Exercises

1 FitzHugh-Nagumo equation

Calculate the FitzHugh-Nagumo equation with $I_{input} = 1.5$. Try also with $I_{input} = 0$.

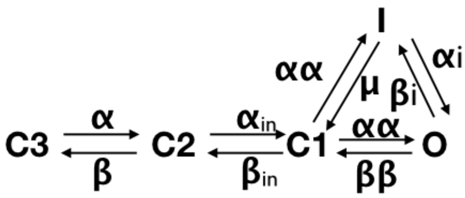
$$\frac{dV}{dt} = 10\left(V - \frac{V^3}{3} - R + I_{input}\right)$$
$$\frac{dR}{dt} = 0.8(-R + 1.25V + 1.5)$$

Draw the V-R plot.

✎ Modify `ex07`

2 HERG channel simulation

Try voltage-clamp simulation of HERG potassium channel.
A Markov model of the HERG channel is described by Clancy & Rudy. [*1]



$$\begin{aligned}
I_{Kr} &= G_{Kr} \cdot P(\mathrm{O}) \cdot (\mathrm{V_m} - \mathrm{E_k}) \\
P(\mathrm{O}) &= \text{open probability of } \mathrm{I_{Kr}} \\
G_{Kr} &= 0.0135 \cdot [K^+]_{out}^{0.59} \\
E_K &= (R \cdot T/F) \cdot \ln([K^+]_{out}/[K^+]_{in}) \\
\mathrm{C1} \to \mathrm{O} \text{ or } \mathrm{C1} \to \mathrm{I} &\quad \alpha\alpha = 66.5 \cdot 10^{-3} \cdot \exp(0.05547153 \cdot (\mathrm{v} - 36))) \\
\mathrm{C2} \to \mathrm{C1} &\quad \alpha_{\mathrm{in}} = 2.172 \\
\mathrm{C3} \to \mathrm{C2} &\quad \alpha = 55.5 \cdot 10^{-3} \cdot \exp(0.05547153 \cdot (\mathrm{v} - 12))) \\
\mathrm{C2} \to \mathrm{C3} &\quad \beta = 2.357 \cdot 10^{-3} \cdot \exp(-0.036588 \cdot \mathrm{v}) \\
\mathrm{C1} \to \mathrm{C2} &\quad \beta_{\mathrm{in}} = 1.077 \\
\mathrm{O} \to \mathrm{C1} &\quad \beta\beta = 2.9357 \cdot 10^{-3} \cdot \exp(-0.02158 \cdot \mathrm{v}) \\
\mathrm{I} \to \mathrm{O} &\quad \alpha\mathrm{i} = 0.439 \cdot \exp(-0.02352 \cdot (\mathrm{v} + 25))) \cdot 4.5/[\mathrm{K}^+]_{\mathrm{out}} \\
\mathrm{O} \to \mathrm{I} &\quad \beta\mathrm{i} = 0.656 \cdot \exp(0.000942 \cdot \mathrm{v}) \cdot 4.5^{0.3}/[\mathrm{K}^+]_{\mathrm{out}}^{0.3} \\
\mathrm{I} \to \mathrm{C1} &\quad \mu = (\alpha\mathrm{i} \cdot \beta\alpha \cdot \alpha\alpha)/(\alpha\alpha \cdot \beta\mathrm{i})
\end{aligned}$$

✎ Modify `ex08`

[*1] Cardiovascular Research 50:301 - 313, 2001.

3 Synaptic protein

Synaptic proteins can be counted using the SDS-digested freeze-fracture replica labeling electron-microscopy. If n protein particles are observed, how do you estimate the surface area of the synaptic contact?

Assume the synaptic contact is round, and the particles are distributed randomly.

✎ Python or Matlab is more convenient for this kind of calculation.
Use the Monte-Carlo method (`ex10`). See Hagiwara et al (2005)*2

4 Free calcium concentration in the presence of multiple calcium buffers

In the presence of the buffers listed below,

a. Calculate the total calcium concentration when the free calcium concentration is 100 nM.

b. Calculate the free calcium concentration when 100 μM EGTA is added.

	concentration (μM)	K_D (μM)
mobile buffer	290	200
fixed buffer	160	2
EGTA	(100)	0.07

✎ Solve the equation using the regula falsi method.

*2 J Comp Neurol. 489:195-216, 2005.