数理解析研究所講究録
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「差異•パターン形成と拡散方程式の現在」

パネルディスカッション

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1. 形やダイナミクスが似ていればモデルは本質をとらえているのか？

2. チューリングモデルの成功と限界：チューリングモデルは超えられるか？

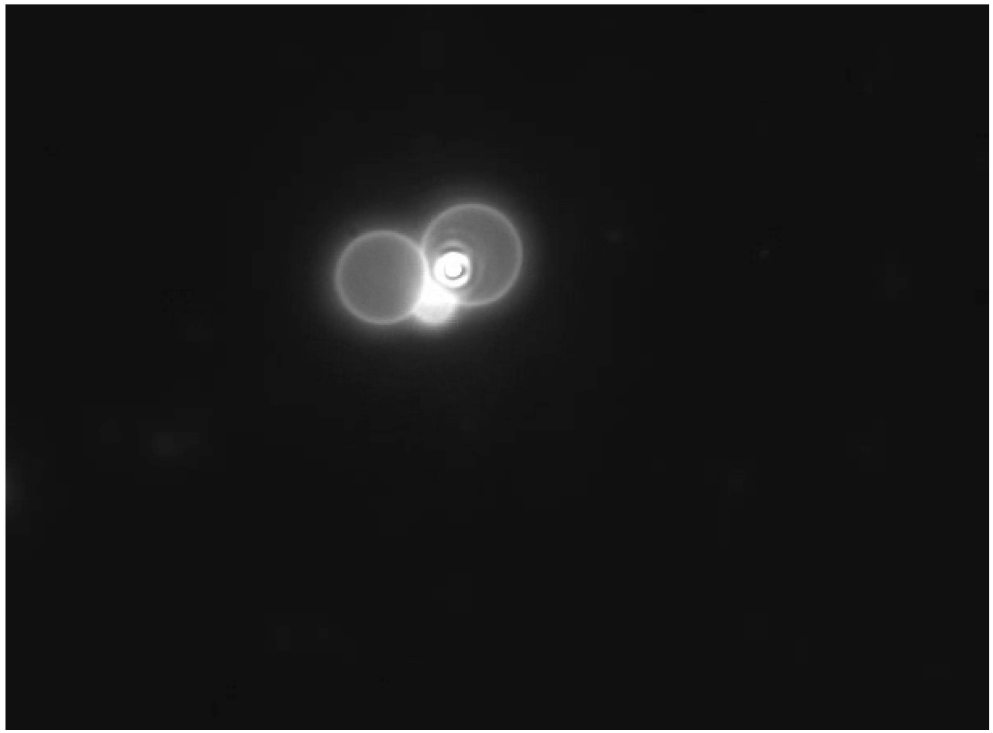
3. 形態形成現象において美しくかつ解かれていない問題のリスト

4. 生命現象において現在の数学・物理では十分に捉えきれていない問題は何か？

1．形やダイナミクスが似ていればモデルは本質をとらえているのか？

Self-replicating Patternの例

分裂するベシクル



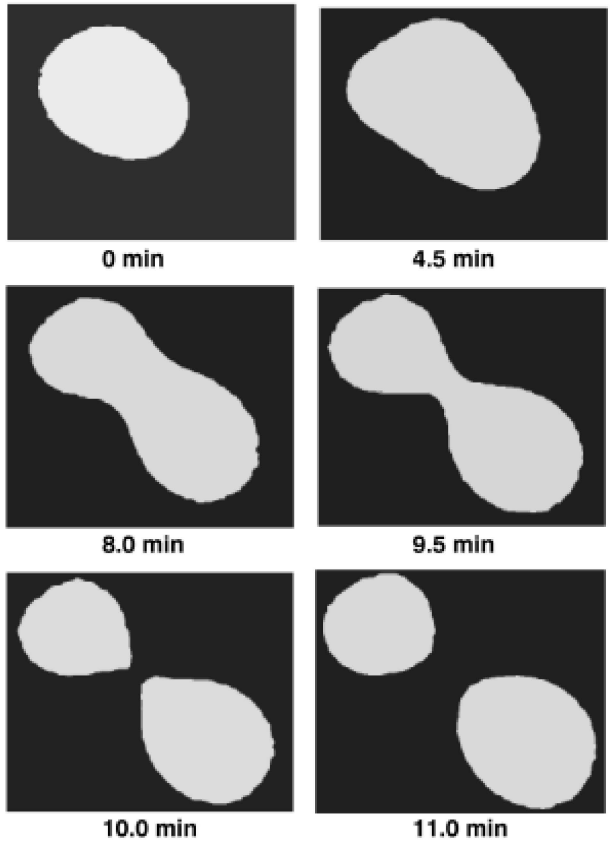
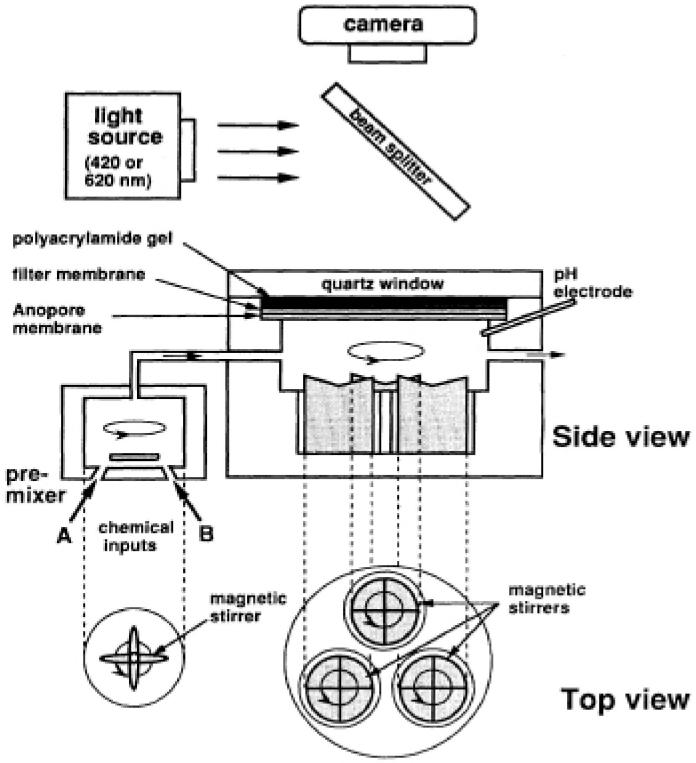


FIG. 10. Self-replication of a spot. The flow rate is 148 m㎥/h and the gel is 0.2 mm thick [as in Fig. 1(d)]. Each frame is 3.9×3.5 mm^2.

Lee & Swinney, PRE (1995)

Self-replicating Pattern I

FIS (ferrocyanide-iodate-sulfite) reaction: A bistable system of high (white) and low (black) pH.



Lee & Swinney, PRE (1995)

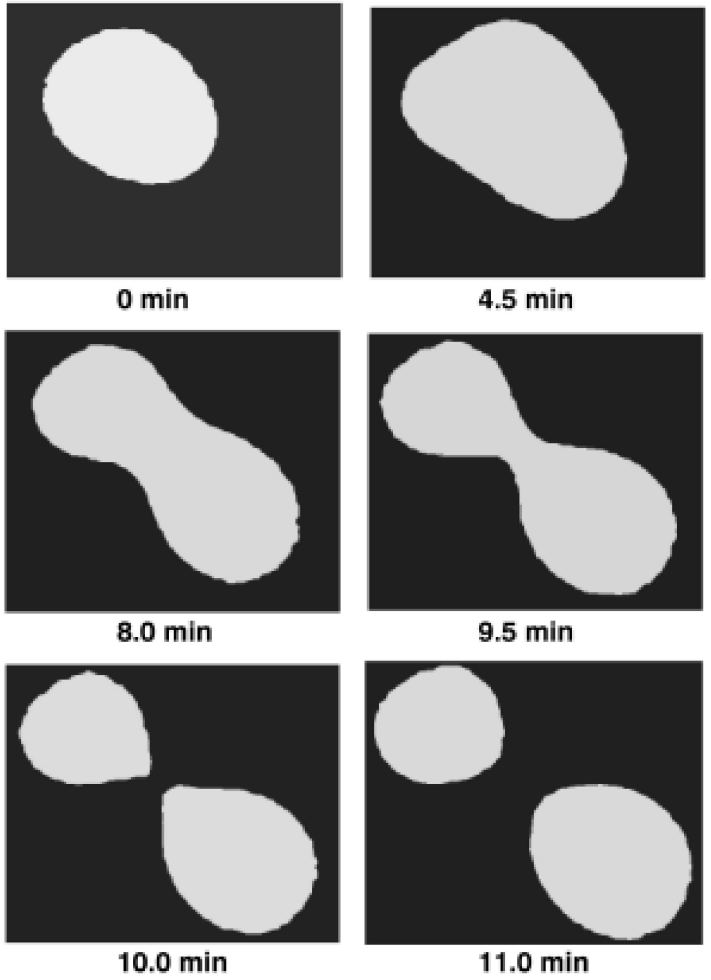
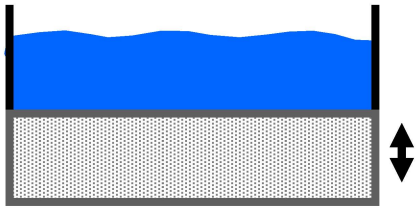
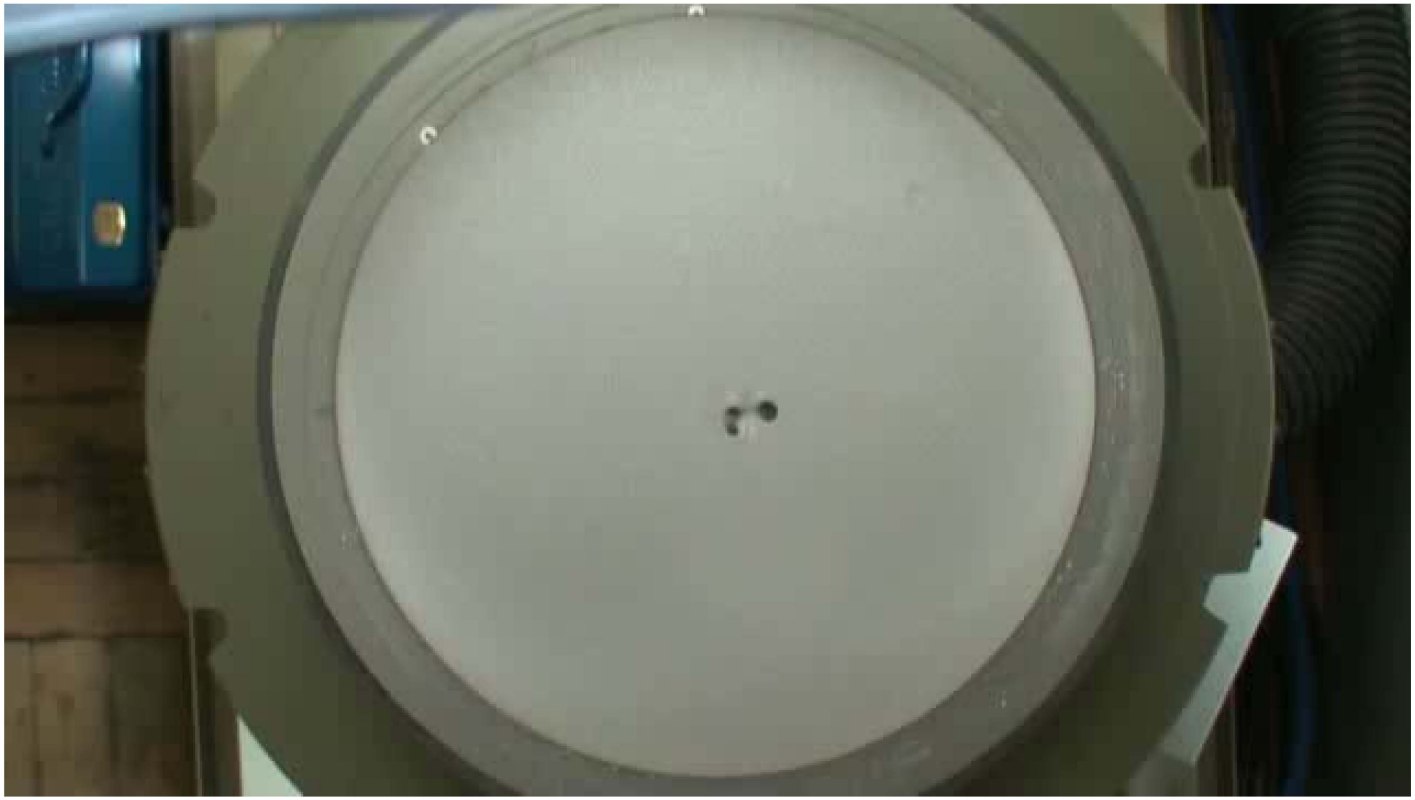


FIG. 10. Self-replication of a spot. The flow rate is 148 m/h and the gel is 0.2 mm thick [as in Fig. 1(d)]. Each frame is 3.9×3.5 mm^2.

Self-replicating Pattern II

Farady surface waves
(stripes and squares)





粘弾性体（ポテトスターチ）の垂直振動 (Ebata & Sano)

Self-replicating patternの反応拡散モデル

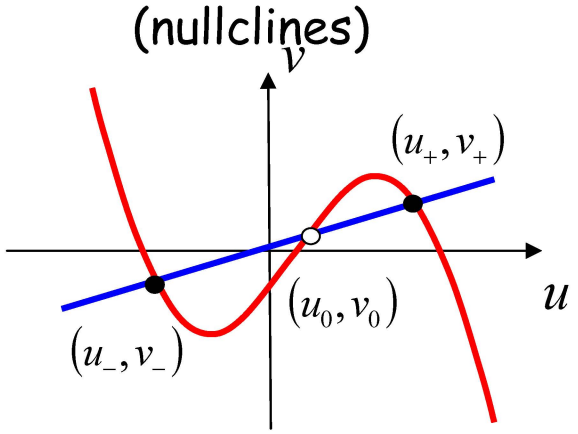
FitzHugh-Nagumo (FHN) model:

$$u_t = u - u^3 - v + \nabla^2 u$$

$$v_t = \varepsilon(u - a_1 v - a_0) + \delta\nabla^2 v$$

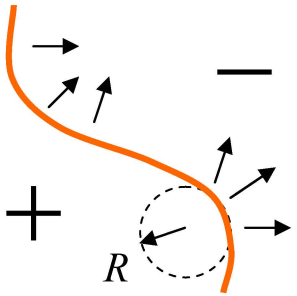
u: activator, v: inhibitor → Bistability

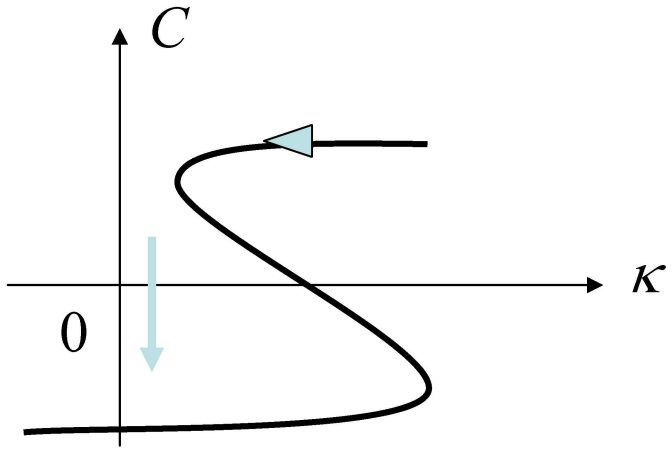
E. Meron et al.

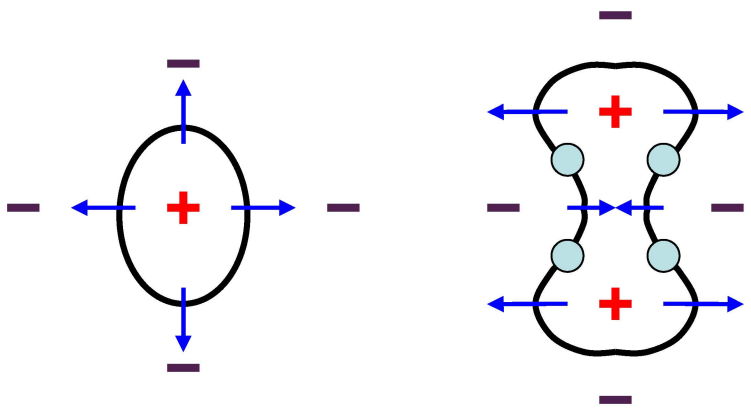


Front Dynamics

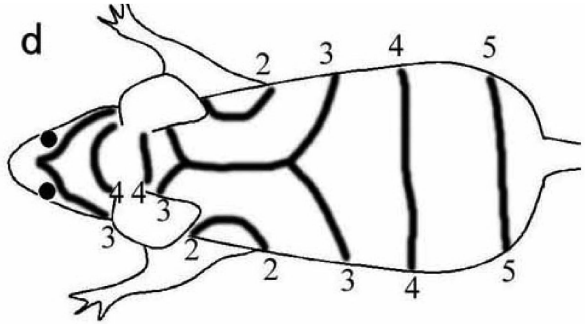
front velocity C: $C = C(\kappa)$ $\kappa = 1/R$

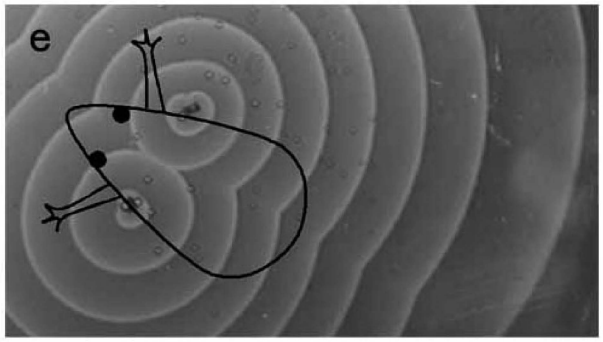






2. チューリングモデルは超えられるか？

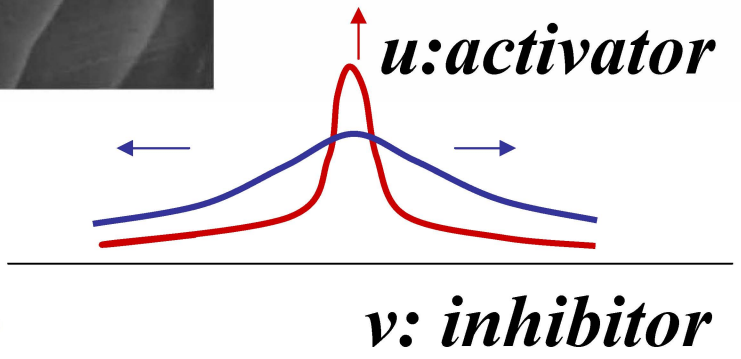




S. Kondo

Local Activation +

Long Range Inhibition

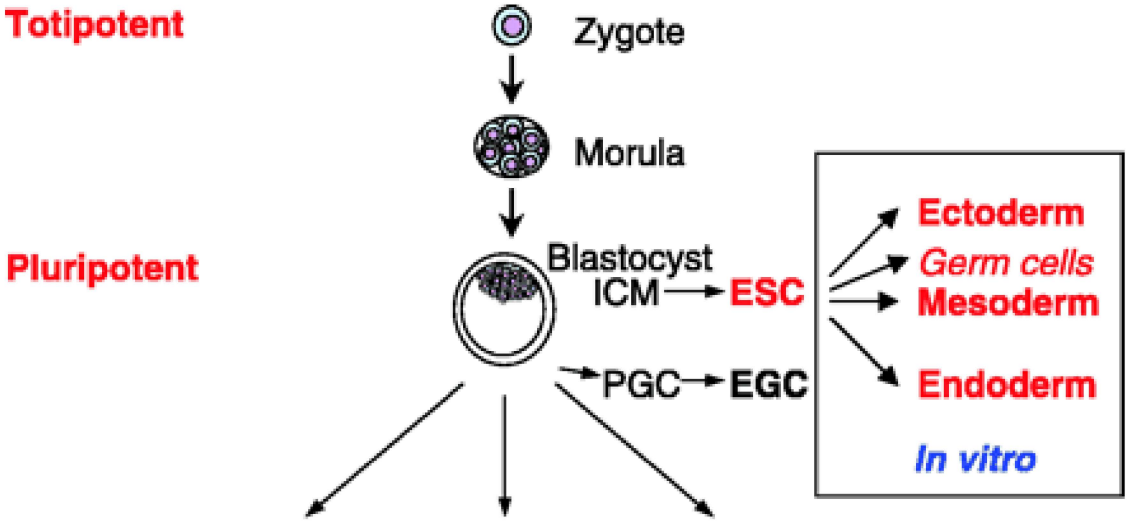


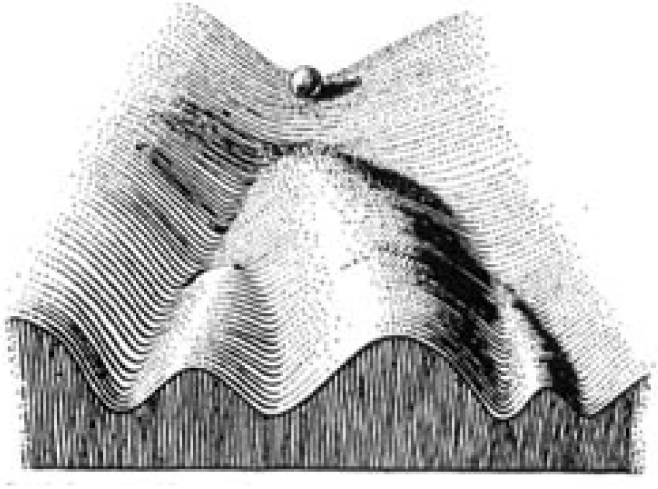
自発的対称性の破れ：空間並進対称性

$$\dot{u} = au - bv + D_u \nabla^2 u, \quad (a,b,c,d > 0)$$

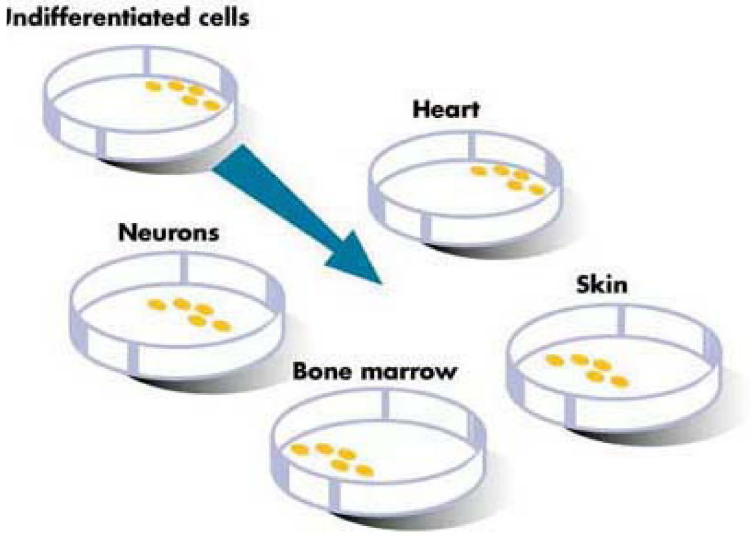
$$\dot{v} = cu - dv + D_v \nabla^2 v, \qquad D_u << D_v$$

3. 解かれていない問題の例：発生・分化
Development of Cell is Irreversible





Waddington's Epigenetic Landscape



--Why iPS (induced pluripotent cells) cells become pluripotent by adding only three genes --

- 30,000 genes can be activated by 3 genes
- 3 is enough to create infinite complexity

Examples:

- 3 variables are enough to create Chaos!
- Period 3 implies Chaos

⇒ However, Chaos is not robust in general !

Two Major Possibilities: #1

- Network structure

3 genes control downstream genes, downstream genes control further down,,, cascade

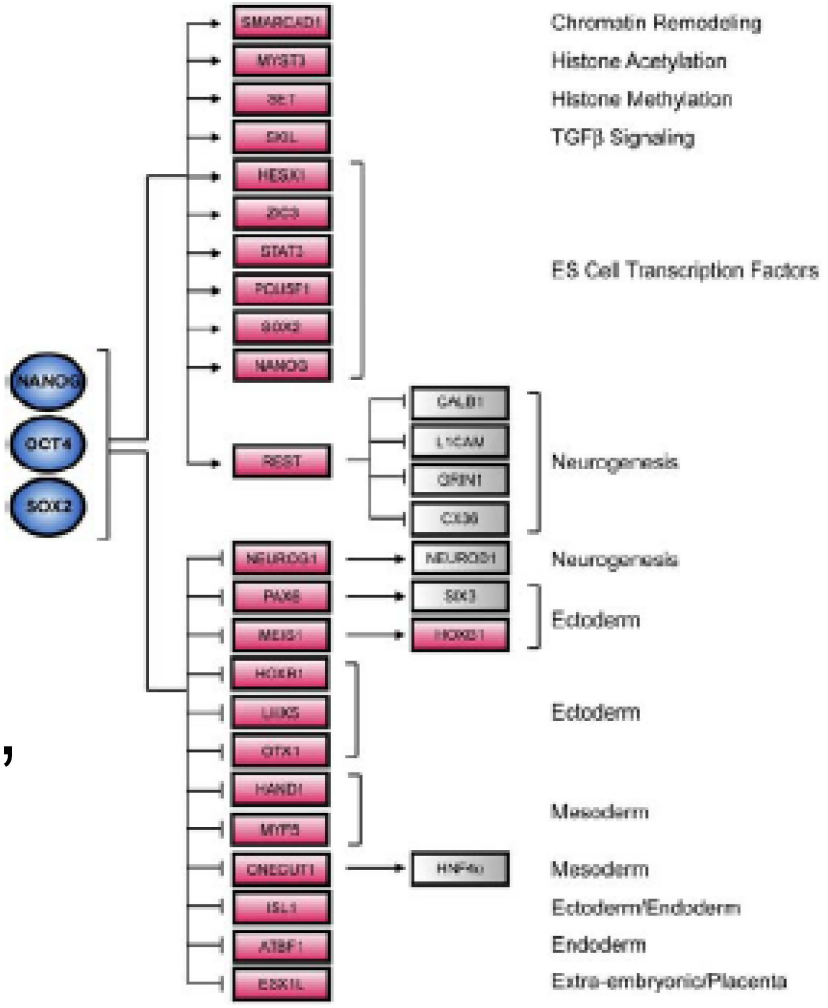


Figure 5. Core Transcriptional Regulatory Network in Human ES Cells

Two Major Possibilities: #2

DNA methylation and chromatin remodeling

DNAの情報が読まれるか否か（Transcription Activity）

DNAのみではダイナミックレンジ10倍

クロマチン構造により＞2000倍のレンジで制御される。

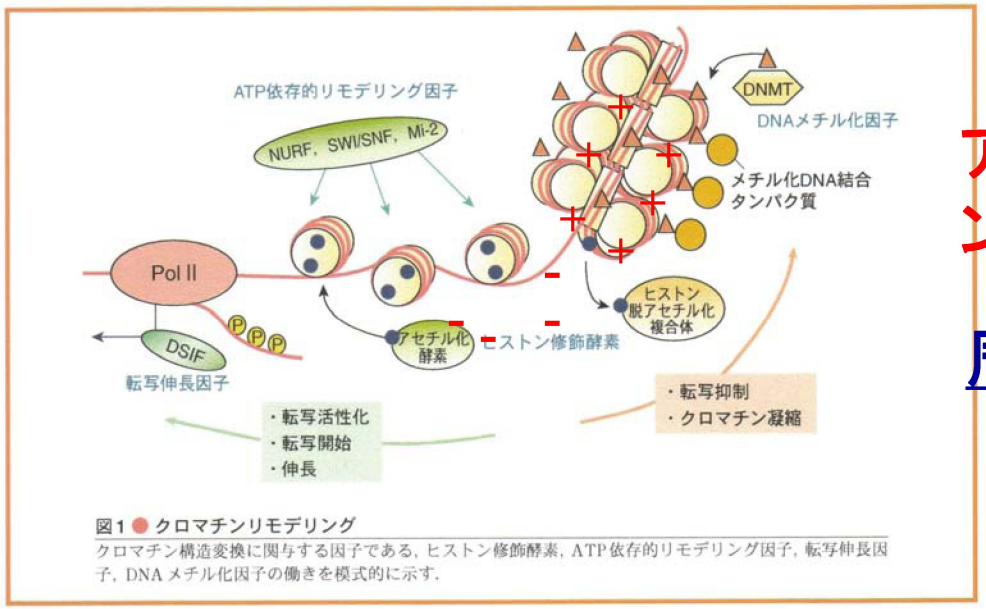


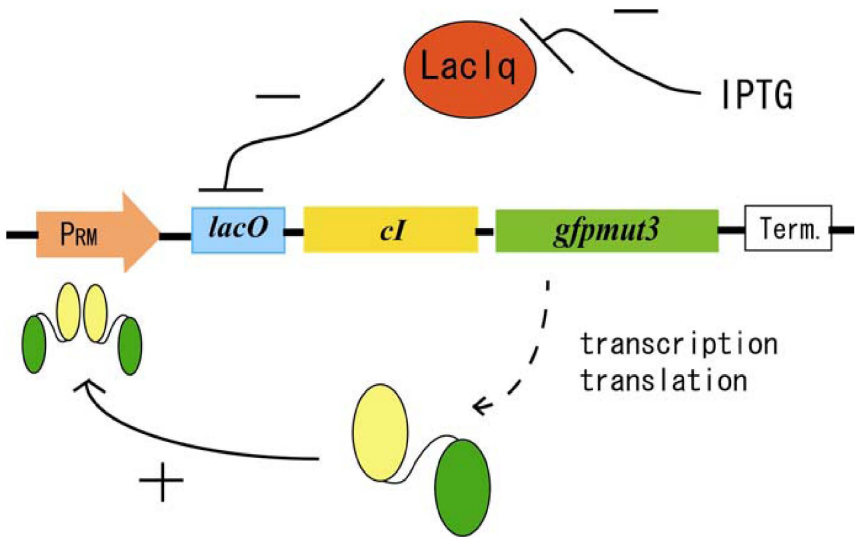
図1 ● クロマチンリモデリング
クロマチン構造変換に関与する因子である，ヒストン修飾酵素，ATP依存的リモデリング因子，転写伸長因子，DNAメチル化因子の働きを模式的に示す．

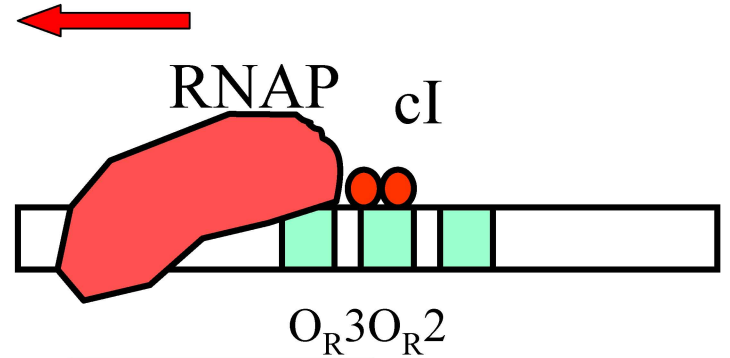
アセチル化によりヒストンの正電荷が減少

周辺を活性化する

メカニズムの本質は分かっていない

遺伝子ネットワークだけではゆらぎが大きい





On

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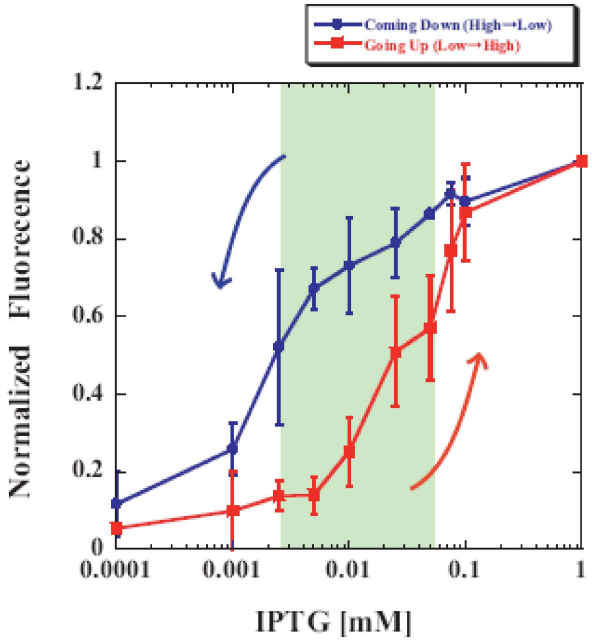

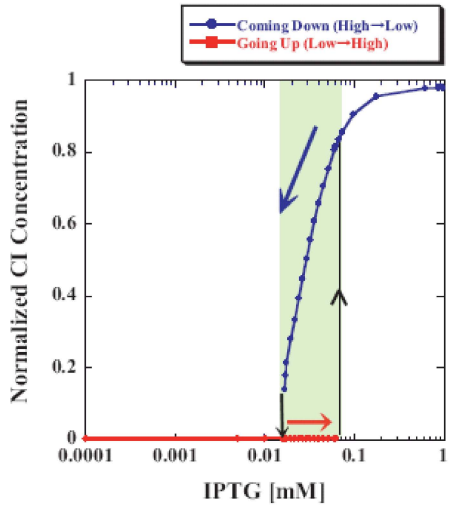

Y. Maeda, M. Sano, JMB (2006)