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Appendices

Appendix A: Rate of Concentration

That is,

$$r + \Psi = r_0 \text{ and } \rho + \Psi = \rho_0$$

$$\begin{aligned}
\frac{\partial \Psi}{\partial t} &= k\,\rho\,r - k'\Psi \\
&= k\left(\rho\,r - \frac{k'}{k}\,\Psi\right) \\
&= k\ (\ [\rho_0 - \Psi]\ [r_0 - \Psi] - K\Psi\ ) \\
&= k\left(\rho_0\,r_0 - (\rho_0 + r_0)\,\Psi + \Psi^2 - K\Psi\right) \\
&= k\left[\Psi^2 - (\rho_0 + r_0 + K)\,\Psi + \rho_0\,r_0\right] \\
&= k\left[\left(\Psi - \left(\frac{\rho_0 + r_0 + K}{2}\right)\right)^2 - \left(\frac{\rho_0 + r_0 + K}{2}\right)^2 + \rho_0\,r_0\right] \\
&= k\left[(\Psi - a)^2 - a^2 + b^2\right]
\end{aligned}$$

where

$$a = \tfrac{1}{2}\,(\rho_0 + r_0 + K)$$

$$b = \sqrt{\rho_0 r_0}$$

Then

$$\begin{aligned}
\frac{\partial \Psi}{\partial t} &= k\left[(\Psi - a)^2 - a^2 + b^2\right] \\
&= k\left[(a - \Psi)^2 - \left(a^2 - b^2\right)\right] \\
&= k\left[(a - \Psi) + \sqrt{a^2 - b^2}\right]\left[(a - \Psi) - \sqrt{a^2 - b^2}\right] \\
&= k\left[a + \sqrt{a^2 - b^2} - \Psi\right]\left[a - \sqrt{a^2 - b^2} - \Psi\right] \\
&= k\ [\rho_K - \Psi]\ [r_K - \Psi]
\end{aligned}$$

where

$$\rho_K = a + \sqrt{a^2 - b^2}$$

$$r_K = a - \sqrt{a^2 - b^2}$$

and in the another consider as

$$\begin{aligned}
\frac{\partial \Psi}{\partial t} &= k \left[\, (a - \Psi)^2 - \left(a^2 - b^2\right)\right] \\
&= k \left[a^2 \left(1 - \frac{\Psi}{a}\right)^2 - \left(a^2 - b^2\right)\right] \\
&= k \left(1 - \frac{\Psi}{a}\right)^2 \left[a^2 - \frac{(a^2 - b^2)}{\left(1 - \frac{\Psi}{a}\right)^2}\right]
\end{aligned}$$

And the finally we want to solve in phisiology time as

$$\begin{aligned}
\frac{\partial \Psi}{\partial t} &= k \, [\, \rho_K - \Psi] \, [\, r_K - \Psi] \\
\frac{1}{[\, \rho_K - \Psi] \, [\, r_K - \Psi]} \partial \Psi &= k \, \partial t \\
\left[\frac{1}{r_K - \Psi} - \frac{1}{\rho_K - \Psi}\right] \partial \Psi &= (\, \rho_K - r_K) \, k \, \partial t \\
-\ln \left[\frac{r_K - \Psi}{r_K}\right] + \ln \left[\frac{\rho_K - \Psi}{\rho_K}\right] &= 2 \, k \, \sqrt{a^2 - b^2} \, t \\
\ln \left[\frac{\rho_K - \Psi}{r_K - \Psi} \frac{r_K}{\rho_K}\right] &= 2 \, k \, \sqrt{a^2 - b^2} \, t \\
\ln \left[\frac{\rho'}{r'_K} \frac{r_K}{\rho_K}\right] &= 2 \, k \, \sqrt{a^2 - b^2} \, t
\end{aligned}$$

where .

$$\rho' = \rho_K - \Psi$$

$$r'_K = r_K - \Psi$$

Appendix B: Long Range with Nonlocal Correlation

From the equation

$$\frac{\partial \Psi}{\partial t} = k \left(1 - \frac{\Psi}{a}\right)^2 \left[a^2 - \frac{(a^2 - b^2)}{\left(1 - \frac{\Psi}{a}\right)^2} \right] \tag{B.1}$$

for nonlocal correlation

$$\varphi = \mu \frac{1}{1 - \Psi/a}$$

rearrange form as

$$\Psi = a \left(1 - \frac{\mu}{\varphi}\right)$$

so,

$$\frac{\partial \Psi}{\partial t} = \frac{a\ \mu}{\varphi^2} \frac{\partial \varphi}{\partial t}$$

Then we substitute all this in to above Eq. (B.1) , we obtain

$$\begin{aligned}
\frac{a\ \mu}{\varphi^2} \frac{\partial \varphi}{\partial t} &= k \left(\frac{\mu}{\varphi}\right)^2 \left(a^2 - \frac{(a^2 - b^2)}{\mu^2} \varphi^2 \right) \\
\frac{\partial \varphi}{\partial t} &= k \frac{\mu}{a} \frac{a^2}{\mu^2} \left(\mu^2 - \frac{(a^2 - b^2)}{a^2} \varphi^2 \right) \\
&= k \frac{a}{\mu} \left(\mu - \frac{\sqrt{a^2 - b^2}}{a} \varphi \right) \left(\mu + \frac{\sqrt{a^2 - b^2}}{a} \varphi \right) \\
&= k \frac{a}{\mu} \frac{a^2 - b^2}{a^2} (\ y - \varphi)(\ y + \varphi)
\end{aligned}$$

where $y = (\mu a)/\sqrt{a^2 - b^2}$

then

$$\begin{aligned}
\frac{1}{(\ y - \varphi)(\ y + \varphi)} \frac{\partial \varphi}{\partial t} &= \frac{k}{\mu} \frac{a^2 - b^2}{a} \\
\frac{1}{(\ y - \varphi)} \partial \varphi + \frac{1}{(\ y + \varphi)} \partial \varphi &= 2y \frac{k}{\mu} \frac{a^2 - b^2}{a} \partial t
\end{aligned}$$

$$\begin{aligned}
\ln\left[\frac{(\ y+\varphi)}{(\ y-\varphi)}\right] &= 2\ \frac{\mu a}{\sqrt{a^2-b^2}}\ \frac{k}{\mu}\ \frac{a^2-b^2}{a}\ t \\
&= 2\ k\ \sqrt{a^2-b^2}\ t \\
\frac{(\ y+\varphi)}{(\ y-\varphi)} &= \exp\left[2\ k\ \sqrt{a^2-b^2}\ t\right] \\
\left(1+\exp\left[2\ k\ \sqrt{a^2-b^2}\ t\right]\right)\varphi &= \left(\exp\left[2\ k\ \sqrt{a^2-b^2}\ t\right]-1\right)\ y
\end{aligned}$$

$$\varphi=\frac{\exp\left[\ k\ \sqrt{a^2-b^2}\ t\right]}{\exp\left[\ k\ \sqrt{a^2-b^2}\ t\right]}\ \frac{\exp\left[\ k\ \sqrt{a^2-b^2}\ t\right]-\exp\left[-\ k\ \sqrt{a^2-b^2}\ t\right]}{\exp\left[\ k\ \sqrt{a^2-b^2}\ t\right]+\exp\left[-\ k\ \sqrt{a^2-b^2}\ t\right]}\ y$$

Then

$$\varphi=\frac{\mu a}{\sqrt{a^2-b^2}}\ \frac{\sinh\left[\ k\ \sqrt{a^2-b^2}\ t\right]}{\cosh\left[\ k\ \sqrt{a^2-b^2}\ t\right]}$$

However, as usual in nature, the system chooses one of its lowest energy states

$$\varphi\rightarrow\ -\frac{\mu a}{\sqrt{a^2-b^2}}+\varphi$$

Then, the solution becomes

$$\varphi=\frac{\mu a}{\sqrt{a^2-b^2}}\ \left[\ 1+\ \tanh\left[\ k\ \sqrt{a^2-b^2}\ t\right]\ \right]$$

Appendix C: Mean Current

This can analize the mean current as folllow

$$\langle I \rangle = N\ i\ P_0$$

where

$$P_0 = \frac{1}{2}\ [\ 1 + \tanh [H]\ ]$$
$$H = \frac{m}{2}\ (\varepsilon + \theta)\ \frac{1}{k_B T}$$
$$\theta = \theta_0 + k_B T\ \ln [\rho]$$

So

$$\begin{aligned} P_0 &= \frac{1}{2} \left[1 + \ \tanh \left[\frac{1}{2}\ (\varepsilon + \theta)\ \frac{m}{k_B T} \right] \right] \\ &= \frac{1}{2} \left[1 + \ \tanh \left[\frac{1}{2}\ \ln \left[\exp \left[(\varepsilon + \theta)\ \frac{m}{k_B T} \right] \right] \right] \right] \\ &= \frac{1}{2}\ 2 \frac{x}{x+1} \end{aligned}$$

where

$$\begin{aligned} x &= \exp \left[(\varepsilon + \theta)\ \frac{m}{k_B T} \right] \\ &= \exp \left[(\varepsilon + \theta_0 + k_B T\ \ln [\rho])\ \frac{m}{k_B T} \right] \\ &= \exp \left[(\varepsilon + \theta_0) \frac{m}{k_B T} + k_B T\ \ln [\rho]\ \frac{m}{k_B T} \right] \\ &= \exp \left[(\varepsilon + \theta_0) \frac{m}{k_B T} \right]\ \exp [m\ \ln [\rho]\ ] \\ &= \rho^m \exp \left[(\varepsilon + \theta_0) \frac{m}{k_B T} \right] \end{aligned}$$

$$x^{-1} = \rho^{-m}\ \exp \left[- (\varepsilon + \theta_0) \frac{m}{k_B T} \right]$$

then substitute on

$$\begin{aligned} P_0 &= \frac{1}{1+x^{-1}} \\ &= \frac{\rho^m}{\rho^m + \exp\left[-(\varepsilon+\theta_0)\frac{m}{k_B T}\right]} \end{aligned}$$

Vitae

Mr. Santipong Boribarn was born on March 4, 1974 in Bangkok. He has received a Bachelor of Science degree and a Master of Science degree from Chulalongkorn University in 1995 and 1998 respectively.