

# 計算モデル特論

プロセス計算

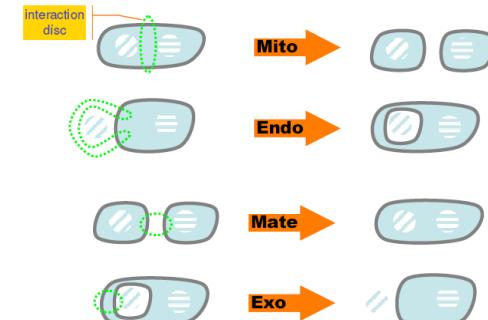
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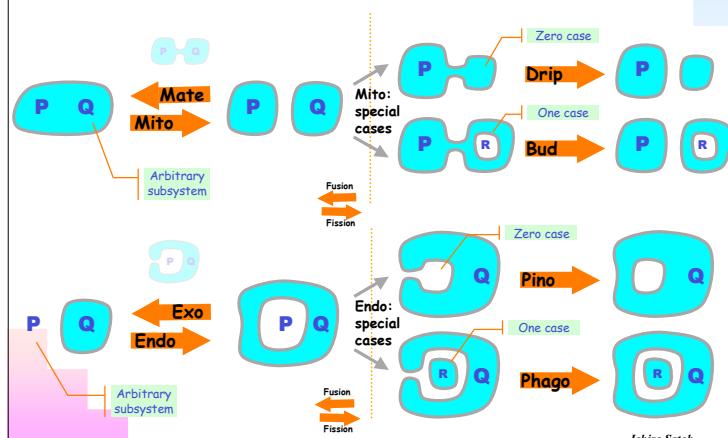
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## 細胞膜と動作



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## 細胞膜と動作



## Membrane Calculus

構文

$X ::=$	membrane system
$\diamond$	empty system
$X \circ X$	composition of subsystems
$(X)$	subsystem inside membrane

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## Membrane Calculus

### 操作意味論

$$X_1 \circ X_2 \equiv X_2 \circ X_1$$

$$X_1 \circ (X_2 \circ X_3) \equiv (X_1 \circ X_2) \circ X_3$$

$$X \circ \diamond \equiv X$$

$$X_1 \rightarrow X_2 \Rightarrow X_1 \circ X \rightarrow X_2 \circ X$$

$$X_1 \rightarrow X_2 \Rightarrow \langle\langle X_1 \rangle\rangle \rightarrow \langle\langle X_2 \rangle\rangle$$

$$X_1 \equiv X'_1 \rightarrow X'_2 \equiv X_2 \Rightarrow X_1 \rightarrow X_2$$

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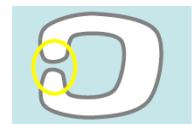
## Endo/Exo

### (逆)内包化

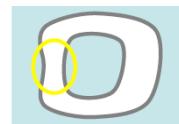
$$\diamond \leftrightharpoons \langle \diamond \rangle$$

$$X \circ \langle Y \rangle \leftrightharpoons \langle \langle X \rangle \circ Y \rangle$$

Froth/Fizz  
Endo/Exo



**Endo  
Exo  
(dual)**



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## 細胞分裂と結合

### 分裂(Mite)と結合(Mate)

$$\langle\langle X \rangle\rangle \circ \langle\langle X' \rangle\rangle \leftrightharpoons \langle\langle X \circ X' \rangle\rangle \quad \text{Mito/Mate}$$

$$X \leftrightharpoons \langle\langle X \rangle\rangle \quad \text{Peel/Pad}$$



Mito

(Fission)



Mate



(Fusion)

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## 例題

### 基本動作の表現

$$\langle\langle X \rangle\rangle \circ \langle\langle X' \rangle\rangle \leftrightharpoons \langle\langle X \circ X' \rangle\rangle \quad \text{Mito/Mate}$$

$$X \leftrightharpoons \langle\langle X \rangle\rangle \quad \text{Peel/Pad}$$

### 証明(表現可能性)

$$\begin{aligned} \langle\langle X \rangle\rangle \circ \langle\langle X' \rangle\rangle &\leftrightharpoons \langle\langle \langle\langle X \rangle\rangle \circ X' \rangle\rangle \equiv \langle\langle \langle \diamond \circ \langle\langle X \rangle\rangle \circ X' \rangle\rangle \\ &\equiv \langle\langle \langle \diamond \rangle \circ X \circ X' \rangle\rangle \leftrightharpoons \diamond \circ \langle\langle X \circ X' \rangle\rangle \equiv \langle\langle X \circ X' \rangle\rangle \end{aligned}$$

$$X \equiv X \circ \diamond \leftrightharpoons X \circ \langle \diamond \rangle \leftrightharpoons \langle\langle \langle X \rangle\rangle \circ \diamond \rangle \equiv \langle\langle X \rangle\rangle$$

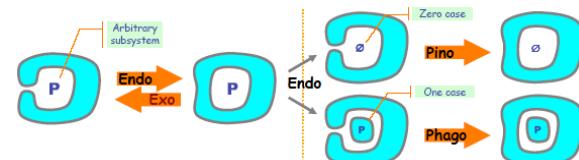
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## ▶ 表現性

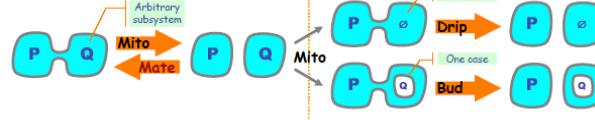
The reactions Mito and Mate can be represented by Endo and Exo.



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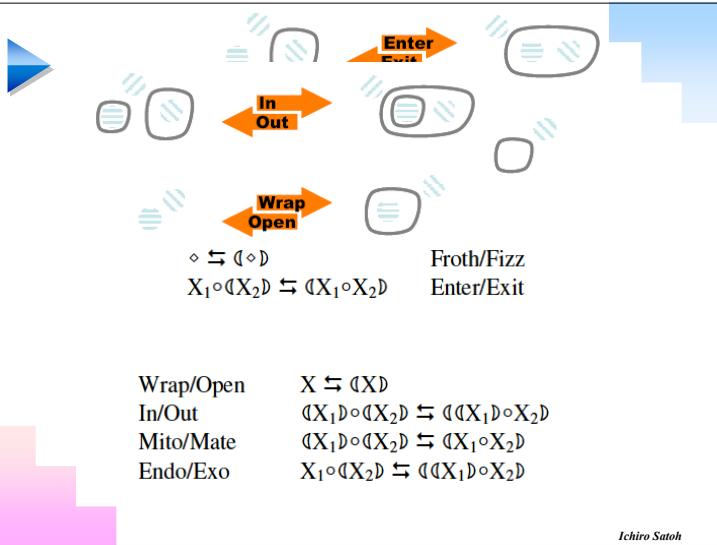


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Wrap/Open	$X \subseteq \langle X \rangle$
In/Out	$\langle X_1 \rangle \circ \langle X_2 \rangle \leftrightharpoons \langle \langle X_1 \rangle \circ X_2 \rangle$
Mito/Mate	$\langle X_1 \rangle \circ \langle X_2 \rangle \leftrightharpoons \langle X_1 \circ X_2 \rangle$
Endo/Exo	$X_1 \circ \langle X_2 \rangle \leftrightharpoons \langle \langle X_1 \rangle \circ X_2 \rangle$



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