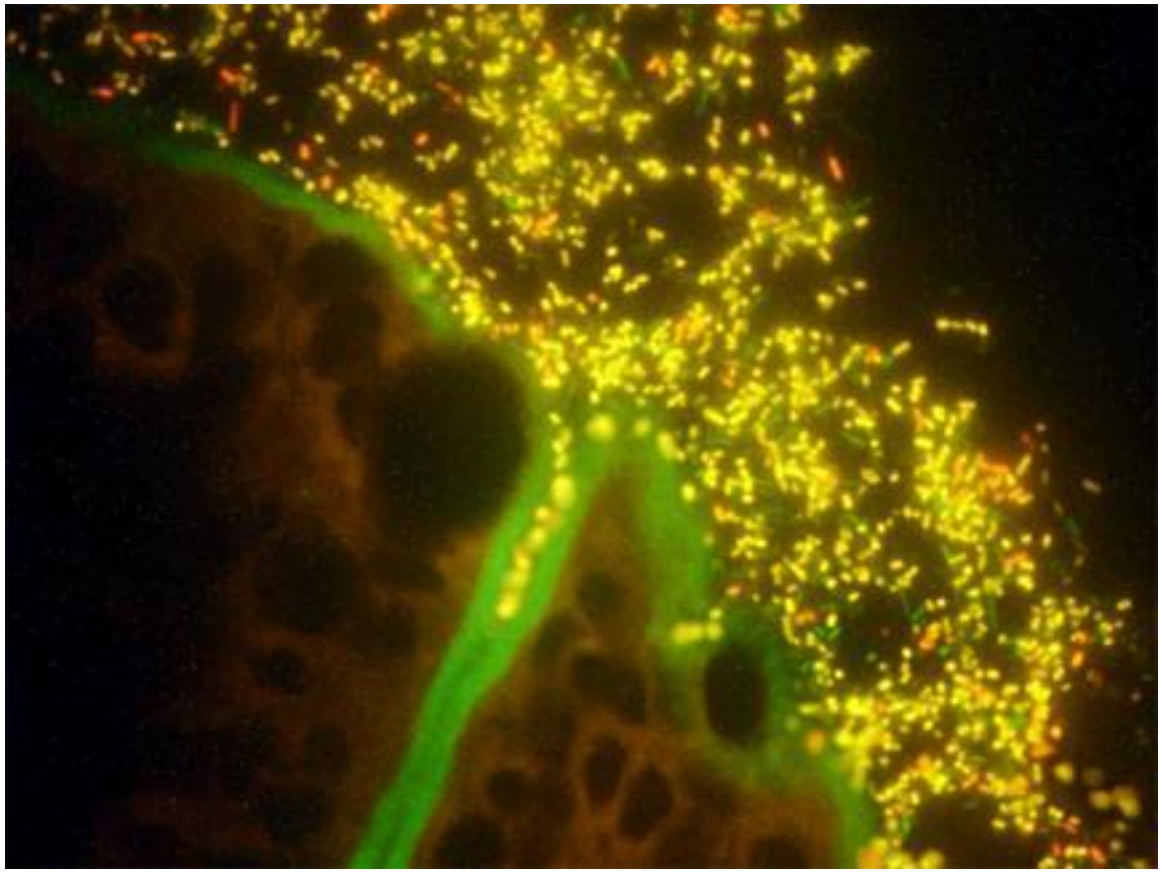


rPHK-FISH hybridization. Bacteroides – orange color, Eubacterium rectale - red, others green (x400).



The disturbance of bowel microbiota

rPHK-FISH hybridization. Bacteroides – orange color, Eubacterium rectale - red, others green (x400).



catastrophe

The Digestive glands.

- Salivary glands. During the first months of life the physiological role of them in children is very small.
- The Pancreas anatomy. The primordial of pancreas appears in embryo on 3-th week of gestation in manner of two sacs (diverticulums) on gut lumen. There are a big dorsal sac being the future tail of pancreas and a small ventral sac as a primordial of pancreatic head. The both appear independently and little bit latter the consolidation of this parts happens. After that the fusion of intra-gland-channel-system occurs.
- The typical abnormality of anatomical pancreatic development is its annular form, which develops because there are an unusual knitting of the dorsal and ventral buds. The annular pancreas can cause the duodenal obstruction.
- The pancreatic enzymes. On 12-th week of embryonic development the proteolytic enzyme activity of trypsin can be define. The pancreas produces the trypsin in non-active form of pancreatic trypsinogen. The last one is activated by the intestinal enterokynasa. The activity of tripling increases quickly in accordance with gestation lasting. The hymotrypsin (hymotrypsinogen activated by trypsin) can be defined in 18- weeks old embryo. Lipase is activated by bilious salt of the liver bile and can be defined on 12-weeks of gestation. And only pancreatic amylase appears after child birth.
- The pancreatic isles (Langergans' isles) are formed from the embriogenic epithelial cords in the early stage of in uteri development.

The Liver and bilious ducti. The Gall bladder

- **The Liver with the system of bilious ducti and gall bladder** are develop from the liver premordium - diverticulum on ventral site of the primary gut in 4 weeks of gestation. The Future bilious ducti and gall bladder are formed from the proximate part of diverticulum and a liver beams from distal part.
- The liver is one of the largest organ at birth. It occupies in volume about 1\3-1\2 of abdominal cavity and its mass forms upto 4 - 4,5 % from all mass of newborn body. It elaborates the bile and provides intracellular digestion in hepatocytes. The left lobe of the liver is very massive at birth. This fenomenon can be explained by its original blood supply in uteri. According its big size the liver should be palpated easily in small children.
- **The Gall bladder** in newborns, as a rule, is hidden by liver that obstructs its palpation.

Atresia of the liver dusts

- **Most common hereditary pathology of the liver is an atresia of the liver dusts. Their underdevelopment is most often connected with virus hepatitis action in early stage of fetal period. The intrahepatic and extrahepatic liver ductis obliteration can be defined. The second form is characterized by gall bladder presence on the ultrasound imaging.**

The Particularities of digestive processes in children. Evolutionary types of feeding.

Antenatal period. The several types of feeding.

- In embryo the main type of feeding is hysterothrophic. The embryo is fed by the elements of uterus mucous after its implantation. The late embryo uses for feeding the materials of its vitelline sac.
- The hemotrophic type of feeding establishes after placenta forming on second - third months of the fetus intranatal developments. The hemotrophic type of feeding exists to account of nutrients assimilation transported from the mother blood into fetus umbilical vena blood through placenta. The digestion of all nutrients discussing above happens inside of hepatocytes and has to be nominated as an intracellular digestion, realized by means of pinocytosis. From 16-20th weeks of gestation the amniotrophic type feeding begins in fetus. It means that the fetus uses the amniotic liquids containing some nutrients like proteins, carbohydrates, vitamins, salts and water as additional feeding within the time of placenta existence. It is important to emphasize that the baby in uteri starts to swallow and digest nutrients much time before the birth.

Only breast or milk feeding!

- **The condition of digestive organs at the moment of the human baby birth is characterized by their common immaturity and only breast (or milk) feeding can provide for newborns acceptable possibilities to survive. On the first hand the immaturity of newborns` digestive system depends on relative deficiency of distant digestion.**

What is the distant digestion?

- **The distant digestion is a process realized by action of digestive enzymes mixed with meal masses directly in digestive tube (in gastrointestinal tract).** ***The salivary glands, stomach, pancreas and liver are the organs which secrets provide the distant digestion.***

Salivary glands

- During the first months of life the physiological role of saliva in children is very small. It provides only a good capsulation in oral cavity within sucking as well as formation of small friable clots of milk casein.
- When the infant begins to feed with additional to milk meals like vegetable puree and porridges containing a big amount of carbohydrates the role of salivary glands is rising. At this time and after the saliva has big importance in carbohydrate digestion and shaping the food wads.
- Since 4-5 months of age the infants usually have physiological hypersalivation as a signal to advise them solid meals. Also the infants` hypersalivation is related with age dependant ineffective swallowing in young children.

Stomach

- After establishing of enteral feeding the capacity of stomach quickly increases. On 4th day after birth the stomach volume increases from 7 ml up to 40-50 ml. At 10-th day it is 80-100 ml. By the end of the first year of life the average physiological capacity of the stomach reaches about 250 ml. This chart shows haw much meals an infant should ingest.
- In children aged 3 year the stomach should contain 400-600 ml. At age from 4 to 7 years capacity of stomach slowly increases. After 7 years the period of quick growing approaches and 10-12 years aged children are able to get 1300-1500 ml.
- The regulation of gastric secretion begins at the first month of life. In line of gastric proteolytic enzymes in infants the chymosin is dominated by its activity. Its biological role is to denaturize the main protein in milk - the casein. In children aged less then one year the activity of gastric lipase is comparatively higher then in adults persons because of its ability to hydrolyze milk fats in stomach in conditions of liver bile acids absence.

Pancreas

- **The exocrine (digestive) function of pancreas in small children is comparatively low, but it provides sufficient hydrolysis of milk for its easy assimilation. The amylolytic activity of pancreas is getting mature only in 4-5mo aged children.**

Liver

- **The liver is comparatively large in newborn but in its functional attitude it characterizes by low digestive possibilities. The bile contains less amount of bilious acids which play the important role in processes of fat digestion. This fact probably quite often serves the reason of physiological steatorrhea in newborns. They have a big in contrast with adults persons amount of fatty acids and neutral fats in faces. This phenomenon is called a physiological steatorrhea.**

Considering limited possibilities of distant digestion in early infants the milk feeding is the important stage of ontogenesis in adaptation of newborn to extrauterinal life.

Membranous digestion

- **The bowel of infants compensates the enzymes insufficiency of organs which provide the distant digestion in milk feeding. The membranous (parietal, on enterocytes` villus surface) digestion has enormous importance because only this mechanism provides digestion of carbohydrates (disaccharides, espessialy lactose). This substances only constitute the main energetic pool in milk. The glycolytic enzymes (first of all lactasa) preformed in enterocytes` surface are enough active even in late fetuses and well newborns.**

Particularities of the digestion in heterotrophic feeding stage.

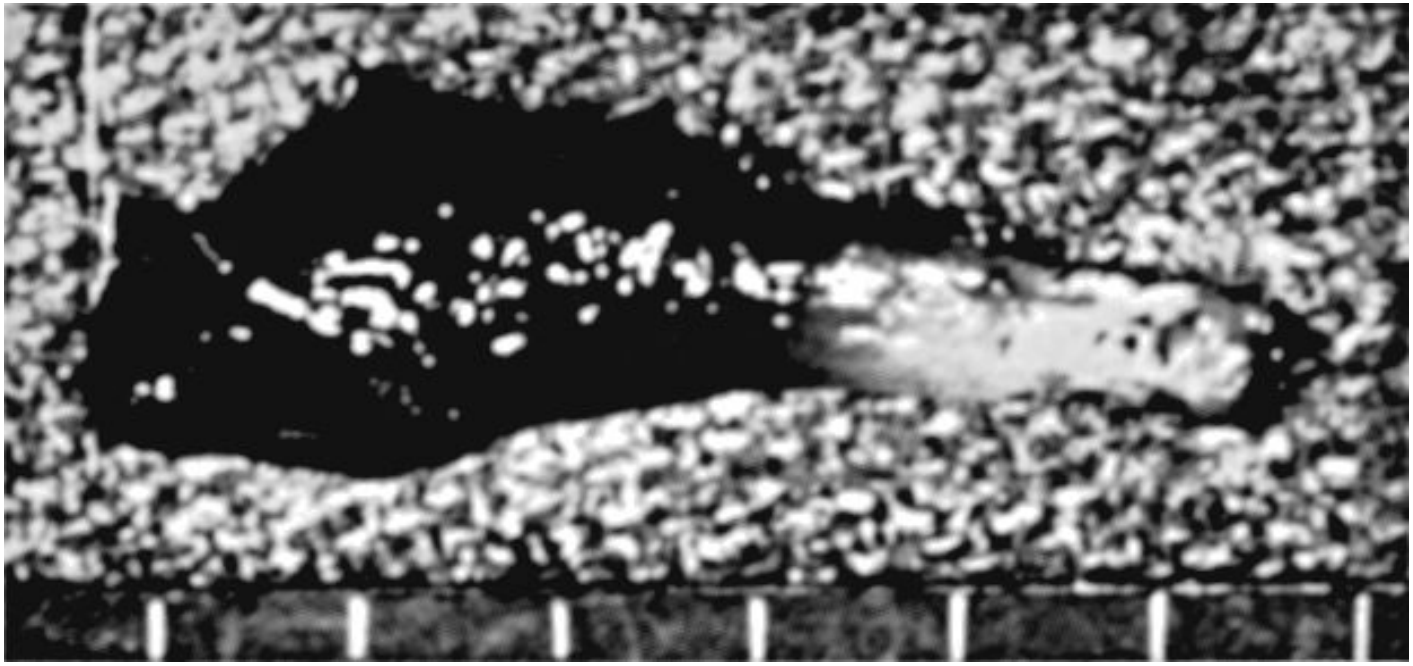
- After full transition of the child to heterotrophic type of feeding the intensity of distant digestion steadily increases.
- Simultaneously the activity of membranous digestions on enterocytes weakens. Since age the gradual reduction of lactase activities in enterocytes occurs even some adult persons should not ingest native cows` milk at all.
- Colonic Lactobacillus and Bifidobacteriaceae microbiota progressively decrease in their quantity since infancy till toddlerhood.

Particularities of bowel motor functions in children.

- **The bowel motor function is realized in children due to deep pendullar movement mixing food and peristaltic waves promoting food output. The intestinal active motility is reflecting in the frequency of defecations.**

Meconium

- **During the first days (before 72 hours) after the birth a well children discharge stool. It calls meconium. The meconium (or inborn stool) is greenish-black of color. It contains the bile, epithelial cells, enzymes swallowed with amniotic fluids. Commonly the first portion of meconium contains also the solid meconial plug which in proper measure protects the prematurely defecation in uteri.**



Anorectal plug from child who had not passed meconium for 2 days after birth. Pale end was adjacent to the anus.

Meconial aspiration

- Some times the fetus should do defecation in uteri before the birth or during the labor.
- The intrauteral hypoxia predisposes the fetus for defecation. This condition is usually undesirable because of dangerous consequences following by high risk of aspiration.
- The meconial aspiration happens in babies during their first breath having faces clots in mouth and airways.
- So the finding of meconium clots in amniotic fluid before delivery obliges the medical staff to get ready for newborns` management. If there is a situation of high risk the trachea intubation has to be performed immediately for meconium suction from the airways. In opposite case without care the severe bronchial obstruction and neonatal pneumonia can occur.

Stool

- **In well newborns and breast fed infants the stool has a soft consistency, is golden-yellowish coloration and acidous smell. At a contact with air the stool of well infants some times is getting greenish. In infants the reflex to defecate occurs 3-6 times per day or less for the first 2 mo, and after it becomes rarer. The older children excrete stool 1 - 2 times daily and even day by day.**