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The Hypothetical Secondary Brain of the Excretory Apparatus

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Abstract: *The kidney excretes excess substances through urine: decomposition products of substances foreign to the metabolism and organism (medicines, nutritional supplements). The kidneys also play an important regulatory role (fluid and water balance, pH, blood pressure, hematopoiesis, bone metabolism). The body water is adjustment by osmosis phenomena of the excretory apparatus. Water accounts for 50%-70% of body weight, with an average value of 60%. Starting from Bertalanffy's systems theory, we wrote the differential equation systems of the excretory apparatus. We need to consider the excretory apparatus as a so-called hierarchical system. The excretory apparatus has a two-level control nervous and hormones. So in our opinion, the excretory apparatus should have a control associated with its own structure, which is likely to consist of neurons with hyperordonated spatial structure, called the "hypothetical secondary brain", which performs certain control functions.*
Key words: *excretory apparatus, biophysical modelling, Starling' principle, hypothetical secondary brain*

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I. INTRODUCTION

Excretory processes are the final link in metabolism within the organism; their immediate result is elimination of breakdown products that are of no further use to the organism. The kidney excretes excess substances through urine: decomposition products of substances foreign to the metabolism and organism (medicines, nutritional supplements). The kidneys also play an important regulatory role [1] (fluid and water balance, pH, blood pressure, hematopoiesis [2], bone metabolism). The kidney regulates certain ions of the body (Na^+, K^+ and chlorides) and its total water content, and thus regulates the osmotic pressure [3] of the extracellular space. (Table I..)

Table I. The quantity of the filtration and reabsorb matter

Matter	Filtration quantity	Reabsorb quantity	Excretion quantity	Proportion of reabsorb %
glucose (g/day)	180	160	0	0
bikarkonat mM/day	2160	2159	1	>99,9
Na^+ (mM/day)	25.560	25.410	150	99,4
K^+ (mM/day)	756	664	92	87,8
Cl^- (mM/day)	19.440	19.260	180	99,1
urea (g/day)	46,8	23,4	23,4	50
creatinine (g/day)	1,8	0	1,8	0

In addition to regulating ionic balance, the kidney also plays an important role in the excretion of metabolites resulting from metabolism. The end product of proteolysis is urea (residual nitrogen), while the end product of nucleic acid decomposition is uric acid. Creatinine is the metabolite of muscle metabolism. The kidneys also play an important role in the excretion of many drugs and other foreign substances and in the elimination of red blood cell metabolites (bilirubin) in liver disease.

Distribution of water among the body fluids

Water accounts for 50%-70% of body weight, with an average value of 60%. The percentage of total body water varies, depending on gender and the amount of adipose tissue in the body. Total body water is distributed between two major compartments: intracellular fluid and extracellular fluid**.** Approximately two-

thirds of total body water is in the intracellular fluid, and about one-third is in the extracellular fluid. The body water is adjustment by osmosis phenomena of the excretory apparatus.

The various compartments of the living organisms are separated from one another through membranes with selective permeability. Between two solutions of various concentrations of the same solvent, separated through a membrane impermeable for the solvent, the migration of the solvent takes place from the diluted solution in the concentrated one. This phenomenon is called osmosis. We observe that osmosis [4] is a particular case of diffusion.

If on a part of the semipermeable membrane there is pure solvent and on the other side a solution of this solvent, then the molar concentration of the solvent in the first compartment will be $\mathbf{c_1 = 1}$, and in the second one it will be:

$$c_2 = \frac{m_0}{m_0 + m}$$

where: $\mathbf{m_0}$ – number of solvent molls in the volume unit; **m** – number of the molls of the substance dissolved from the same volume. Since $\mathbf{c_1 > c_2}$, according to the laws of diffusion, the solvent will pass from the first compartment to the second one where its concentration is lower. Following the movement of the solvent from the point of view of the solvate, this being the parameter we are measuring, we can state that the osmotic flow always passes from the more diluted solution towards the most concentrated. The solvent diffuses until the equalising of the existing hydrostatic pressure.

The necessary pressure for preventing osmosis is called osmotic pressure, whose value is calculated on the van't Hoff's law:

$$\boldsymbol{\pi} = \mathbf{R} \cdot \mathbf{T} \cdot \frac{c}{M}$$

where: **c/M** – number of solvate molls; **R** – universal gas constant, **T** – absolute temperature. Osmotic pressure can also be determined through cryoscopic determinations:

$$\boldsymbol{\pi} = \mathbf{R} \cdot \mathbf{T} \cdot \frac{\Delta T}{K_c}$$

where $\mathbf{\Delta T}$ – the difference between the cryoscopic points of the solvate and solvent; $\mathbf{K_c}$ – cryoscopic constant.

Knowing this, we can review the osmosis laws:

– all the solutions of the same concentration, at equal temperatures, have the same osmotic pressure;

– at constant temperature, the osmotic pressure is directly proportional with the value of the solution's concentration;

– when the concentration is constant, the osmotic pressure varies directly proportional with temperature.

The osmosis is frequently found in the living organisms, due to the numerous semipermeable membranes between the various compartments.

The walls of the capillaries, for example, act like such a membrane placed between blood and the interstitial liquid. If the osmotic pressure of a solution coincides with the one of the blood plasma, we talk about an isotonic solution.

The osmotic pressure of the isotonic solutions is equal to the one of the blood plasma, the one of the hypotonic solution is lower and the osmotic pressure of the hypertonic solutions is higher than the plasma's. If the plasma is diluted with a hypotonic solution, the red cells swell osmotically with water, until (in the virtue of the osmosis laws) they break (they lyse). In hypertonic solutions, the red cells loose water and they shrivel. In both cases the red cell's functionality is compromised.

If a semipermeable membrane interposes between two solutions with different molarity ($\mathbf{n_1}$ and $\mathbf{n_2}$) the osmotic pressure will be:

$$\boldsymbol{\pi} = (\mathbf{n_1} - \mathbf{n_2})\ \mathbf{RT}.$$

On equal concentrations, there is no osmotic pressure.

When an external pressure (P) is exerted on the solution different from the osmotic pressure (π), then for $\mathbf{P > \pi}$ the solvent flow goes from the solution towards the solvent and for $\mathbf{P<\pi}$ the solvent flow will have a different direction.

This phenomenon lies at the basis of the capillary exchanges: at the arterial end of the capillaries the blood's hydrostatic pressure is higher then to the osmotic one and the substances pass in the interstitia; at the venous end the osmotic pressure is lower then to the osmotic one and the substances pass in the blood.

In the case of osmosis, the generalized force is the pressure gradient, which generates a volume flow. The characteristic parameter of the process is the osmotic pressure (π). By making the necessary replacements in the general equation of the transport processes, we obtain the relation:

$$\pi = \frac{R.T}{M} \cdot c + \frac{R.T}{V_1 \cdot \rho^2}(0,5 - \tau) \cdot c^2 + \frac{R.T}{V \cdot \rho^3_1} \cdot c^3 + \cdots$$

Sometimes, we find the notion of osmotic mechanical work. (**L**). It shows that in the case of existence of an osmotic pressure π, due to which a substance is transported through a membrane which separates the two compartments, an osmotic mechanical work is performed.

When the two solutions of various concentrations ($\mathbf{c_1 < c_2}$) are separated through a membrane permeable only for the solvent, this will cross the membrane towards the most concentrated solution, until a difference of hydrostatic pressure equal to osmotic pressure $\boldsymbol{\pi = p}$ appears. In this case the system itself performed an osmotic mechanical work (**L**), whose expression can be deducted in the following mode:

$$L = \int_{p_0}^{p_0 + \pi} p \, dV$$

Using the osmosis law, we obtain for osmotic mechanical work:

$$L = \int_{p_0}^{p_0 + \pi} p \, dV = n \cdot R \cdot T \cdot \ln \frac{p_0}{p_0 + \pi}$$

The osmosis laws apply only in certain dilutions: in the case of very high or very low concentrations of dissolved substance or at temperatures over 40^0C. For the electrolytes (which dissociates) it does not apply anymore.

The filtration is the separation of the components of a solution through a porous environment. Particles with a diameter higher than the diameter of the pores of that environment are retained.

The ultrafiltration is a phenomenon analogue to filtration, having the pores with a very small diameter, which retain the macromolecules.

Modeling of the renal function

According to the physiological data measured, 800 liters of blood (liquid state) flow through the kidneys daily, producing 160–180 liters of primary filtrate. The body protects the functional and structural integrity of the kidneys in the nephron so that they do not all work at the same time, but seems to “rest” some of them, and then they start working again. This alternating period of activity and rest of the nephrons probably exists to allow for a partial state of regeneration at rest.

The flow rates of the primary filtrate layers in the proximal and distal tubules differ quite significantly, because the layers at the walls flow much slower than the layers inside the tubules due to the frictional force. The energy resulting from the differences in frictional force and flow rates is converted into heat energy, and therefore the temperature difference between the layers of the flowing filtrate reaches several degrees. [5]

Temperature differences in flowing fluids can cause cavitation. Cavitation means that the difference in the speed of flow causes the pressure to drop so much that the formation of a vapor bubble in the filtrate begins, the collapse of which can cause damage to the wall of the tubules. When the cavitation caverns are destroyed, the filtrate hits the wall of the tubule and causes a large pulse that damages the wall. It is likely that during the resting period of the nephrons, among other things, the cells that form the wall of the tubules are regenerated. [6]

Vortexes are formed in any liquid when the fluid flow suddenly changes direction because the barrier acts as a vortex-forming surface. In the distal tubules, the filtrate flows in a direction opposite of 180^0 to that of the proximal section of the filtrate, and therefore, in the loop of Henle, a vortex is formed in every nephron. It

follows that, for the flow of a portion of the primary filtrate (in the case of the loop of Henle and the subsequent section), the flow laws of hydromechanics used for vortex fluids are applicable. [7]
A vortex flow is a flow in which the vortex vector **ω** is not zero at some points of the flow space. One of the characteristics of the vortex flow is the so-called vortex flux of the vortex tube (a spatial shape formed by vortex lines passing through a small closed curve). What is defined by

$$\mu = \int \omega_n \, df$$

surface integral, where: $\boldsymbol{\omega_n}$ is the perpendicular component of the vector **ω** at each point on the arbitrary smooth surface bounded by the curved fluid of the selected vortex tube. In the case of vortex thread, this integral is easy to calculate and thus

$$\mu = \omega.f,$$

where: f is the cross-sectional area of the vortex thread. In this case μ is the so-called vorticity. The Friedmann equation resulting from the Eulerian equation of hydrodynamics is ideal for the theoretical description of the vortex flow of fluids:

$$\frac{\partial \omega}{\partial t} + (v.grad\ )\ \omega - (\omega \cdot grad\ )\ v + \omega \cdot div\ \ v =$$

$$rot\ \ F + \frac{1}{\rho^2} grad\ \ \rho \times grad\ \ p$$

where: v – the velocity of the fluid, **ω** – the vortex vector, F – the resultant of external forces acting on the mass unit, ρ – the density of the fluid, p – the pressure. This equation, in the case of external conservative forces and incompressible fluid, turns into the Helmholtz equation of:

$$\frac{\partial \omega}{\partial t} + (vgrad\ )\ \omega = (\omega\ \ grad\ )\ v$$

Thus, in the case of the flow of the primary filtrate both the phenomenon of cavitation that may occur, as well as the phenomenon of the whirling flux at the level of the loop of Henle must be taken into account.
The amount of filtrate can be calculated based on the Starling principle. When a volume is filled with a solution, and is divided by a semipermeable membrane into two compartments, an osmotic system is created. If both compartments are subjected to different hydrostatic pressures, filtration occurs. The amount of the filtrate (m) is calculated by using the formula:

$$m = F.(\Delta P - \Delta\pi)$$

where: F – filtration coefficient; ΔP – difference in hydrostatic pressure between the two compartments; Δπ – osmotic pressure difference between the two compartments. This is the Starling principle. If ΔP>Δπ, the filtrate flows from compartment 1 to compartment 2; ΔP <Δπ, the filtrate flows from compartment 2 to compartment 1.
When applying the Starling principle to the kidney to calculate the filtrate, certain adjustments need to be considered. Hydrostatic pressure at capillary level is given by blood pressure, whereas oncotic pressure should be used instead of osmotic pressure. Albumins are responsible for 79%, globulins are responsible for 20%, while fibrinogens are responsible for 1% of oncotic pressure. The effective filtration pressure (P_e) can be given by:

$$P_e = (P_c - P_i) - \sigma(\pi_c - \pi_i)$$

where: σ ε (0.75–0.95) is the rejection ratio of proteins: in case of continuous capillary. If the effective filtration pressure is positive, there is filtration, if negative, it is reabsorption. We use the Starling equation for this case:

$$m = F.[(P_c\text{-}P_i) - \sigma(\pi_c\text{-}\pi_i)]$$

The filtration coefficient depends on the capillary surface, the permeability of the wall etc., and is very different in each capillary. (It is of very small value in the brain, large in the gut, and moderate in muscle.) Endothelial cells are capable of altering the size of the pores, and thus can greatly influence the amount of material filtered. Table II.

Table. II. The pressure valour of the filtration

Surface	Blood pressure mmHg	Oncotical pressure mmHg	Interstitial pressure mmHg
Arterial	35	25	1
Venous	12	5	1

Using the values in the table, we calculate the effective pressure for both filtration and reabsorption:

filtration: $P_{es} = (35 - 1) - (25 - 5) = 14$ (mmHg)
reabsorption: $P_{es} = (12 - 1) - (25 - 5) = -9$ (mmHg)

Applying Starling's equation, the total degree of filtration is approx. 20 ml/min, 90% of which, 18 ml/min is reabsorbed, and a volume of 2 ml/min is excreted into the lymph.
Clearance is the amount of plasma that is completely cleared of a certain material by the kidney over a given time period. This virtual blood that is specific to a substance is the plasma volume.
The sensory part is located in the ascending thick limb of loop of Henle, and when more tubular fluid is present, the smooth muscle of the vascular wall is more tightened, causing the smooth muscle to contract and the afferent arteriole to narrow, reducing blood flow, and thus reducing glomerular filtration. [8]
Nerve control: sympathetic innervation of afferent arteriole: vascular cross-section narrows and clearance decreases, and the volume of urine is also reduced. Angiotensin plays a role in hormonal regulation, which is produced by renin and has a strong vasoconstrictor role.
We assume that there is a third regulation. In severe brain injuries, it has been observed that kidney filtration and reabsorption work, and therefore it is assumed that there is a "hypothetical secondary brain" of the excretory apparatus. [9]
So in our opinion, the excretory apparatus should have a control associated with its own structure, which is likely to consist of neurons with hyperordonated spatial structure, called the "hypothetical secondary brain", which performs certain control functions. [10] This "hypothetical secondary brain" of the excretory apparatus, in humans, functions continuously throughout their life, only so poorly controlled that it has not yet been detected and discovered by scientific research in addition to the dominant role of the central nervous system.

The two-level biophysical control of the excretory apparatus in human organism

Starting from Bertalanffy's systems theory, we wrote the differential equation systems of the excretory apparatus. We need to consider the excretory system as a so-called hierarchical system, because it has many subsystems. Let us examine the excretory system from the point of view of systems theory. We have to assume that the excretory system as a system is an integrated whole, even though it derives from various structures and subfunctions. [11] The other starting point should be that as a system it has a certain objective, and that the balance of these can vary greatly. The processes taking place in the excretory system aim to optimize the functions of the system as a whole according to the objective, and to achieve maximum compatibility of the excretory subsystem. The main goal is to make the whole system work, not for a subset to operate optimally. A given system, with its core inputs and outputs, is a subset of a larger "super system", the human organism. The excretory system has a two-level control.

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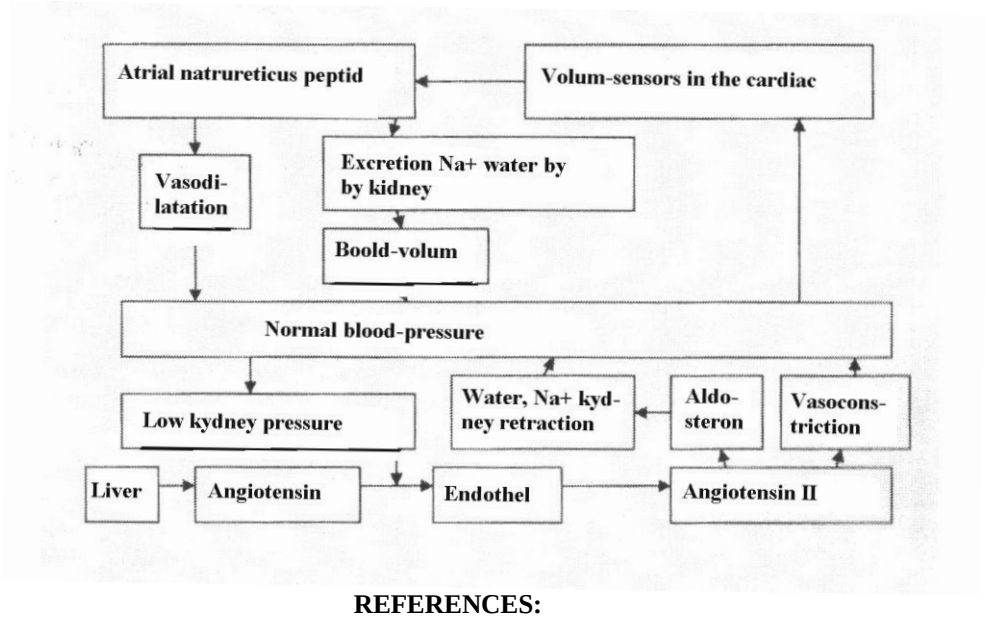
The connection between renal function and blood pressure

In addition to its excretory function, the kidney also performs regulatory functions by producing endocrine substances. The kidney produces erythropoietin that stimulates hematopoiesis. Cholecalciferol (Vitamin D: 1.25-$(OH)_2D_3$) is activated in the kidney (25-hydroxylation) to stimulate intestinal Ca^{2+} absorption. Renin is produced in the kidneys: an important regulator of fluid and electrolytes and blood pressure through activation of angiotensin and aldosterone. [12]

The kidney is the most important regulator of blood pressure as it determines the extracellular volume (water excretion) and the functioning of the renin-angiotensin-aldosterone system. In the so-called juxtaglomerular apparatus of the kidney, the renin produced in the positive cells of the afferent arteriolar renin splits the angiotensinogen (angiotensin I/decapeptide) produced in the liver, which is further split to angiotensin II (octapeptide) as a result of the angiotensin converting enzyme produced in the lungs. Angiotensin II is the most powerful vasoconstrictor of the body, which increases blood pressure by tightening small blood vessels and reducing glomerular filtration in the kidney by tightening the afferent arteriole. Angiotensin II, in addition, enhances aldosterone production in the adrenal cortex. The main effect of aldosterone in the renal tubules is the reabsorption of Na^+ (and consequently water) from the urine formed.

The figure 1. block diagram illustrates the role of the kidneys in controlling blood pressure.



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