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**МЕДИЦИНА, ХИМИЯ, ВЕТЕРИНАРНЫЕ НАУКИ,
ФАРМАЦЕВТИЧЕСКИЕ НАУКИ, БИОЛОГИЧЕСКИЕ НАУКИ,
СЕЛЬСКОХОЗЯЙСТВЕННЫЕ НАУКИ, НАУКИ О ЗЕМЛЕ**

TO KINETICS OF GROWTH, DUPLICATION AND DESTRUCTION OF MICROORGANISMS

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It is expedient to divide the problem connecting with process of growth, duplication and destructions of microorganisms on micro kinetic and macro kinetic theories.

Micro kinetic theory should study growth, way of duplication and destruction of the separate isolated cell depending on its physiological condition, depending on substratum components in the nearest environment of a cell and depending on speed of a metabolism with the purpose of definition of probability of the elementary acts of process of growth, division and destruction of a microorganism per time unit in given volume of system.

The micro kinetic equations of growth of a cell:

$$\frac{dm}{dt} = \mu(t)m = U_1(m, C),$$

- when the process of microbiological synthesis is limited by biochemical transformations inside a cell [1];

$$\frac{dm}{dt} = \beta S(t)\psi(t) = U_2(m, C)$$

- if the process of microbiological synthesis is limited by diffusion carry of nutritious substances to a surface of a cell,

where $m_0 \leq m(t) \leq 2m_0$, $0 \leq t \leq t_g$, $\mu = \frac{\mu_m C}{K_C + C}$, $\psi(t) = \psi(C)$, $m(t)$ – mass of a separate cell at a moment of time t (m – the determined value); $t = t_g$ – time of generation (of division of a cell); m_0 – mass of a cell at a moment of time $t = 0$; $U(m, C)$ – growth rate of a cell; C - concentration of substratum (of nutritious liquid); μ_m and K_C – constant values; β – coefficient of mass exchange; $\beta = \frac{D_M}{d}$, D_M – coefficient of molecular diffusion dependent on temperature of a surrounding nutritious liquid, d – thickness of a “boundary film” dependent on hydrodynamic conditions in a vicinity of a cell; $S(t)$ – an external surface of a cell at a moment of time t . It is supposed, that, at $m(t) = 2m_0$, a division of a cell on two ones takes place.

It is necessary to include in a circle of tasks of *macro kinetic theory*: a conclusion, research and development of mathematical methods of the solution of kinetic equations describing evolution of distribution function of a population on masses (volumes) at the given law of growth, duplication and destruction of a separate cell.

Synchronous division of cells. According to [2], on a limited interval of time it is possible to create such conditions in system, when all cells will divide synchronously. In this case, at $\frac{dm}{dt} = \mu(t)m(t)$, the following dependences take place:

$$m(t) = m_0 2^\tau, \quad \tau < 1;$$

$$\tau = \frac{1}{\ln 2} \int_0^t \mu(t) dt, \quad N(t) = N_0 2^{E(\tau)}, \quad M(t) = M_0 2^\tau, \quad \tau \geq 0,$$

where $M(t)$ and $N(t)$ - mass and quantity of cells of microorganisms at a moment of time $t \geq 0$ per unit of volume of system, $M_0 = M(0)$, $N_0 = N(0)$, $E(\tau)$ – the whole part of τ , which equal to the greatest integer which don't surpass τ . So, $E(\tau) = 0$ at $0 \leq \tau < 1$; $E(\tau) = 1$ at $\tau = 1+0$ and $E(\tau) = 0$ at $\tau = 1-0$. It is obvious, that $M(t)/N(t) = x(t) = m_0 2^{\tau-E(\tau)}$ – periodic function t with the period $T = 1$. If, for example, the parent cell grows by the law $\frac{dm}{dt} = u_0$, where u_0 – constant value, then

$$m(t) = m_0(1 + \tau_1), \quad \tau_1 < 1, \quad \tau_1 = t/\tau_0, \quad \tau_0 = m_0/u_0, \quad \tau = \tau_1 \frac{1}{\ln 2},$$

$$x(t) = m_0[1 + \tau_1 - E(\tau_1)], \quad N(t) = N_0 2^{E(\tau)}, \quad M(t) = x(t)N(t), \quad \tau \geq 0.$$

However, in process of growth of a population of cells, step-by-step dependence of quantity of cells is broken, that is caused by a stochastic nature of growth and duplication of microorganisms. Moreover, as a rule, microorganisms population represents an enormous congestion of cells asynchronously dividing and growing with some indi-

vidual speeds according to their age and according to casual change of concentration of components and of metabolism in vicinity of a separate cell, each of which represents tiny bioreactor of variable volume, in which the nutritious substances are continuously transformed, and also new ones, necessary for viability of a microorganism, are synthesized.

Macro kinetic equations. At creation of mathematical model of considered process, problems of prime importance are next: revealing common laws and development of mathematical methods of the description of evolutionary processes connected to growth, duplication and destruction of microorganisms in spatial - homogeneous and heterogeneous dispersion systems, on the basis of the uniform logic approach. But the mathematical description of process of formation of a spectrum of masses of microorganisms in dispersion environment, generally, is an extremely difficult task. However, if such complex process is considered as a set of less complex ("elementary") processes participating at formation of mass spectrum of microorganisms, such as continuous growth, duplication of cells, hydrodynamical conditions in system etc., then for the mathematical description of complex process it is expedient to use a principle of a superposition, which essence consists in the following statements.

Let us admit $\left(\frac{\partial f}{\partial t}\right)_i$ is speed of change of density of function of distribution of quantity of microorganisms on masses (volumes) in considered system at a moment of time t , caused by "elementary" i -th process, for example, by growth of cells, in such case, speed of change of density of function of distribution for complex process can be submitted as a superposition of speeds for "elementary" processes [3]:

$$\frac{\partial f}{\partial t} = \sum_{i=1}^n \left(\frac{\partial f}{\partial t} \right)_i .$$

Such approach to mathematical modeling of processes controlled by linear and quasi linear differential and integral-differential evolutionary equations of mathematical physics, allows describe the complex process on a basis of kinetic equations describing "elementary" processes.

So, let us admit, that $f(x, t)$ – density of distribution function (differential function of distribution) of quantity of alive (capable to growth and duplication) microorganisms at a moment of time t on masses x per unit of volume of dispersion system; $f_p(x, t)$ – density of distribution function of quantity of dead (not capable to growth and division) cells on masses x per unit of volume of system at a moment of time t ; $\Gamma(x, t)f(x, t)$ – quantity of microorganisms of mass x , perishing per unit of time in unit of volume of system at a moment of time t by natural death; $f(x, t) \int_{x_0}^{2x_0} G(x, \zeta, t) f(\zeta, t) d\zeta$ – quantity of cells of mass x , perishing per unit of time in unit of volume of system at

a moment of time t , owing to intraspecific struggle, where $\Gamma(x, t)$ and $G(x, \zeta, t)$ – the certain functions of their arguments.

Then, according to above stated approach, for spatial-homogeneous systems, when the cells are distributed uniformly on volume, it is possible to receive following quasilinear integral-differential equations describing growth, duplication and destruction of microorganisms:

$$\begin{aligned} \frac{\partial}{\partial t} f(x, t) + \Gamma(x, t)f(x, t) + \int_{x_0}^{2x_0} G(x, \zeta, t) f(x, t) f(\zeta, t) d\zeta + \frac{\partial}{\partial x} \left[U - \frac{\partial}{\partial x} D_C \right] f(x, t) = \\ = \gamma N [2\delta(x - x_0) - \delta(x - 2x_0)], \end{aligned} \quad (1.1)$$

$$\frac{\partial}{\partial t} f_p(x, t) = \Gamma(x, t)f(x, t) + \int_{x_0}^{2x_0} G(x, \zeta, t) f(x, t) f(\zeta, t) d\zeta, \quad (1.2)$$

$$\frac{dC}{dt} + \frac{1}{Y} \frac{\langle U \rangle}{\langle x \rangle} M = 0, \quad (1.3)$$

where $U = U(x, C, t)$ – growth speed of cells with mass x at a moment of time t ;

$D_C = D_C(x, C, t)$ – stochastic parameter (D_C – diffusion coefficient in space of masses); γ - specific speed of receipt of cells with mass x_0 , formed by division of cells with mass $2x_0$, into the system of microorganisms; $\delta(z)$ – Dirac delta-function of z ; $\langle \dots \rangle$ – a designation of average value of the given function; Y - economic coefficient;

$$M = \int_{x_0}^{2x_0} x f(x, t) dx = \langle x \rangle N \text{ and } M_p = \int_{x_0}^{2x_0} x f_p(x, t) dx = \langle x \rangle_p N_p \text{ – accordingly mass of } N \text{ alive cells and of } N_p$$

dead cells per unit of volume of system at a moment of time t .

System of the equations (1.1) – (1.3) is not closed. For the additional information, we multiply the equation (1.1) and (1.2) on x and take integral over x between of limits from $x = x_0$ up to $x = 2x_0$. In result we receive the equations for definition of $M(t)$ and $M_p(t)$:

$$\frac{dM}{dt} + \int_{x_0}^{2x_0} x\Gamma(x,t)f(x,t)dx + \int_{x_0}^{2x_0} xf(x,t) \int_{x_0}^{2x_0} G(x,\zeta,t)f(\zeta,t)d\zeta dx = \frac{\langle U \rangle}{\langle x \rangle} M, \quad (1.4)$$

$$\frac{dM_p}{dt} = \int_{x_0}^{2x_0} x\Gamma(x,t)f(x,t)dx + \int_{x_0}^{2x_0} xf(x,t) \int_{x_0}^{2x_0} G(x,\zeta,t)f(\zeta,t)d\zeta dx \quad (1.5)$$

The equations (1.1) - (1.5) satisfy to the law of preservation of substance:

$$M(t) + M_p(t) + YC(t) = M_0 + YC_0, \quad M_p(0) = 0, \quad (1.6)$$

where C_0 and M_0 – meanings of $M(t)$ and $C(t)$ at $t=0$. For the decision of the equations (1.1) - (1.6) it is necessary to set initial conditions and boundary conditions.

The initial conditions:

$$f(x,0) = f_0(x), \quad f_p(x,0) = 0, \quad M(0) = M_0, \quad M_p(0) = 0, \quad C(0) = C_0,$$

where $f_0(x)$, M_0 and C_0 – the determined values.

The boundary conditions:

$$f(x,t) \Big|_{x=x_0-0} = f(x,t) \Big|_{x=2x_0+0} = 0;$$

$$D_C \Big|_{x=x_0 \pm 0} = D_C \Big|_{x=2x_0 \pm 0} = 0;$$

$$(U - D'_C)\phi(x,t) \Big|_{x=x_0+0} = 2(U - D'_C)\phi(x,t) \Big|_{x=2x_0-0} = 2\gamma,$$

where $\phi = \frac{f}{N}$, $D'_C = \frac{dD_C}{dx}$; it is supposed, that $U > D'_C$ at all $x \in [x_0, 2x_0]$.

At replacement of required function $f(x,t)$ on $F(x,t)$ under the formula

Considering, that $\theta(z) = 0$ at $z < 0$ and $\theta(z) = 1$ at $z > 0$,

Where $\delta(z)$ – delta - function of Dirac, the equation (1.1) is transformed to the equation

At replacement of required function $f(x,t)$ on $F(x,t)$ under the formula

$$f(x,t) = [\theta(x-x_0) - \theta(x-2x_0)]F(x,t), \quad (1.7)$$

at the account of that $\theta(z) = 0$ at $z < 0$ and $\theta(z) = 1$ at $z > 0$,

$$\frac{d\theta}{dz} = \delta(z), \quad z\delta(z) = 0, \quad f(x,t)\delta(x-z) = f(z,t)\delta(x-z),$$

where $\delta(z)$ – the delta - function of Dirac, equation (1.1) will be transformed to the equation

$$\frac{\partial}{\partial t} F + \left[\Gamma(x,t) + \int_{x_0}^{2x_0} G(x,\zeta,t)F(\zeta,t)d\zeta \right] F(x,t) + \frac{\partial}{\partial x} \left[UF - \frac{\partial}{\partial x} D_C F \right] = 0, \quad (2.1)$$

at what, its decision should satisfy to the initial condition $F(x,0) = F_0(x)$ and to boundary condition

$$(U - D'_C)F(x,t) \Big|_{x=x_0+0} = 2(U - D'_C)F(x,t) \Big|_{x=2x_0-0} = 2\gamma N. \quad (2.2)$$

The analytical decision of the received system of the equations represents significant difficulties. It is obvious, that it becomes simpler, if the equalities take place:

$$\Gamma(x,t) = \Gamma_0, \quad G(x,\zeta,t) = G_0, \quad U(x,C,t) = x\psi(C),$$

where $\psi(0) = 0$, Γ_0 and G_0 – constant values, and $\psi(C)$ – the certain function of its argument. In this variant, decision of system of the equations (1.2) - (1.6) is represented as:

$$M(C) = M_0 + Y(C_0 - C) - M_p(C), \quad C \geq C^*, \quad (2.3)$$

$$M_p(C) = Y \int_c^{C_0} \frac{dz}{\psi(z)} [\Gamma_0 + \alpha M_0 + \alpha Y(C_0 - z)] \exp \left(- \int_c^z \frac{Y\alpha}{\psi(\zeta)} d\zeta \right), \quad C \geq C^*, \quad (2.4)$$

where $\alpha = \frac{G}{\langle x \rangle}$. From a condition $M(C) = 0$ at $C = C^*$, the equation for definition of value $C = C^*$ follows:

$$M_0 + Y(C_0 - C^*) = M_p(C^*). \quad (2.5)$$

According to the equation (1.3) it is possible to find $C(t)$, knowing dependence of function M from C :

$$\int_{C(t)}^{C_0} \frac{dC}{\psi(C)M(C)} = Yt. \quad (2.6)$$

The expressions (2.3) - (2.6), at $G_0 = 0$, were received [4] earlier.

Analysis. From the equation $\frac{dM}{dt} = [\psi(C) - (\Gamma_0 + \alpha M)]M$ follows, what at

$\psi(C) > \Gamma_0 + \alpha M$ the function $M(t)$ grows from $M = M_0$ up to $M = M_{\max}$, and at $\psi(C) < \Gamma_0 + \alpha M$ the function $M(t)$ decreases. Hence, at $\psi(C_\lambda) = \Gamma_0 + \alpha M(C_\lambda)$ the function $M(t)$ reaches the maximal meaning.

In turn, the function $M_p(t)$ grows from zero up to $M_p = M_0 + Y(C_0 - C^*)$, and its diagram has a point of an excess at $C=C_\lambda$.

From the equation (2.5) follows, that at destruction of cells there is a threshold minimal concentration of substrate, lower which, the cellular increase in mass of alive cells stops.

However it is necessary to notice, that for definition of value $C=C^*$, agrees (2.4) and (2.5), it is necessary to know value $\langle x \rangle$, which, in turn, it is possible to find only in case the function $P(x,t)=F(x,t)/N(t)$ is known. It is obvious, that the equation for definition of required function $P(x,t)$ can be received, using the equations for functions $F(x,t)$ and $N(t)$:

$$\frac{\partial F}{\partial t} + (\Gamma_0 + G_0 N) F + \frac{\partial}{\partial x} \left[UF - \frac{\partial}{\partial x} D_C F \right] = 0, \quad (2.7)$$

$$\frac{dN}{dt} = \gamma N - (\Gamma_0 + G_0 N) N. \quad (2.8)$$

Really, as $F(x,t)=P(x,t)N(t)$, we, having excepted value $N(t)$ from the equation (2.7), receive the equations for required functions $P(x,t)$ and $\langle x \rangle$:

$$\frac{\partial P}{\partial t} + \gamma P + \frac{\partial}{\partial x} \left[UP - \frac{\partial}{\partial x} D_C P \right] = 0, \quad (2.9)$$

$$\frac{d\langle x \rangle}{dt} + \gamma \langle x \rangle = \langle U \rangle = \langle \varphi(x) \rangle \psi(C). \quad (2.10)$$

The equation (2.7) is fair also in that case, when $\langle U \rangle = \langle \varphi(x) \rangle \psi(C)$, where $\varphi(x)$ - the given function.

For the decision of the equation (2.9) we use quasistationary approximation, when $\frac{\partial P}{\partial t} = \frac{d\langle x \rangle}{dt} = 0$. In this approximation

$$\gamma = \frac{\langle U \rangle}{\langle x \rangle} = \frac{\langle \varphi \rangle}{\langle x \rangle} \psi(C). \quad (2.11)$$

The equation (2.9) considerably becomes simpler, when $\varphi(x)=x$. In this variant, in quasistationary approximation, if the left and right parts of the equation (2.9) will be multiplied on x and integrated on x from $x=x_0$ up to $x=x$, using the appropriate boundary conditions, at $D_C(x,t)=U(x,t)b(x)$, we shall receive the compact enough equation

$$P(x) = \frac{2x_0}{x^2} + \frac{d}{dx} [b(x)P(x)], \quad (3.1)$$

$$\text{where } b(x)|_{x=x_0} = b(x)|_{x=2x_0} = 0, xP(1-b')|_{x=x_0+0} = 2xP(1-b')|_{x=2x_0-0} = 2.$$

We shall proceed to dimensionless variable $x = x_0 z$. At

$$b(x) = \frac{b_0(x-x_0)(2x_0-x)}{2x_0}, \quad (3.2)$$

in this case, the equation (3.1) will be transformed to a kind

$$P(z) = \frac{2}{z^2} + \lambda \frac{d}{dz} [(z-1)(2-z)P(z)], \quad (3.3)$$

and its solution satisfying to boundary conditions

$$P(z)|_{z=1+0} = \frac{2}{1-\lambda}, \quad P(z)|_{z=2-0} = \frac{1}{2(1+\lambda)}, \quad \lambda = \frac{b_0}{2}, \quad (3.4)$$

can be represented as

$$P(z) = \frac{2(z-1)^{\frac{1}{\lambda}-1}}{\lambda(2-z)^{\frac{1}{\lambda}+1}} \int_z^{\infty} \frac{dx}{x^2} \left(\frac{2-x}{x-1} \right)^{\frac{1}{\lambda}}, \quad 0 < \lambda < 1; \quad (3.5)$$

$$P(z) = \frac{2}{z^2}, \quad \lambda = 0. \quad (3.6)$$

So, $\langle x \rangle = 2x_0 \ln 2$ takes place at $\lambda = 0$ and the inequality

$$2x_0 \ln 2 - \frac{\lambda x_0}{4} < \langle x \rangle < 2x_0 \ln 2 \quad (3.7)$$

is fair at $\lambda > 0$.

Further, as $\frac{d}{dz} \left(\frac{z-1}{2-z} \right)^{\frac{1}{\lambda}} = \frac{1}{\lambda} \frac{(z-1)^{\frac{1}{\lambda}-1}}{(2-z)^{\frac{1}{\lambda}+1}}$ takes place, it is easy to show, that the function $P(z)$ is normalized on

unit.

In the conclusion it is necessary to note that the offered equations for the description of growth, duplication and destruction of microorganisms in closed spatial-nonuniform dispersion systems can be easily generalized upon open systems with a outflow and external source of microorganisms (see, for example, [5]).

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**ИСТОКИ СТАНОВЛЕНИЯ ПОНЯТИЯ «ОБЩЕНИЕ» В СФЕРЕ МЕДИЦИНЫ:
МЕЖДИСЦИПЛИНАРНОЕ ИССЛЕДОВАНИЕ**

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Система здравоохранения возникла и до настоящего времени существует как институт общественного предназначения. Основной целью деятельности социального института медицины является оказание врачебной помощи больному человеку. Данный процесс представляется нам как социальное взаимодействие врача и пациента, успешность которого, определяется целым рядом глобальных и локальных факторов.

Уточним, что объём понятия "взаимодействие" достаточно широк и включает целый ряд трактовок, таких как "система действий", "воздействие субъектов друг на друга", "вербальный и невербальный контакт", "общение". Представленные характеристики не раскрывают сущностной природы понятия "взаимодействие" и требуют дальнейшего уточнения. Тем не менее, приведённые определения демонстрируют тесную связь таких понятий, как социальное взаимодействие и общение.

Действительно, общение является необходимым условием человеческого существования вообще и трудовой деятельности, в частности. Работа врача представляет собой особый вид деятельности, предполагающий наличие специальных знаний, умений и навыков в области медицины, а также особой организации общения. А. А. Леонтьев указывает, что взаимодействие (интеракция) опосредовано общением и благодаря общению люди могут вступать во взаимодействие. Навыки общения необходимы врачу для более продуктивного взаимодействия с пациентом, его семьёй и другими специалистами, участвующими в лечебном процессе. Долгое время важным признаком профессионализма медика было молчаливое выполнение работы. Только в последние 15-20 лет учёные стали говорить об особой группе коммуникативных профессий, относящихся к областям «повышенной речевой ответственности» (Л. А. Петровская, Ю. П. Тимофеев). Е. А. Климов относит профессию врача к типу профессий "человек-человек", а А. А. Леонтьев говорит об острой необходимости обучения межличностному общению при формировании профессиональных навыков врача [Леонтьев, 2008, с. 37].

Один из наиболее важных видов социальной интеракции в сфере медицины осуществляется при участии врача и пациента. Вслед за целым рядом работ авторов, утверждающих важность повышения эффективности коммуникации в медицинской деятельности (Ю. Н. Емельянов, С. А. Ефименко, В. В. Жура, В. И. Карасик, В. А. Лабунская, Л. А. Петровская, Е. В. Харченко, Л. А. Цветкова, Н. В. Яковлева и др.) мы рассматриваем процесс общения "врач - больной" как особый вид межличностного взаимодействия в профессиональной сфере медицины, протекающего в форме диалога. Диалог напрямую связан с лечебным сотрудничеством и усиливает его эффективность.

Мы уже указывали на то, что термин "взаимодействие" часто трактуется в научной литературе как "интеракция", "общение", "коммуникация". Зарубежные исследователи давно стали использовать эти понятия как синонимы. Позднее такой подход был принят и отечественными учёными. Данные понятия имеют сходные черты, но имеют целый ряд особенностей. Существование множества различных определений связано с разными подходами к этой проблеме. В связи с этим необходимо указать на специфичность проблемы общения в целом в отечественной социальной психологии. Термин «общение» не имеет точного аналога в традиционной (западной) социальной психологии [Свеницкий, 2009, с. 236]. Подобное положение дел привело к тому, что при изучении проблемы общения рассматривается целый комплекс проблем, таких как соотношение общения и деятельности, сопоставление общения, коммуникации, взаимодействия, определение вида взаимоотношений (субъект-объект, субъект-субъект) и другие. Признавая актуальность подобных направлений исследования, в данной работе мы остановимся на вопросе об истоках и становлении теории общения, а также междисциплинарном характере этого понятия.

В трудах античных философов на начальном этапе проблема человеческого общения, проблема отношения человека к человеку не рассматривалась вообще. Только в более поздний период философия приобретает более антропоцентричный характер. В трудах софистов, Сократа, Платона и Аристотеля межличностные отношения становятся предметом риторики как искусства речи и этики. Сократ говорил о диалектике, осуществляющей в форме диалога, как одном из методов, помогающих осуществлять процесс общения. Аристотель был создателем первой схемы процесса общения. Он писал, что для любого акта общения необходимы 3 элемента: 1) лицо, которое говорит; 2) речь, которую это лицо произносит; 3) лицо, которое эту речь слушает.