Kidney International, Vol. 34 (1988), pp. 273–277

HISTORICAL ARCHIVES

Theory of urine formation and uroscopic diagnosis in the Medical School of Salerno

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Salerno is a little town lying on the seaside in southern Italy. Early after the fall of the Roman Empire, Salerno became the capital of an independent Lombard dukedom and the site of a rich and potent bishop. Monks living in the monastery of the Cathedral were the first to practice medicine, by growing and collecting the "simplices", that is, the "simple" basic herbs that were used to compound medications. The reputation of these monks attracted secular students, and with time also "Magistri" (Masters) of medicine settled in Salerno, giving rise to a permanent school.

The Salernitan School was active from the 9th to the 15th centuries, and for a long time (between the 10th and the 14th century) was the most important school of medicine in Europe. The geographic position of the town was a main determinant of the success of the medical school. Salerno, in fact, is very close to Amalfi, one of the four Marine Republics (with Genoa, Pisa and Venice) that had the monopoly of trade in the Mediterranean Sea during the Middle Ages. Consequently, Amalfi and the nearby Salerno were melting pots of Latin, Greek, Arabian and Eastern cultures, all of which contributed medical knowledge to the Salernitan School. Of special importance was the influence of the Arabian medicine. One of the most famous magistri of the Salernitan School, in fact, was the Arabian Constantinus Africanus (11th century), who translated into Latin the writings of the greatest physician of Islam, Isaac Ebreus (880–940. A.D.) [1]. Isaac emphasized in his book *Guida Medicorum* (*Guide for Physicians*) the diagnostic importance of urine and fixed in an orderly system of thought the rules of "Uroscopy", that is, the science of urine observation. Thus uroscopy became fundamentally important in Salernitan medicine, in contrast with classic Roman and Greek medicine, which sustained the preeminent diagnostic value of pulse examination over urine observation.

Many Salernitan magistri wrote books specializing on uroscopy; of them, Magister Maurus, Magister Ursus and Gilles de Corbeil were the most famous [2]. Of particular interest is Gilles, who came to Salerno from Paris. After completing his studies, he returned to Paris, where he was one of the first professors of medicine in the University and became the Court physician of the king Philippe-Auguste. Gilles de Corbeil wrote the *Carmina de Urinarum Iudiciis* (*Songs on Urinary Judgments*) a composition in verse that was famous in Europe until the 16th century.

Received for publication October 15, 1986
and in revised form April 20 and September 25, 1987

Theory of urine formation

The theory of urine formation as it was conceived in Salernitan medicine was clearly defined by Magister Maurus in his book *Regulae Urinarum* (*Rules on Urine*) written around 1250. According to this theory urine is the result of three consecutive processes of "digestion", where the word digestion indicates a separation between the "pure" and the "impure" part of a biological fluid [3].

The first digestion occurs in the stomach and the initial tracts of the bowel called "Portanarium", "Duodenum" and "Jejunum" (Fig. 1). The "pure" part of the juice contained in these organs is separated and enters the "Venae Meseraicae" (Mesenteric veins), then arriving at the liver through the "Vena Lactea Porta" (The Portal vein, called "lactea", that is, milky).

The second digestion takes place in the liver (Fig. 2). This digestion is most important, because during this digestion the "humors" are generated. The "humors" are the four fluids whose combination determines both the physical and psychological characters of any individual. They are the blood, the choler, the phlegm and the melancholy. The blood is the "pure" content of the fluid entering the liver from the bowel. In contrast, choler, phlegm and melancholy are specific impurities that are separated in the digestive process. After separation of the humors, a non-specific impurity remains, a "superfluitas" (a superfluous remainder): this is urine. Once generated, the humors are drained from the liver to different organs. The choler is concentrated in the gall bladder, the phlegm in the lungs, brain, joints, the melancholy in the spleen. The blood enters the "vena quilim" (the inferior vena cava) in association with urine. Small amounts of the "impure" humors, however, flow into the vena quilim and are mixed with blood and urine. This mixture goes to the kidneys where urine is filtered through specific holes, the "uritides pori".

Even if urine is formed in the second digestion, the quality of urine depends to a large extent on what occurs in the third digestion (Fig. 3). This takes place in all peripheral tissues, where blood is transported, after leaving the kidneys, by the peripheral venous system (the medieval medicine ignored the difference between arterial and venous circulation). In peripheral organs, the blood goes out of the veins through holes that

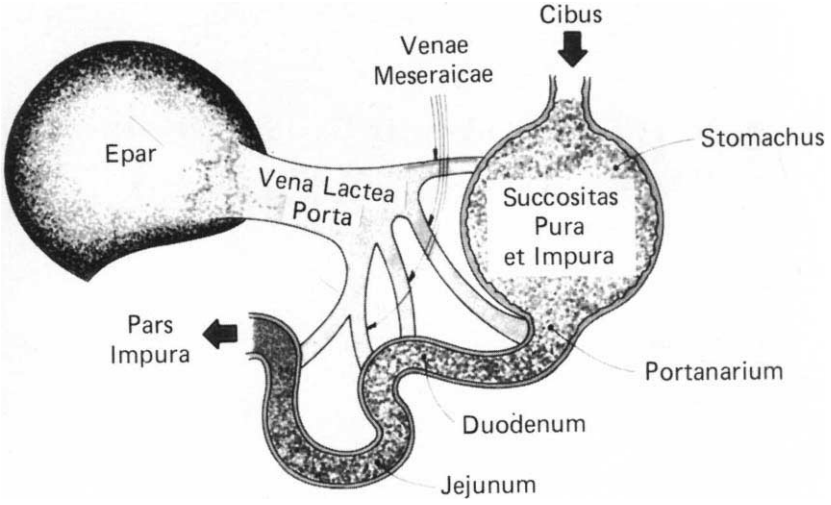

Fig. 1. *The first Digestion in Salernitan Medicine.* Translation of Latin names: epar, liver; vena lactea porta, portal vein; pars impura, impure part; venae meseraicae, mesenteric veins; cibus, food; succositas pura et impura, juice pure and impure.

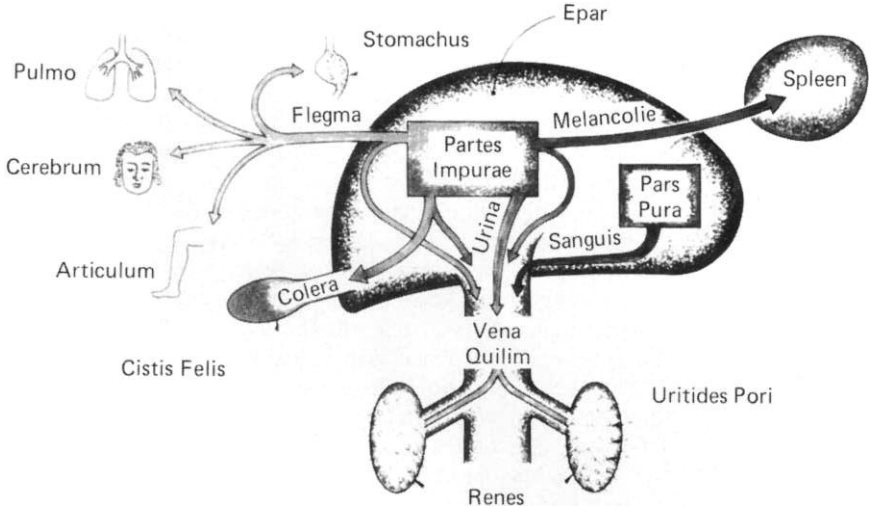

Fig. 2. *The second Digestion in Salernitan Medicine.* Translation of Latin names: pulmo, lung; cerebrum, brain; articulum, joint; cistis felis, gall bladder; stomacus, stomach, partes impures, impurities; epar, liver; splen, spleen; sanguis, blood; colera, choler, flegma, phlegm; melancolie, melancholy; renes, kidneys.

are called "meatus". In this passage to the tissues blood is digested, that is purified, it becomes whitish and clear and it is eventually transformed in the substance itself of the tissues. In the healthy individual, the impure part of blood gives rise during the third digestion to sweat and heat. But, whenever there is a disease, this interferes with the third digestion. The disease, in fact, results in excess of one of the humors in the diseased member of the body. The excess of humor is drained back into the veins through the same meatus from which blood comes out, and is transported to the liver. Here, the excess of humor is mixed with urine and is eventually excreted with urine by the kidneys. Thus, the quality and characteristics of urine are changed by the excess of humor. The latter concepts are distinctive of Salernitan medicine and were derived from the assumption of Isaac Ebreus that "urina est colamentum sanguinis et aliorum umorum" (urine results from straining blood and the other humors), in contrast with Classic medicine in which urine was considered a strain of blood only [4].

Uroscopic diagnoses

The aforesaid theories give a rationale to uroscopic diagnoses. A disease in any member of the body, in fact, will result in a change in the quality of urine, and the change will be specific, depending on the humor present in excess. The last point may seem intriguing to us, but identification of the guilty humor was actually simple for medieval physicians. They learned, in fact, from Classic medicine that any humor has its specific qualities (Table 1). Blood and choler are "warm", phlegm and melancholy are "cold". Blood and phlegm are "humid", choler and melancholy are "dry". In addition, they knew that the degree of heat is unrevealed by the color of urine, because heat intensifies while cold mutes color. Thus, a very hot urine is black, a warm urine is red, a cold urine is pale green, and an iced urine is white [2]. Also the degree of humidity can be understood by taking into account the density of urine, because humidity increases density. A humid urine is dense and non-transparent, a dry urine is light, clear, transpar-

Table 1. The qualities of humors according to the Medical School of Salerno

	Blood	Choler	Phlegm	Melancholy
Temperature	Warm	Warm	Cold	Cold
Degree of humidity	Humid	Dry	Humid	Dry

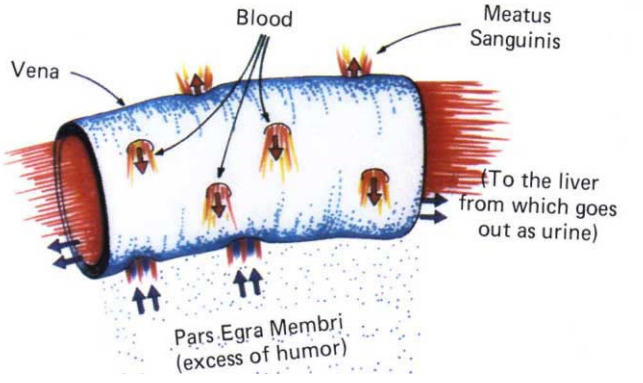

Fig. 3. *The third Digestion in Salernitan Medicine.* Translation of Latin names: vena, vein; pars egra membri, diseased part of a member (of the body); meatus sanguinis, "meatus" of blood. Blood (red) goes out from the vein through the same holes (meatus) by which the excess of humor (blue) enters the vein.

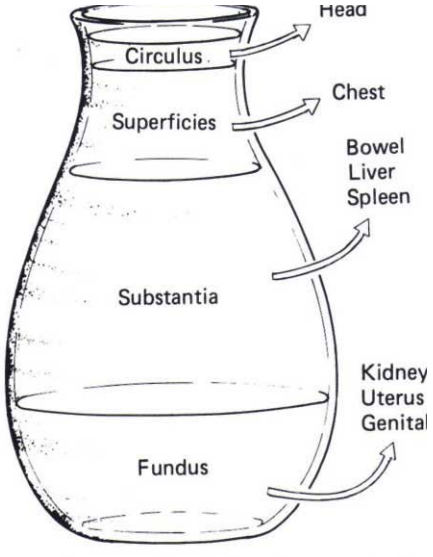

Fig. 4. *The matula, special bottle for urine examination.*

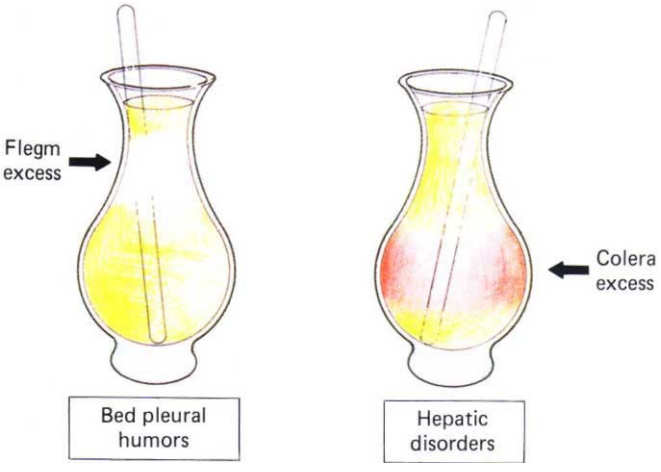

Fig. 5. *Examples of changes in urine useful for uroscopic diagnoses.*

ent. The appropriate combination of color and density will, therefore, unmask what humor is responsible for the disease. These physicians could also discern the location of disease, or excess secretion of humors, within the body. This information can be obtained by examining urine in an appropriate container, a bottle of glass called "matula". Medieval manuscripts give detailed descriptions of both the shape and the quality of glass by which the matula should be made [5]. Figure 4 reproduces a idealized matula; its shape is very important because, once it is filled with urine, the urine occupying the "circulus" (ring, the most superficial part) will correspond to the head; the urine in the "superficies" (the neck of the bottle) to the chest; the urine in the "substantia" (the central part of the bottle) to the abdomen; the urine in the "fundus" (the bottom) to the genito-urinary organs. Thus, changes occurring in urine at different levels in the matula indicate diseases in the corresponding regions of the body. Examples of uroscopic diagnoses are depicted in Figure 5, that has been drawn following the descriptions of an anonymous manuscript of the 14th century [6]. Urine on the right has a red color in the middle ("substantia") and is transparent. This indicates excess of choler in the liver, a hepatic disorder. Urine on the left has a whitish and dense appearance in the "superficies". This means that there is an excess of phlegm in the lungs, or "bed pleural humors". Not all diagnoses were, however, so simple and direct. It was the skill of the physician to understand nuances of color and transparency and to associate them with other signs of disease, thus arriving at the diagnosis. How sophisticated and varied these could be is shown by the content of an anonymous manuscript [6], that we have translated for the first time from Latin into English in the **Appendix**.

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Appendix

Here following is the translation of an anonymous manuscript of the Salernitan School, entitled "De Urinis". The manuscript was written between the 13th and the 14th century and is now kept in the Putti library of the Istituto Ortopedico Rizzoli, in Bologna, Italy.

About urine

Since we are going to deal with the science of urine, we have to take into account anything is known about urine with subtle diligence. It is known in which way urine is generated from food! Food, properly received to cure the main defects of both the body and the heart, is processed into a juice whose particles are masticated by the stomach. A rough content is left, the superfluous part of which is transmitted through the "pro-

portonarium"[1] to the duodenum and then the digiunum; the part of this juice that remains after the first digestion is collected in the bowel, while the superfluous juice is received, through the mesenteric veins, by the branched vein of the liver in which, by natural virtue, the different humors are operated in a way depending on the essential properties of that juice. The digestive virtue of the colon, in fact, transforms into "silicem humorem"[2] the dry content of that juice, and so on. Thus, if choleric essence is abundant in dudenum, choler (is generated), if bloody essence blood (is generated), and so on. And since urine is a remnant part of this digestion that generates the humors, urine retains the humidity: therefore, in healthy people, in whom digestion takes place in the body will be apparent; in ill people, the humor that is the cause (of the disease) will appear from the color of urine; similarly, the matter of the same (humor) will be shown by the parts of urine, and we shall understand the symptoms of disease by means of urine's transparency. Urine, therefore, is divided into four parts: the first is the "circulus" (ring), the second is the "corpus acreum" (acrid body), the third is the "perforacia" (filter), the fourth is the "fundus" (bottom).

We will understand, therefore, that there is a disease of the head, or of the brain, by means of the "circulus"; in the "corpus acreum" (we will understand) a disease of the respiratory ways or of the stomach; in the "perforacia" of the liver and the spleen; in the "fundus" of the kidneys, the bladder, the reproductive apparatus and the legs.

Therefore, if we have to know why the forehead is warm and humid, why the blood is excessive in the right (half of the head), or flows down of the left part, or flows better in the rear, the color of the circulus will be the indicator. When blood is excessive, this may be excessive into the veins and give rise to the "sinoche"[3]; sometimes the blood is excessive out (of the veins) and pleurisy or pleuropneumonia occurs. Thus, urine will be red or reddish and dense, far from the good transparency, indicating sinoche.

Urine diffusely red, quite clear, indicates "epimasticatio"[4]; in this urine, a sediment apparently black or green indicates coming death. Urine red or reddish, uniformly altered, with some green obscurity at the surface of the acrid body means pleurisy; without the green color, it indicates inflamed blood in the highest part of head. Urine red or reddish, omogeneous, and with some livid obscurity around the acrid body, means pleuropneumonia, unless a vein has been broken in the kidneys or there are menses, or jaundice. Urine red or reddish, equally disturbed, shows a continuous fever; but it is equally disturbed in hyperacute diseases as when digestion begins.

Light urine in "interpolatis"[5] that begins to thicken due to some matter indicates digestion, but when the choler becomes putrid, sometimes this occurs in veins, sometimes out (of the veins); in veins (the choler) becomes putrid either alone or together with blood; if it is alone it causes a tertian fever, if it is with blood it causes sinoche or "causon"[6], if it is associated with phlegm it causes "emitreum".[7]

Rubicond urine, uniformly altered, purple in the middle, with a color like arsenic at its surface, indicates causon. Red or reddish urine, uniformly altered, having the same color in every point, indicates either emitreum or persistent tertian fever.

Urine red and reddish, shadowed and quite black both in its upper and lower part indicates double tertian fever. Rubicond urine uniformly disturbed, close to the color of liver, shows sinoche, unless there is a flow from the belly or an alteration of the liver. Urine citrine and pale is a sign of choler when it begins to be citrine, and indicates the well-known tertian fever if it becomes shadowed both in its upper and lower part.

Urine red whose color begins to fade, shadowed in its upper and lower part, clear in its middle, indicates liver disease.

When phlegm becomes putrid, this occurs either in veins or out (of the veins): when in veins it causes daily continuous (fever) or minor emitreum. Therefore, urine diluted and white with a quite black color close to the circulum, and glaucous circulum, shows minor emitreum.

Urine red or reddish, lightly shadowed in its upper part, with a white circulum, indicates daily fever due to salt phlegm; urine red and thick, with a red circulum indicates daily fever due to sweet phlegm.

Urine pale, with a glaucous circulum, indicates defective phlegm with black acetic content. Urine thick and white, while a disease is healing, shows that the matter of the disease is purged. The melancholy can become putrid; sometimes this occurs in the veins, sometimes out (of the veins), when it becomes putrid in the veins it causes major emitreum, or continuous quartan fever—this is the opinion of Joannem de Plateario—and when it becomes putrid out of the veins it determines interpolate quartan fever. Urine black, whose circulum is diffusely altered, indicates major emitreum. Urine at the beginning of quartan fever is glaucous, at the end of fever is black.

Clear urine with several small rods indicates disorder of spleen. Clear and white urine, clear around the middle region, indicates pain or stone in the kidneys, or pain in the liver.

Milky and thick and scant urine, with scales, shows stones in the body; without scales diarrhea; if it is completely without scales and (flows) in drops, it indicates defect of micturition. Urine scant and dense, red or reddish, containing wide and red particles, shows dysentary.

Red urine, with round white corpuscles in its upper region, quite dense, indicates ectic fever.[8] Yellow urine which is pale with granules at the surface of the acrid body, indicates "phtisim".[9] Urine pale in its lower part indicates renal pain in males, genital defect in females.

Urine which is white after having been colored, with green circulus, means frenzy. Indeed, a black circulus in this urine

[1] The Proportonarium corresponds to the pylorus.

[2] The meaning of "silicem humorem" is not clear. Literally, it means "silica humor". In the context, this expression may allude to the ability of the colon to transform the fluid content of the intestine into a matter dry like silica.

[3] Sinoche indicates a fever lasting only a few days, associated with minor sensorial disturbances.

[4] Epimasticatio means chewing (masticatio) that occurs superficially (epi). In the context, this expression indicates an incomplete digestion.

[5] Interpolatis are the days without fever between two fever attacks.

[6] Causon is a very high, burning fever.

[7] Emitreum is a fever that occurs every other day.

[8] Ectic fever is a continuous fever.

[9] Phtisim indicates wasting of the body.

announces death. Urine which is dense and lead-gray close to the middle region indicates paralysis. Light and white urine, abundant and citrine in its upper region, which is associated with thirst indicates diabetes.

Citrine or clear urine, pale, almost green, in males indicates pain in the stomach, in females indicates inflammation or phlegm from the umbilicus to the throat, and thirst.

Thick urine, glassy, warm in its upper part, indicates difficult digestion either in the kidneys or in the bladder, alternatively it may indicate bad pleural humors.

Milky urine, shadowed in its upper and lower part, clear in the middle region, is a sign of hydropisis. When a green or black sediment occurs in any acute disease, death can undoubtedly be expected.

Urine which is shadowed in the perforacia indicates engorgement of the stomach or the liver. Urine which is Citrine or red with fluid beams means disease of the spleen.

A red circulus means pain in the head due to blood. A white circulus, dense and livid, indicates pain in the forehead due to phlegm. A thin and green circulus indicates headache due to choler. A glaucous and black circulus indicates pain due to melancholy.

It should be known that urine is especially indicative of two things: either suffering of the liver and veins or of the bladder and kidneys. Among other things, urine is correctly considered to consist of three parts, that is, the color, the substance and the sediment. The color, the substance and the sediment have different origins. In the human body, there are four qualities: heat, cold, dryness and humidity. Two of them are the origin of the color, and two are the origin of the substance: heat renders urine colored, cold decreases urine's color; dryness attenuates the substance, humidity gives rise to a dense substance. Therefore, if urine is red and dense, this means that blood has been given; if (urine is) red and thin, choler; if (urine is) white and thin, this means that melancholy has been given. But, since the head is the root of all diseases, we have to begin from it. If urine has a large circulus, this indicates fatness of the head. A red circulus is caused by blood in the forehead. A circulus yellow and thin means choler in the right part. A dense and white circulus is phlegm in the posterior part of the head. A black or white thin circulus is from melancholy in the left part.

It should be seen that red and dense urine in the course of fever means a sinoche fever. This occurs from blood, which is warm and humid; heat renders urine red, humidity dense.

If in the course of fever urine is red and thin, this indicates tertian fever, caused by choler. Choler, in fact, is warm and makes urine red, and is dry, thus making urine thin; when urine is white and dense, it means a quotidian fever, caused by phlegm. Phlegm is cold and humid: cold makes urine white, humidity makes urine dense. But you have to know that when in a quotidian fever urine becomes abundant and red, this indicates relief of fever. Abundancy, in fact, means that the fever has removed the viscous and adherent matter of phlegm. If urine was white and thin in the course of quartan fever, fever occurred from melancholy. Melancholy is cold and dry: cold makes urine white, dryness makes urine thin. But, appearance of urine dense and black in quartan fever means relief of fever.

Light and milky urine, and small volume indicates bladder stone; if sandy sediments appear in urine for a long time, this means that there are stones in the kidney, or that stones will be formed in the future.

Urine sulphurous or foamy means a bruise in the bladder. Urine having a black "ypostasi"[10] during an acute illness means death. Green urine, with a green ypostasi, and small volume during an acute illness means jaundice. Black and small volume urine in the course of acute fever indicates death.

Small volume urine which is sulphurous indicates diarrhea. Abundant and colored urine with sulphurous content indicates commotion of the whole body. Livid urine during an acute fever with livid ypostasi means death.

Urine of a woman or of a man that had a sexual intercourse with a woman is similarly turbid and has a serosity in the bottom.

Urine during menses is almost bloody.

Urine of pregnant woman in the first or second or third (period of gestation) is very clear, and has a great amount of white ypostasi in the bottom; in the fourth (period) pregnant women make a transparent urine with a white and dense ypostasi.

Foamy urine in the upper part indicates toxic disorder and pain of both the kidneys. But one should observe whether this foam occurs in a white or reddish urine. In the latter case, the right kidney has more pain because the right side is more warm than the left side.

Urine is black in all disorders causing death, but in quartan fever, soon after the end of menses, is in disorders of the spleen and in chest pain.

Urine of old women should be white and dense and with a red nuance. Urine of a vicious woman is quite colored. Urine of a virgin girl is clear, white, light and transparent, and after she has corrupted urine will be quite dense. In all vicious women, urine is cloudy by night and dense in the bottom in the morning. Urine of a virgin is light, red or pale, with very small bubbles in the surface. You will recognize urine of a pregnant woman in this way: from the first to the seventh day urine will be very turbid. Indeed, you will know that she has conceived from fragmentation of the ypostasi, between the seventh day and the fourth month. After the fourth month (the pregnant woman) makes transparent urine, with dense white sediment. If urine of a healthy woman reflects your image like a mirror, then you can say that she is pregnant.

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[10]Ypostasi is synonymous with sediment.

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