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GENERALIZED NET MODEL OF REPRODUCTIVE SYSTEM. Part 1 [1]

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1. Introduction

A subnet of the Generalized Net (GN; see [1]) model of human body (see [2,3]) will be discussed.

The reproductive system is the combination of organs and tissues associated with the process of reproduction. Hormones play a dominant part in the physiology of reproduction. Under the influence of releasing factors from the hypothalamus, the anterior pituitary gland produces gonadotrophic hormones which control the activity of the gonads, ovaries in the female and the testes in the male (GN 1). The overall function of the male reproductive system is to produce mature, active sperm and to deliver them outside the body. Spermatogenesis is regulated by secretions from the anterior pituitary gland. Luteinizing hormone (LH) stimulates the interstitial cells of the testes to produce testosterone, which than aids in the process of spermatogenesis. Maintenance of spermatogenesis is assisted by follicle-stimulating hormone (FSH) and growth hormone (GN 2). The function of the female reproductive system is twofold: (1) to produce fertile eggs or ova, and (2) to provide an environment capable of supporting embryonic development if an egg becomes fertilized. The ovaries and the pituitary have a reciprocal effect on one another. During oogenesis, cells surrounding the developing ovum assist in the maturition process and form a spherical structure called a follicle. It continues to grow under the influence of FSH, released from the anterior pituitary gland. In addition, FSH stimulates the cells of the follicle to produce estrogen. As estrogen levels increase, the follicles begin to inhibit the further release of FSH. Ovulation is achieved with the aid of LH. After ovulation, the cells of the follicle are trnasformed into a structure called corpus luteum. LH stimulates the corpus luteum to produce progesteron. Progesteron continues preparation of the uterus for fertilization. The life span of the corpus luteum is approximately ten days and if implantation of a fertilized egg does not occur, the corpus luteum regresses. This event coincides with a decrease in progesteron concentration which includes the lining of the uterus to slough, and causes the characteristic bleeding (menstruation), as shown on GN 3.

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2. Global GN-model of reproductive system (Fig. 1)

At each time-step a token with initial characteristic "either man or woman" enters place l_1.

$$Z_1 =< \{l_1\}, \{l_2\}, \begin{array}{c|c} & l_2 \\ \hline l_1 & true \end{array}, \wedge(l_1) > .$$

The token from place l_1 enters place l_2 with a characteristic "there is activation of the hypothalamus structures connected with the anterior pituitary gland".

$$Z_2 =< \{l_2, l_7, l_9\}, \{l_3\}, \begin{array}{c|c} & l_3 \\ \hline l_2 & W_{2,3} \\ l_7 & W_{7,3} \\ l_9 & W_{9,3} \end{array}, \wedge(l_2, l_7, l_9) >,$$

where
$W_{2,3}$ = "activation of the production of gonadotropin-releasing hormones",
$W_{7,3}$ = "inhibition of the secretion of releasing hormones",
$W_{9,3}$ = "inhibition of the sensitivity of releasing hormones".

The tokens obtain characteristic "a gonadotropin-releasing hormone is secreted from the hypothalamus" in place l_3.

$$Z_3 =< \{l_3, l_6\}, \{l_4, l_5\}, \begin{array}{c|cc} & l_4 & l_5 \\ \hline l_3 & W_{3,4} & W_{3,5} \\ l_6 & W_{6,4} & W_{6,5} \end{array}, \wedge(l_3, l_6) >,$$

where
$W_{3,4}$ = "stimulation of the secretion of follicle-stimulating hormone from the anterior pituitary",
$W_{3,5}$ = "stimulation of the secretion of luteinizing hormone from the anterior pituitary",
$W_{6,4}$ = "inhibition of the secretion of follicle-stimulating hormone from the anterior pituitary",
$W_{6,5}$ = "inhibition of the secretion of luteinizing hormone from the anterior pituitary".

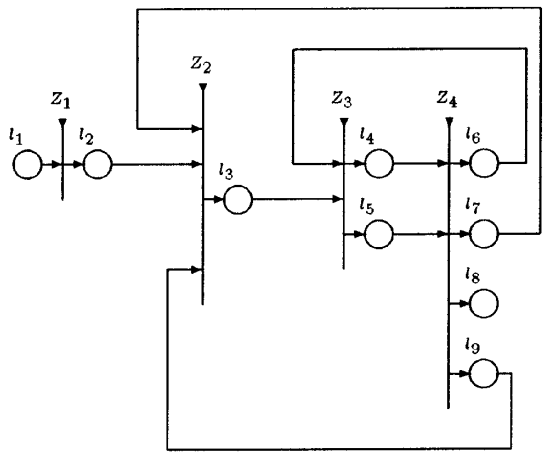

Fig. 1

The tokens obtain characteristic "the gonadotropic follicle-stimulating hormone is secreted from the anterior pituitary gland" in place l_4 and "the gonadotropic luteinizing hormone is secreted from the anterior pituitary gland" in place l_5.

$$Z_4 =< \{l_4, l_5\}, \{l_6, l_7, l_8, l_9\}, \begin{array}{c|cccc} & l_6 & l_7 & l_8 & l_9 \\ \hline l_4 & W_{4,6} & W_{4,7} & W_{4,8} & W_{4,9} \\ l_5 & W_{5,6} & W_{5,7} & W_{5,8} & W_{5,9} \end{array}, \wedge(l_4, l_5) >,$$

where
$W_{4,6}$ = "follicle-stimulating hormone stimulates the gonads to produce estrogen sex steroid hormones",
$W_{4,7}$ = "follicle-stimulating hormone stimulates the gonads to produce androgen sex steroid hormones",
$W_{4,8}$ = "follicle-stimulating hormone stimulates the production of gametes (sperm and ova)",
$W_{4,9}$ = "follicle-stimulating hormone stimulates the gonads to produce inhibin",
$W_{5,6}$ = "luteinizing hormone stimulates the gonads to produce estrogen sex steroid hormones",
$W_{5,7}$ = "luteinizing hormone stimulates the gonads to produce androgen sex steroid hormones",
$W_{5,8}$ = "luteinizing hormone stimulates the production of gametes (sperm and ova)",
$W_{5,9}$ = "luteinizing hormone stimulates the gonads to produce inhibin".

The tokens obtain characteristic "estrogen sex steroid hormones are secreted" in place l_6, "androgen sex steroid hormones are secreted" in place l_7, "gamets (sperm or ova) are produced" in place l_8 and "the polypeptid hormone inhibin is secreted" in place l_9.

3. GN-model of male reproductive system (Fig. 2)

In each time-step a token with initial characteristic "male person" enters place l_1.

$$Z_1 =< \{l_1\}, \{l_2\}, \begin{array}{c|c} & l_2 \\ \hline l_1 & true \end{array}, \wedge(l_1) > .$$

The tokens from place l_1 enter place l_2 with a characteristic "there is activation of the hypothalamus structures related to the anterior pituitary gland".

$$Z_2 =< \{l_2, l_8, l_{13}\}, \{l_3\}, \begin{array}{c|c} & l_3 \\ \hline l_2 & W_{2,3} \\ l_8 & W_{8,3} \\ l_{13} & W_{13,3} \end{array}, \wedge(l_2, l_8, l_{13}) >,$$

where
$W_{2,3}$ = "activation of the production of gonadotropin-releasing hormones",
$W_{8,3}$ = "inhibition of the secretion of releasing hormones",
$W_{13,3}$ = "inhibition of the sensitivity of releasing hormones".

The tokens obtain characteristic "a gonadotropin-releasing hormone is secreted from the hypothalamus" in place l_3.

$$Z_3 =< \{l_3\}, \{l_4, l_5\}, \begin{array}{c|cc} & l_4 & l_5 \\ \hline l_3 & W_{3,4} & W_{3,5} \end{array}, \wedge(l_3) >,$$

where
$W_{3,4}$ = "stimulation of the secretion of follicle-stimulating hormone from the anterior pituitary",
$W_{3,5}$ = "stimulation of the secretion of luteinizing hormone from the anterior pituitary".

The tokens obtain characteristic "the gonadotropic follicle-stimulating hormone is secreted from the anterior pituitary gland" in place l_4 and "the gonadotropic luteinizing hormone is secreted from the anterior pituitary gland" in place l_5.

$$Z_4 =< \{l_4, l_5\}, \{l_6, l_7\}, \begin{array}{c|cc} & l_6 & l_7 \\ \hline l_4 & W_{4,6} & W_{4,7} \\ l_5 & W_{5,6} & W_{5,7} \end{array}, \wedge(l_4, l_5) >,$$

where
$W_{4,6}$ = "follicle-stimulating hormone stimulates the seminiferous tubules of testes",
$W_{4,7}$ = "follicle-stimulating hormone stimulates the seminiferous tubules of testes",
$W_{5,6}$ = "luteinizing hormone stimulates the interstitial Leydig cells of testes",
$W_{5,7}$ = "luteinizing hormone stimulates the interstitial Leydig cells of testes".

The tokens obtain characteristic "seminiferous tubules are stimulated"
in place l_6 and "interstitial Leydig cells are stimulated" in place l_7.

$$Z_5 =< \{l_6\}, \{l_8, l_9\}, \begin{array}{c|cc} & l_8 & l_9 \\ \hline l_6 & W_{6,8} & W_{6,9} \end{array}, \wedge(l_6) >,$$

where
$W_{6,8}$ = "the secretion of inhibin is stimulated",
$W_{6,9}$ = "the spermatogenesis is stimulated".

The tokens obtain characteristic "inhibin is secreted" in place l_8 and "production of sperm" in place l_9.

$$Z_6 =< \{l_7\}, \{l_{10}, l_{11}\}, \begin{array}{c|cc} & l_{10} & l_{11} \\ \hline l_7 & W_{7,10} & W_{7,11} \end{array}, \wedge(l_7) >,$$

where
$W_{7,10}$ = "the interstitial cells maintain the spermatogenesis",
$W_{7,11}$ = "the interstitial cells produce testosterone".

The tokens obtain characteristic "maintenance of the spermatogenesis" in place l_{10} and "secrete testosterone" in place l_{11}.

$$Z_7 =< \{l_9, l_{10}\}, \{l_{12}\}, \begin{array}{c|c} & l_{12} \\ \hline l_9 & true \\ l_{10} & true \end{array}, \wedge(l_9, l_{10}) > .$$

The tokens obtain characteristic "spermatozoides are produced" in place l_{12}.

$$Z_8 =< \{l_{11}\}, \{l_{13}, l_{14}\}, \begin{array}{c|cc} & l_{13} & l_{14} \\ \hline l_{11} & W_{11,13} & W_{11,14} \end{array}, \wedge(l_{11}) >,$$

where
$W_{11,13}$ = "the testosterone reaches the blood and acts as regulator",
$W_{11,14}$ = "the testosterone reaches the blood circulation and acts on the target organs and systems".

The tokens obtain characteristic "feedback control via the blood" in place l_{13} and "via the blood circulation reaches the target organs and tissues" in place l_{14}.

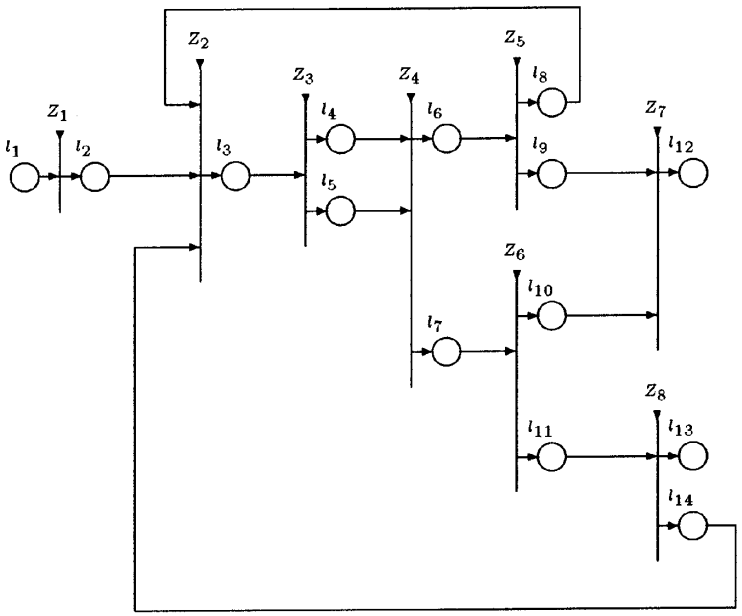

Fig. 2

4. GN-model of mature woman's reproductive system (Fig. 3)

In each time-step a token with initial characteristic
"adult woman" enters place l_1.

$$Z_1 =< \{l_1\}, \{l_2\}, \frac{l_2}{l_1 \mid true}, \Lambda(l_1) > .$$

The tokens from place l_1 enter place l_2 with a characteristic "there is activation of the hypothalamus structures related to the anterior pituitary gland".

$$Z_2 =< \{l_2\}, \{l_3\}, \frac{l_3}{l_2 \mid true}, \Lambda(l_2) > .$$

The tokens obtain in place l_3 the characteristic "a gonadotropin - releasing hormone is secreted from the hypothalamus".

$$Z_3 =< \{l_4\}, \{l_3\}, \frac{l_4}{l_3 \mid true}, \Lambda(l_3) > .$$

The tokens obtain in place l_4 the characteristic "the anterior pituitary gland secretes the follicle-stimulating hormone".

$$Z_4 =< \{l_4\}, \{l_5\}, \begin{array}{c|c} & l_5 \\ \hline l_4 & true \end{array}, \wedge(l_4) > .$$

The tokens obtain in place l_5 the characteristic "there is maturing of follicles and ova".

$$Z_5 =< \{l_5\}, \{l_6, l_7\}, \begin{array}{c|cc} & l_6 & l_7 \\ \hline l_5 & true & true \end{array}, \wedge(l_5) > .$$

The tokens obtain characteristics "the ovum is released from ovary" in place l_6 and "an empty follicle remains" in place l_7.

$$Z_6 =< \{l_6\}, \{l_8, l_9\}, \begin{array}{c|cc} & l_8 & l_9 \\ \hline l_6 & W_{6,8} & W_{6,9} \end{array}, \wedge(l_5) >,$$

where
$W_{6,8}$ ="the ovum is fetilized",
$W_{6,9} = \neg W_{6,8}$.

The tokens obtain characteristics "the ovum is fertilized" in place l_8 and "corpus luteum" in place l_9.

$$Z_7 =< \{l_8\}, \{l_{10}, l_{11}, l_{12}\}, \begin{array}{c|ccc} & l_{10} & l_{11} & l_{12} \\ \hline l_8 & W_{8,10} & W_{8,11} & W_{8,12} \end{array}, \wedge(l_8) >,$$

where
$W_{8,10}$ ="there is pregnancy with lactation",
$W_{8,11}$ ="there is pregnancy with parturition",
$W_{8,12} = \neg W_{8,10} \& \neg W_{8,11}$.

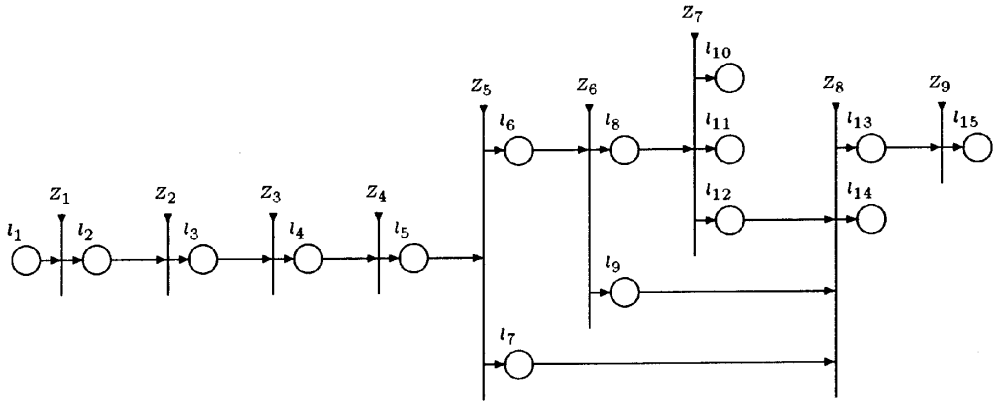

Fig. 3

The tokens obtain characteristics "lactation is stimulated (go to GN model related to lactation [2]" in place l_{10}, "end of pregnancy (papturition) in place l_{11} and "corpus luteum is formed" in place l_{12}.

[2]This GN is in a preparation.

$$Z_8 =< \{l_7, l_9, l_{12}\}, \{l_{13}, l_{14}\}, \begin{array}{c|cc} & l_{13} & l_{14} \\ \hline l_7 & W_{7,13} & W_{7,14} \\ l_9 & false & true \\ l_{12} & true & false \end{array}, \wedge(l_7, \vee(l_9, l_{12})) >,$$

where
$W_{7,13}$ ="there is token in place l_{12}",
$W_{7,14}$ ="there is token in place l_9".

The tokens obtain characteristic "there is degeneration of corpus luteum to corpus albicans" in place l_{13} and "the pregnancy maintains the mother corpus luteum and its production of estradiol and progesterone" in place l_{14}.

$$Z_9 =< \{l_{14}\}, \{l_{15}\}, \begin{array}{c|c} & l_{15} \\ \hline l_{14} & true \end{array}, \wedge(l_{14}) > .$$

The tokens obtain characteristic "there is normal menstruation cycle" in place l_{15}.

References:

[1] Atanassov, K. Generalized Nets. World Scientific, Singapore, New Jersey, London, 1991.

[2] Atanassov K., V. Radeva, A. Shannon, J. Sorsich. Generalized Nets Interpretations of Ivad Dimitrov's Informational Theory of Diseases. "Prof. M. Drinov" Academic Publishing House, Sofia, 2001.

[3] Sorsich J., A. Shannon, K. Atanassov, A global generalized net model of the human body. Proc. of the Conf. "Bioprocess systems'2000", 11-13 Sept. 2000, Sofia, IV.1-IV.4.