

# Coupled enhancer-promoter condensates

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## 1 Enhancer and promoter

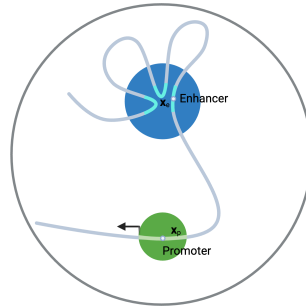


Figure 1: Enhancer and promoter regions on chromatin

## 2 Free energy functional

$$\begin{aligned}
 F(\phi_P(\vec{x}, t), \phi_R(\vec{x}, t)) = & \int d\vec{x} \rho_P (\phi_P - \alpha)^2 (\phi_P - \beta)^2 \\
 & + \rho_R \phi_R^2 \\
 & - \chi \phi_P \phi_R + c \phi_P^2 \phi_R^2 \\
 & + \frac{\kappa}{2} |\nabla \phi_P|^2 \\
 & - \chi_{PD} \phi_P \exp \left\{ -\frac{(\vec{x} - \vec{x}_e)^2}{2\sigma^2} \right\} \\
 & + F_C
 \end{aligned}$$

- Protein-protein double-well potential

$$F_{\text{DW}} = \rho_{\text{P}}(\phi_{\text{P}} - \alpha)^2(\phi_{\text{P}} - \beta)^2$$

- RNA-RNA repulsion

$$\rho_{\text{R}}\phi_{\text{R}}^2$$

- Protein-RNA electrostatic interaction

$$\chi_{\text{PR}}(\phi_{\text{P}}, \phi_{\text{R}}) = \chi\phi_{\text{P}}\phi_{\text{R}} + c\phi_{\text{P}}^2\phi_{\text{R}}^2$$

- Protein-DNA interaction

$$\chi_{\text{PD}}\phi_{\text{P}}\phi_{\text{D}} = \chi_{\text{PD}}\phi_{\text{P}} \exp\left\{-\frac{(\vec{x} - \vec{x}_e)^2}{2\sigma^2}\right\}$$

- Interfacial surface-tension

$$\frac{\kappa}{2}|\nabla\phi_{\text{P}}|^2$$

- Chromatin

$$F(\vec{R}) = \frac{3k_{\text{B}}T}{2} \left( \frac{|\vec{R}|^2}{L_{\text{C}}L_{\text{P}}} \right)$$

### 3 Dynamic equations

- Protein dynamics Model A dynamics. The amount of protein is conserved.

$$\frac{\partial\phi_{\text{P}}}{\partial t} = M_{\text{P}}\nabla^2 \left( \frac{\partial F}{\partial\phi_{\text{P}}} \right) = M_{\text{P}}\nabla^2\mu_{\text{P}}$$

- RNA dynamics

$$\frac{\partial\phi_{\text{R}}}{\partial t} = M_{\text{R}}\nabla^2\phi_{\text{R}} + k_{\text{p}}(\vec{x})\phi_{\text{P}} - k_{\text{d}}\phi_{\text{R}}$$

$$k_{\text{p}}(\vec{x}) = \frac{k_{\text{T}}}{2\pi\sigma^2} \exp\left[\frac{(\vec{x} - \vec{x}_{\text{p}})^2}{2\sigma^2}\right]$$

- Enhancer region dynamics

- Gradient of free energy functional with respect to the vector  $\vec{x}_e$

$$\frac{\partial\vec{x}_e}{\partial t} = M_{\text{D}}\nabla_{\vec{x}_e} F$$