Quasi-stability: revealing the super-magic numbers common to subatomic, biological, and cosmic systems

早稲田大学理工学術院 基幹理工学部　機械科学・航空学科
&
CREST

内藤　健

2012.1.7 at Kyoto Univ.

話題提供の内容

- Naitoh, JJIAM, 1998. 2001. 2011a, 2011b.
- Naitoh, Artificial Life & Robotics, 2005, 2008, 2010.
- 内藤、日経サイエンス、2005
- Naitoh、RIMS講究録、2011.

など。

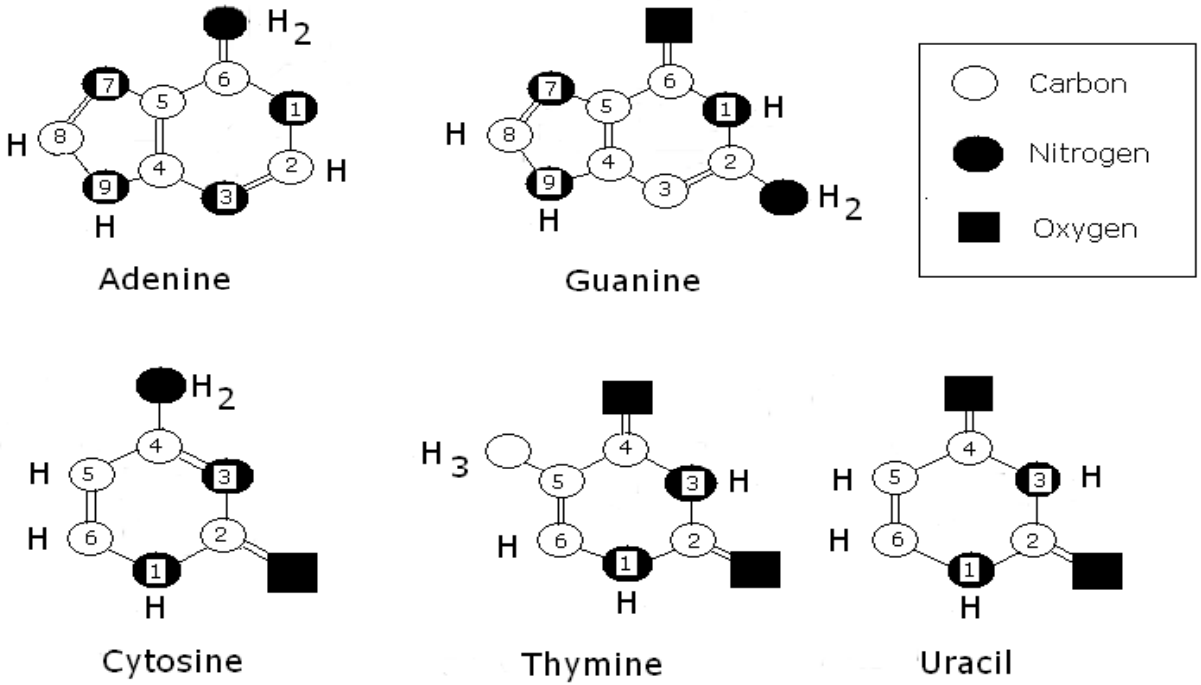
DNAは生命の設計図ではない？！

- DNAは生命の辞書といったほうが良い！？
- 生命の設計図を得るには程遠い
- 新たな設計図の青写真（情報・構造・機能の統合的理解）が必要である！！

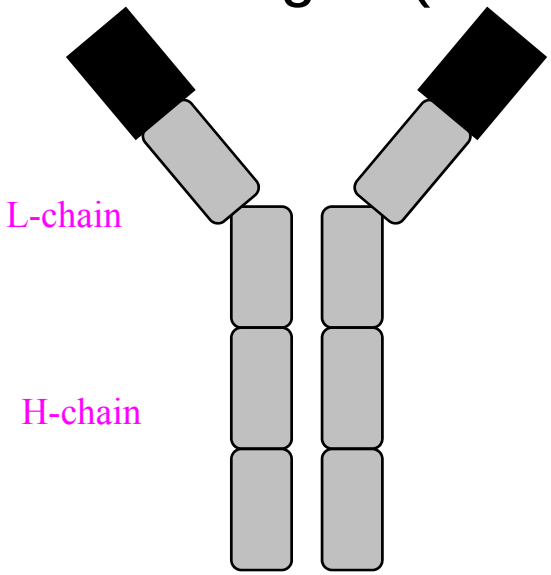
情報の起源は2種類の塩基サイズ：5つの塩基は何故大きいもの2つと小さいもの3つなのか？

Purine

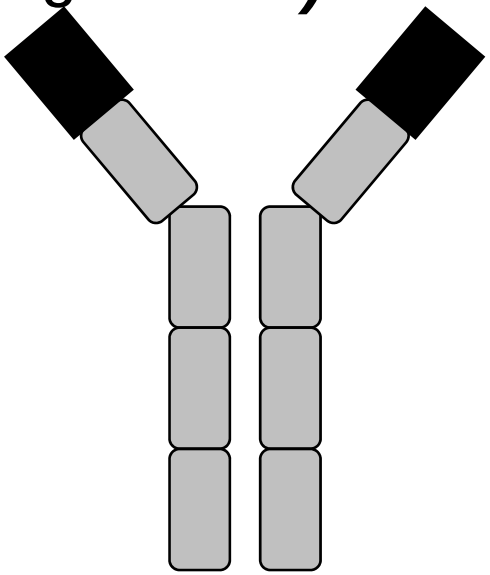
Pyrimidine



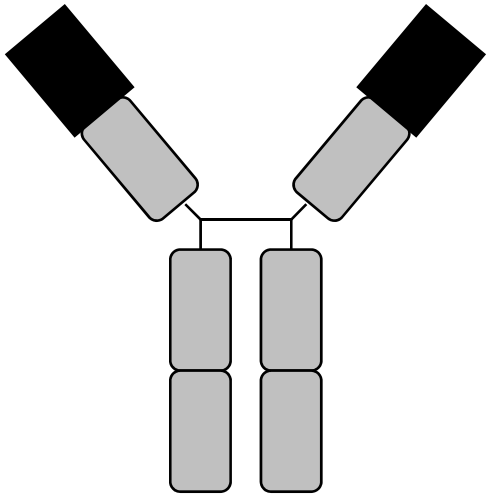
IgX (Immunoglobulin)



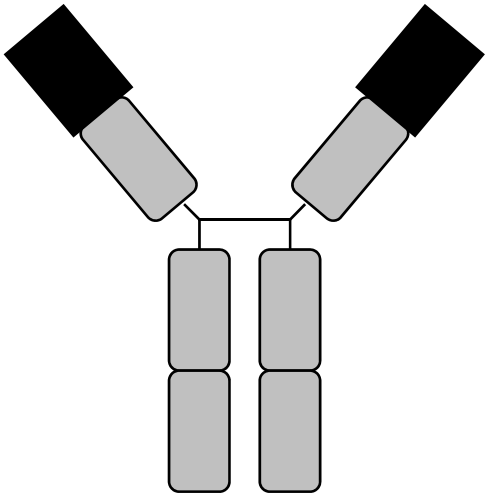
IgM:



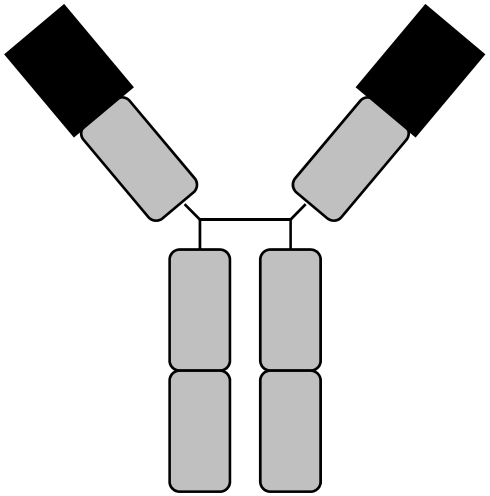
IgE



IgG:



IgD:



IgA:

20種類のアミノ酸

Amino acid	Hydrophilic or hydrophobic
Ala	hydrophobic
Val	hydrophobic
Leu	hydrophobic
Ile	hydrophobic
Pro	hydrophobic
Phe	hydrophobic
Trp	hydrophobic
Met	hydrophobic
Asp	hydorphilic
Glu	hydorphilic
Lys	hydorphilic
Arg	hydorphilic
His	hydorphilic
Gly	hydorphilic
Ser	hydorphilic
Thr	hydorphilic
Cys	hydorphilic
Tyr	hydorphilic
Asn	hydorphilic
Gln	hydorphilic

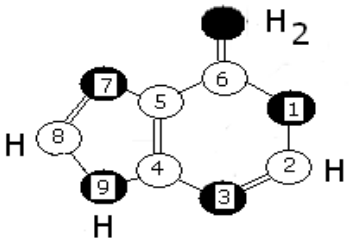
8種類

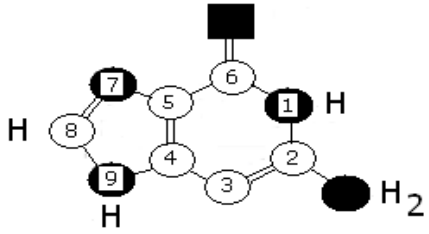
12種類

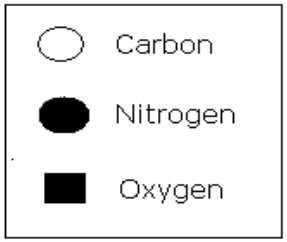
質量保存則:「頻度・濃度・種類数」と「サイズ」は逆比例

$$9 \quad + \quad 9 \quad = 18$$

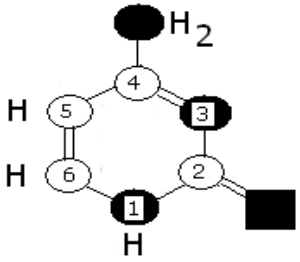
Purine

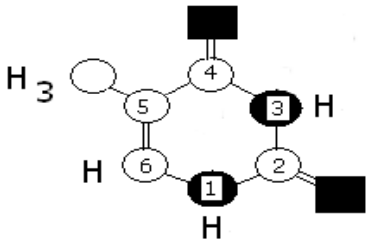


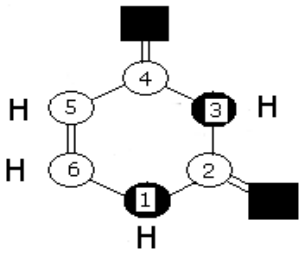




Pyrimidine



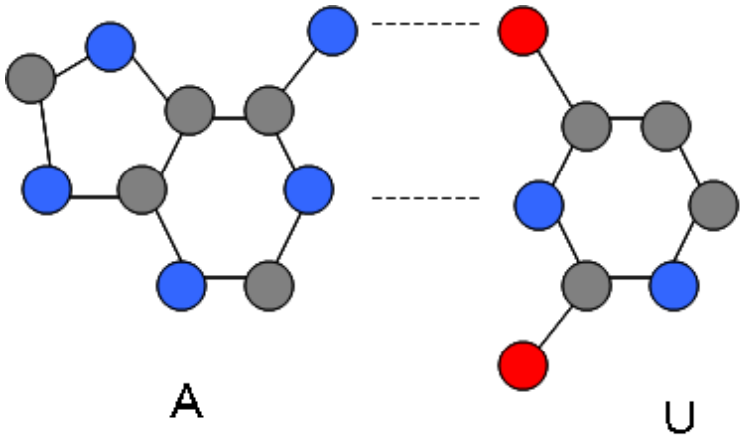




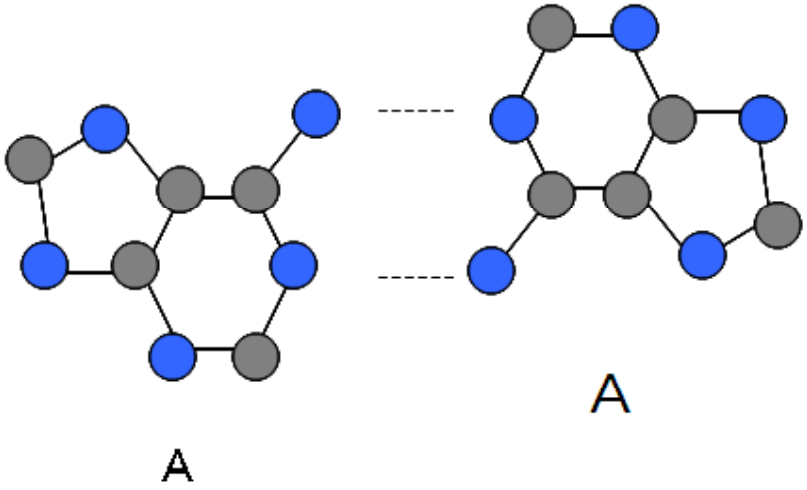
$$6 \quad + \quad 6 \quad 6 = \quad 18$$

サイズ比は？

Actual base pairs



Watson-Crick base-pair in DNA has the asymmetric size ratio around 2:3



Often, base-pair in RNA is in the symmetric size ratio of 1:1.

Some assumptions for particles:

- Particle with three-dimensional flexible axisymmetric shapes such as spheroid,
- One-dimensional free connection of two particles,
- Several interaction forces for several particles such as nuclear force, coulomb force, surface tension, and gravity as the form of 1/r^m.
- Stochastic random disturbance for small scales of phenomena such as bio-molecules and subatomic processes,
- Potential flow inside the particles generated by high impact speeds of water molecules or atoms,
- Particle including water molecules hydrated for nitrogenous bases and amino acids,
- Particle size proportional to parcel size,
- and

Let us go to the formulation.
First is the traditional averaging for the Boltzmann Equation.

$$\rho = m\int f(\vec{c},\vec{x},t)d\vec{c}$$

$$\vec{u} = \frac{m\int \vec{c} f(\vec{c},\vec{x},t)d\vec{c}}{\rho}$$

where $\vec{c}, \vec{u}(=u_1, u_2, u_3)$, $f(\vec{c},\vec{x},t)$, m, $\vec{x}$, ρ denote moleclar velocity, fluid velocity due to continuum assumption, probability density function, molecular weight, cartesian coordinate, and density, respectively.

Let us take an averaging strategy modified from that for the Boltzmann eq. The smallest size dominating the phenomenon inside the very thin early boundary layer, stochastic determinism window, bring the stochastic terms.

$$\overline{\rho} = m\int\int f(\vec{c},\vec{x},t)d\vec{c}\,d\vec{x}_{sd}\,/V_{sd} = \rho - \rho'$$

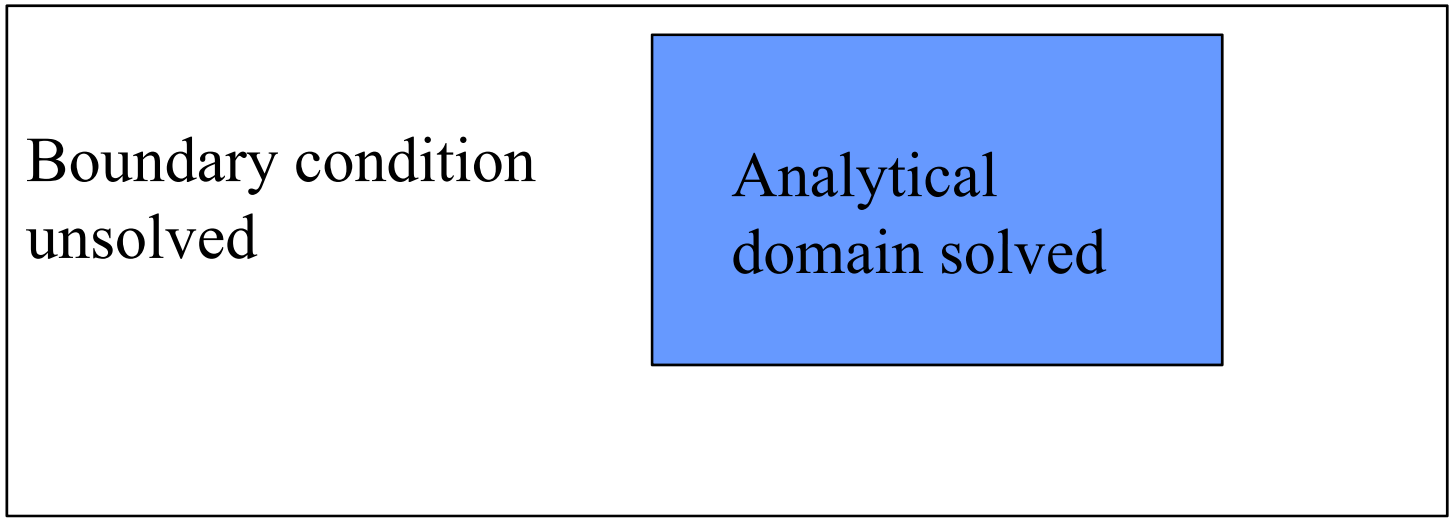
$$\vec{\overline{u}} = \frac{m\int\int \vec{c} f(\vec{c},\vec{x},t)d\vec{c}\,d\vec{x}_{sd}\,/V_{sd}}{\overline{\rho}} = \vec{u} - \vec{u}\,'$$

where dx_{sd} and V_{sd} denote small distance in stochastic determinism window, and control volume of stochastic determinism window, respectively.

Then, the quantities $\overline{\rho}$ and $\overline{u}$ imply those averaged in the stochastic determinism window, while and ρ' and u' are random force terms.

Two indeterminacies:

- **B**oundary condition is also essentially unknown, because we cannot solve all the region on the earth and universe. So, the boundary condition of velocity is also in the other type of indeterminacy.
- We should also consider the stochastic fluctuations inside the analytical domain shown above.
- Thus, the two indeterminacy levels of boundary and inner region should be identical. Consideration of the Liouville equation also bring the identity.



γ - ε equation for two flexible parcels connected

K.Naitoh, Japan J. of Indust. and Applied Mathematics, 2001.など

$$\frac{d^2}{d\bar{t}_i^{\,2}}\gamma_i = \{m_{ci}(\frac{d}{d\bar{t}_i}\gamma_i)^2 + m_{cj}(\frac{d}{d\bar{t}_j}\gamma_j)^2 + m_{si}\,\gamma_i^{\frac{5}{3}-\frac{2}{3}m} + m_{sj}\,\gamma_j^{\frac{5}{3}-\frac{2}{3}m}\}/Det + \delta_{st}$$

$[\text{for } i=1,2.\ j=1,2.\ i\neq j]$

γ : 粒子の変形率

ε : 2つの粒子サイズ比

$$m_{ci} = [(-\varepsilon-\varepsilon^4+\frac{2}{3}\varepsilon E_{0j}\gamma_j^{-1/3})B_{0i} + \frac{2}{9}\varepsilon^{2+m}E_{0i}\varepsilon\gamma_i^{-4/3}]$$

$$m_{cj} = [\frac{2}{3}\varepsilon^{2+m}E_{0i}\gamma_j^{-1/3}B_{0j} - \frac{2}{9}\varepsilon^{2+m}E_{0i}\gamma_j^{-4/3}]$$

$$m_{si} = (-\varepsilon-\varepsilon^4+\frac{2}{3}\varepsilon E_{0j}\gamma_j^{-1/3})C_{0i}$$

$$m_{sj} = \frac{2}{3}\varepsilon^{2+m}E_{0i}\gamma_j^{-1/3}C_{0j}$$

$$Det = -\varepsilon-\varepsilon^4+\frac{2}{3}\varepsilon^4E_{0i}\gamma_i^{-1/3}+\frac{2}{3}\varepsilon\ E_{0j}\gamma_j^{-1/3},\ B_{0k} = \frac{1}{3\gamma_k}\frac{\gamma_k^{\,2}-2}{\gamma_k^{\,2}-1/2},$$

$$C_{0k} = \frac{3}{8}\frac{2\gamma_k^{\,2m}-1/\gamma_k^{\,m}-\gamma_k^{\,m}}{\gamma_k^{\,2}-1/2},\ \text{and}\ E_{0k} = 3\frac{\gamma_k^{\,7/3}}{\gamma_k^{\,2}-1/2}\ [\text{for } k=1,2]$$

Stochastic fluid dynamics and quasi-stability concept can explain the inevitability of about 1:1.5 and 1:1. (1st order of approximation)

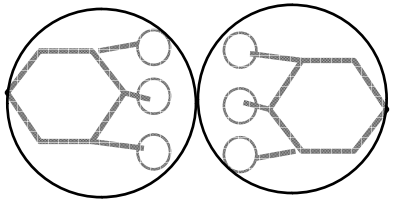
K.Naitoh, Japan J. of Indust. and Applied Mathematics, 2001.など

$$\frac{d^2 y}{dt^2} = (1-\varepsilon)\left(\frac{dy}{dt}\right)^2 + (3-\varepsilon^3)\, y + \Psi(t) + \delta$$

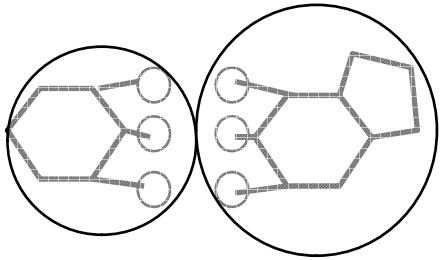
$\varepsilon = 1\ (1:1)$　　$\varepsilon \approx 1.4\ (2:3)$

$y(=\gamma - 1)$: 粒子の変形率

ε: 2つの粒子サイズ比



Pyrimidine　Pyrimidine
Size ratio of 1:1



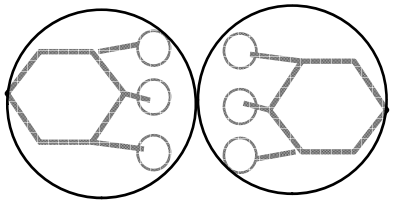
Pyrimidine　Purine
Size ratio around 2:3

Quasi-stability principle is

- One part of equation system (or only one term) is zero.
- This is between neutral stable and unstable conditions.
- Unstable < quasi-stable < Neutral stable < Stable

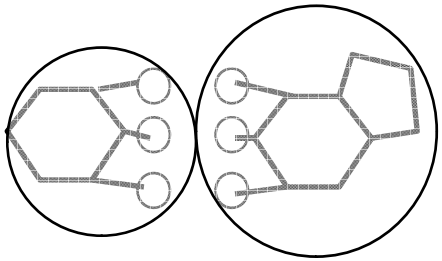
- Natural phenomena such as breakup processes of several particles get stable situation through unstable situation. So, meta-stable condition between stable and unstable situations, i.e., quasi-stable one, is essential.

Symmetry and asymmetry can be described only by the n-th root of n.



Pyrimidine Pyrimidine
Size ratio of 1:1

n = 1: 1:1



Pyrimidine Purine
Size ratio around 2:3

n = 3: $1:\sqrt[3]{3}$
(1:1.44)

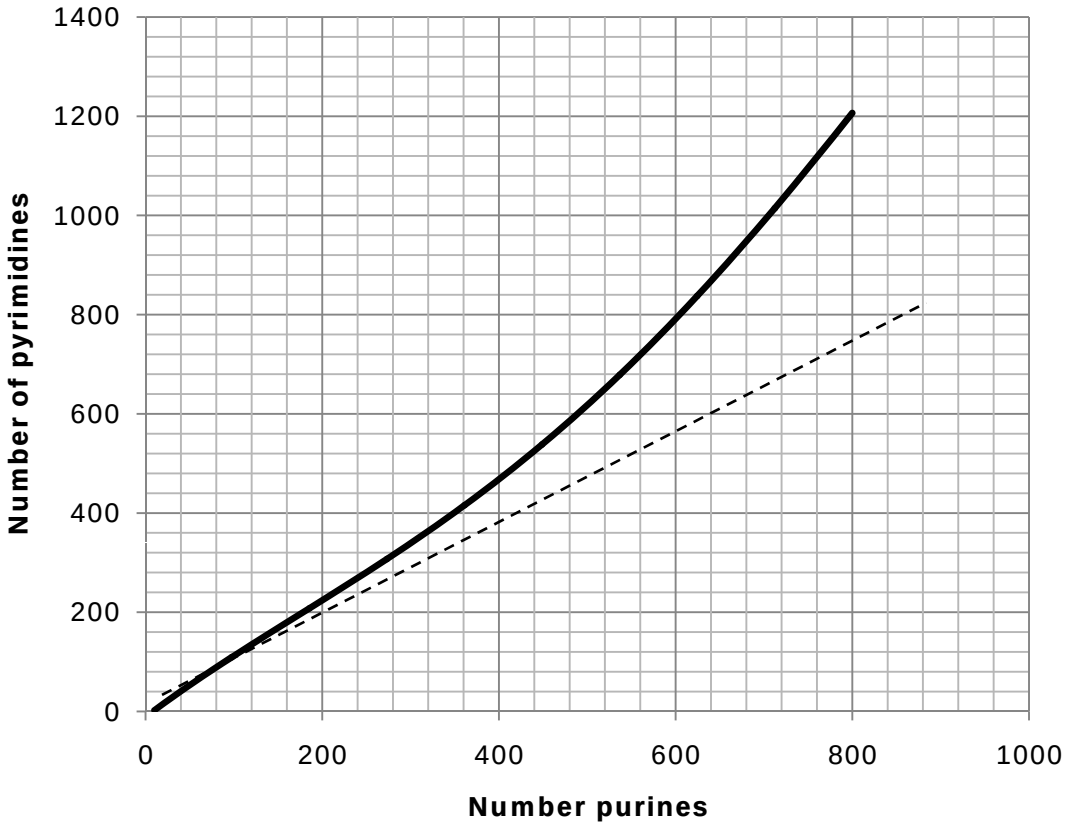
Ken Naitoh, NIKKEI Science、2005
K.Naitoh,J.J.of Industrial and Applied Mathematics,2001

約2:3(黄金比・白銀比)と1:1(大和比)がフラクタル的に存在

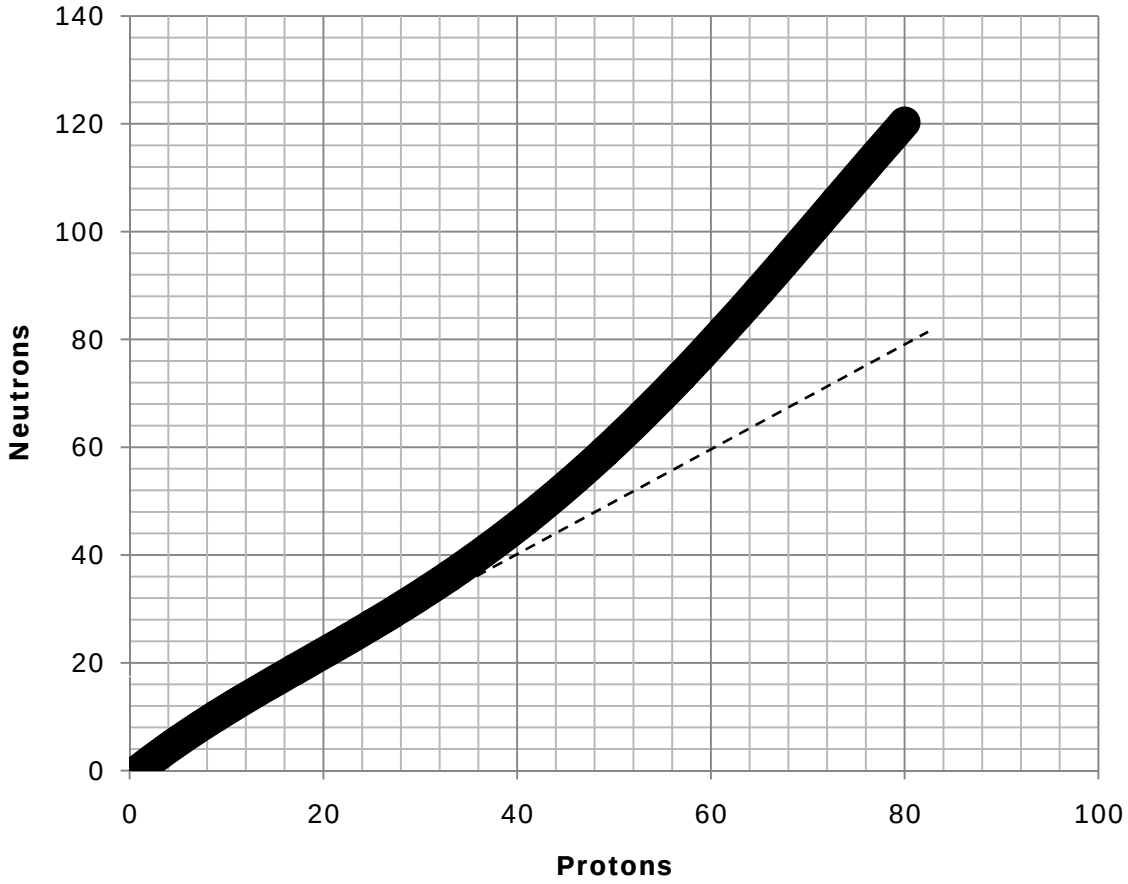
- 流体液粒の分裂
- 細胞の分裂
- 塩基ペア
- RNA中のプリンとピリミジンの頻度比も1:1から2:3
- 原子核の分裂:原子核内中性子と陽子数の比も、1:1から1．1．5
- 素粒子:メソンとバリオンはQuark2個:3個
- 非生命にも2:3があるので、生命起源にこれらの比が現れた

Naitoh，JJIAM, 2001. J. of Cosmology, 2010.等

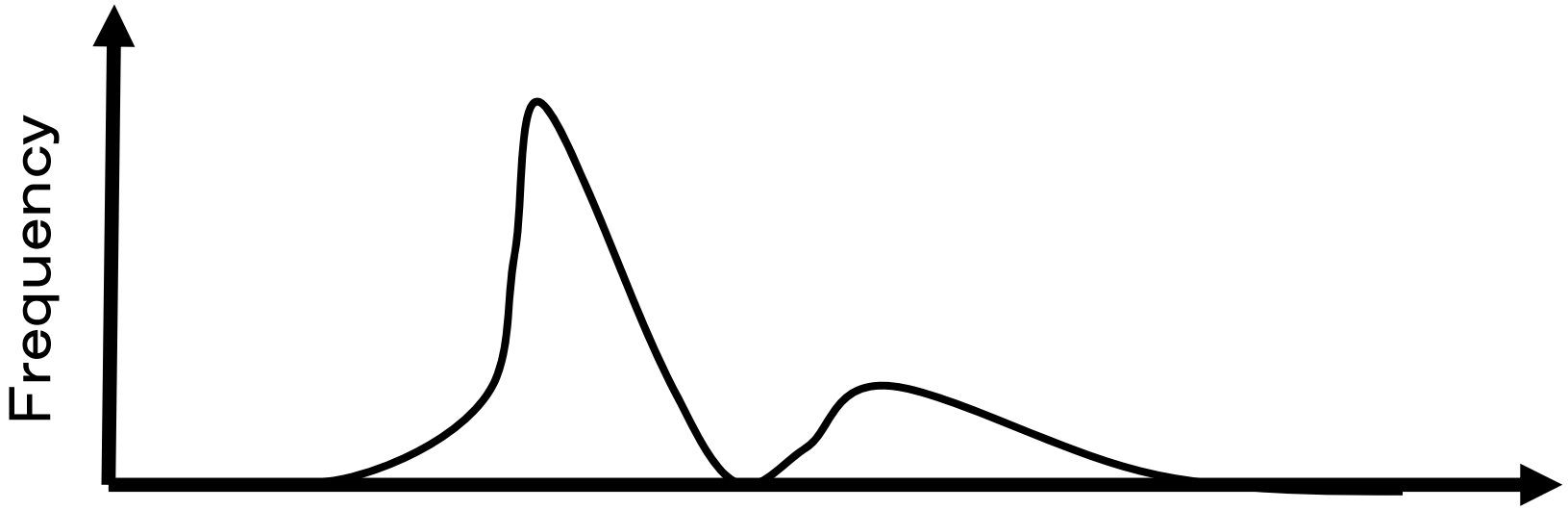
Frequency ratios between 2:3 and 1:1 in RNAs



Frequency ratios between 2:3 and 1:1 in atoms



Stars



Why the specific ratios appear in several systems

- Let us cut a long story short.
- The reason is very simple.
- Each system is “breakup of flexible particles interacting”.
- Fluid dynamic effect is important.

- 美術：黄金比（約2：3）を心地よく感じる
- 日本人の美観：大和比（1：1）も心地よく感じる

1:1と約2:3

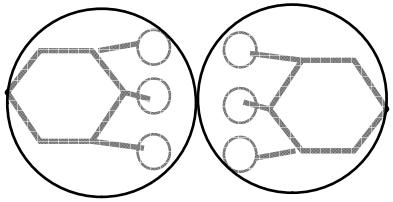
- 生命以外の自然界にもこれらの比が多く存在し、かつ、生命中の様々なレベルに、この比があるので、共鳴するからここちよい
- 生命分子や細胞サイズと同じように、これらの比を持つ細胞群が脳にもあるのではないか？

「1:1と約2:3を含む喜水比に満たされた生命分子、細胞ペア、生命以外の自然界の粒子ペアと共鳴する神経細胞群が脳内にあり、それらのサイズ比も喜水比であるはず。」Naitoh, Japan J. of Indust. And Applied Mathematics, 2001.

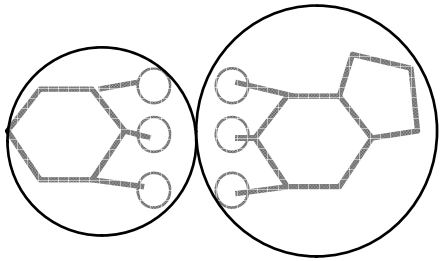
予測が実証された。
ここちよさに関連する脳内の非対称部位が見つかった！
ゼブラフィッシュ手綱核における左右非対称な神経結合

・H.Aizawa, Isaac H. Bianco, T.Hamaoka, T. Miyashita, O. Uemura, Miguel L. Concha, C. Russell, S.W. Wilson and H. Okamoto: Current Biology Vol.15, 8 February 2005, Pages 238-243.

非対称の条件は？



Pyrimidine　Pyrimidine
Size ratio of 1:1

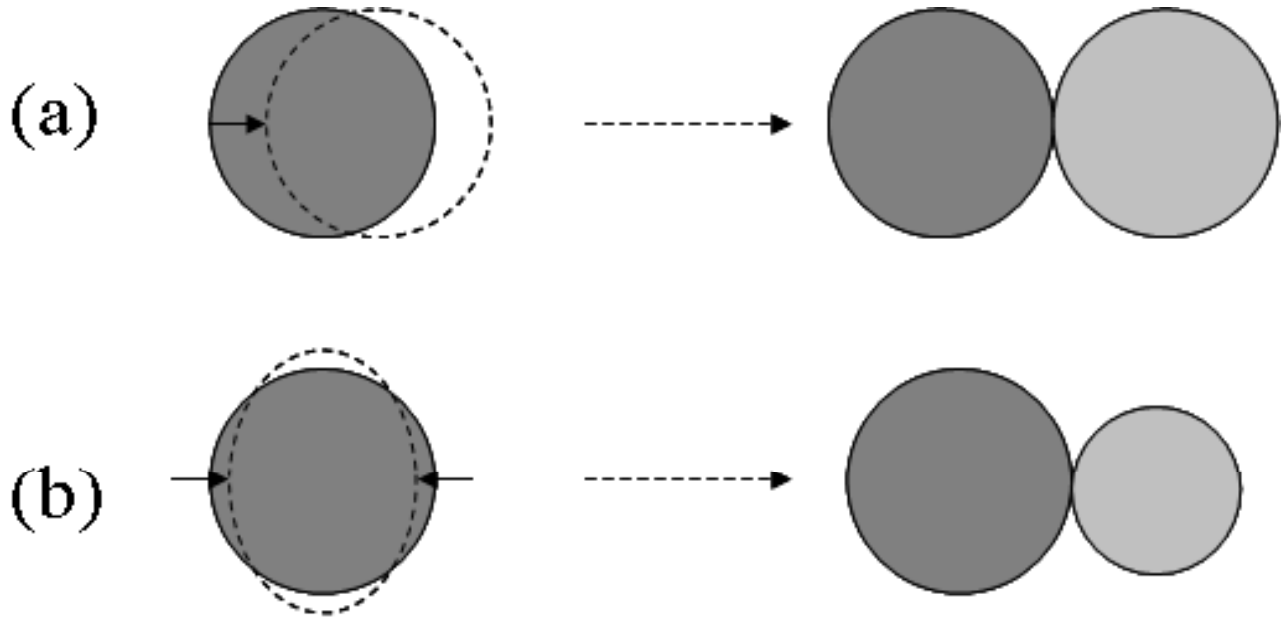


Pyrimidine　Purine
Size ratio around 2:3

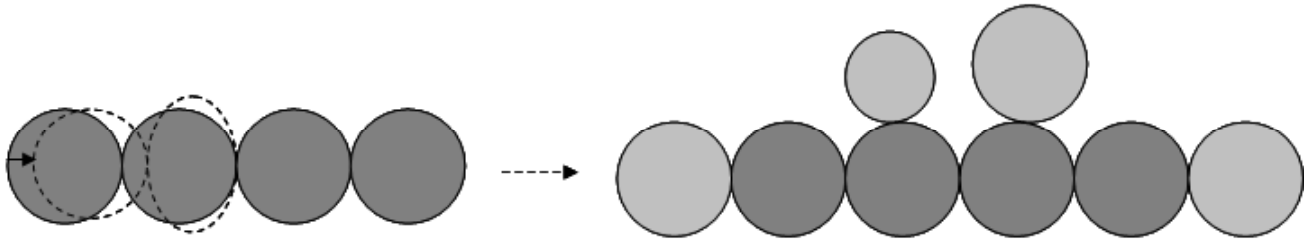
Symmetric　　Asymmetric

Naitoh K (1999) Cyto-fluid Dynamic Theory for Atomization Processes, Oil & Gas Science and Technology, Vol. 54, No. 2: 205-210

細胞の微小変形が非対称分裂を引き起こす



内側の細胞の方が変形しやすいので、内側の細胞が非対称分裂を引き起こす



臓器の構造：発生過程の時空間機構

何故、肝臓や心臓はひとつで左右非対称なのか？
何故、手足、腎臓や肺は2つで左右対称なのか？

左右非対称性を決める因子

- 外界との接触のない閉領域細胞・臓器ー左右非対称、Cf.心臓、肝臓、膵臓、胃腸
- 外界との接触のある開領域の細胞・臓器ー左右対称、Cf. 耳、手足、腎臓、眼球、(肺)

Naitoh, Artificial Life and Robotics, 2008, 2010.

双極性：対称性と非対称性の混在

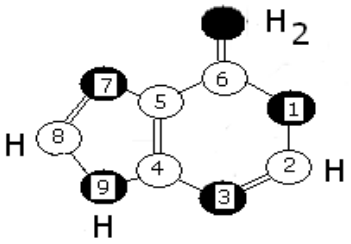
- サイズの情報→対称と非対称な2種類のブロックのペア混在→複雑凹凸構造を生成→マクロな機能生成（例えば手足）

分子は？

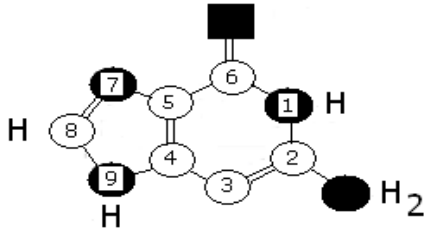
- 基本情報（サイズ）→頻度→構造→機能

5つの塩基

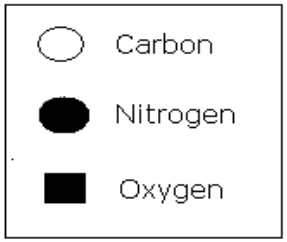
Purine



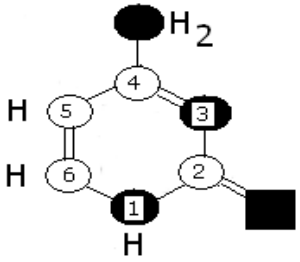
Adenine



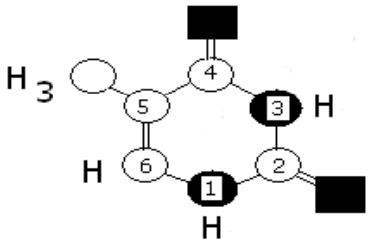
Guanine



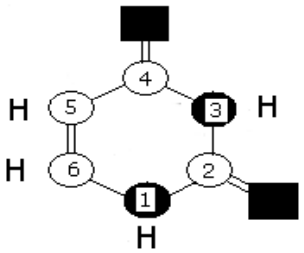
Pyrimidine



Cytosine

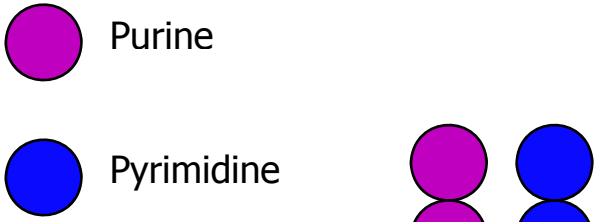


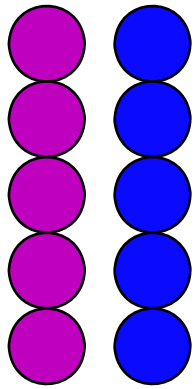
Thymine



Uracil

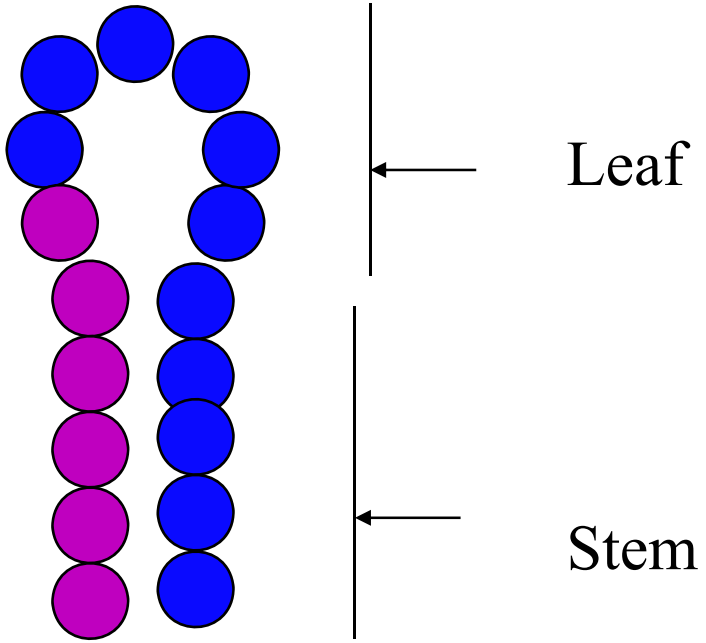
Asymmetric frequency ratio of purine and pyrimidine results in complex structure.





1:1

DNA has base-pair
at each locus because of
Frequency ratio of 1:1.



1:1.1- 1:1.5

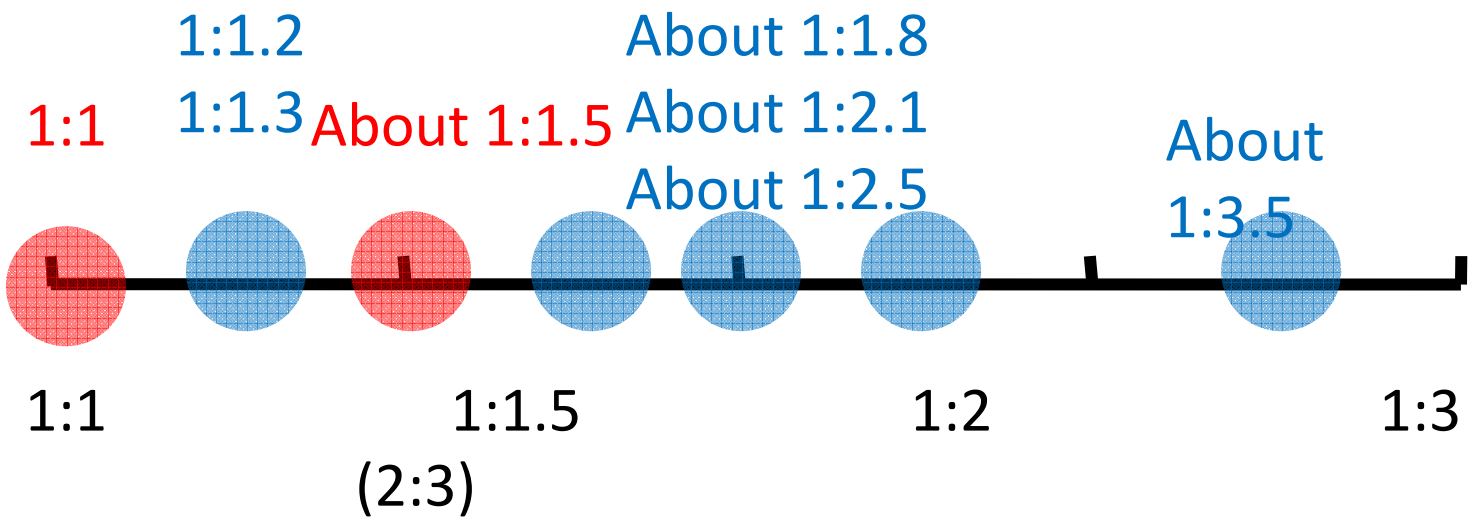
RNA is with free bases because of asymmetric frequency ratio around 1.5. So, leaf exists.

だから、20種類のアミノ酸！

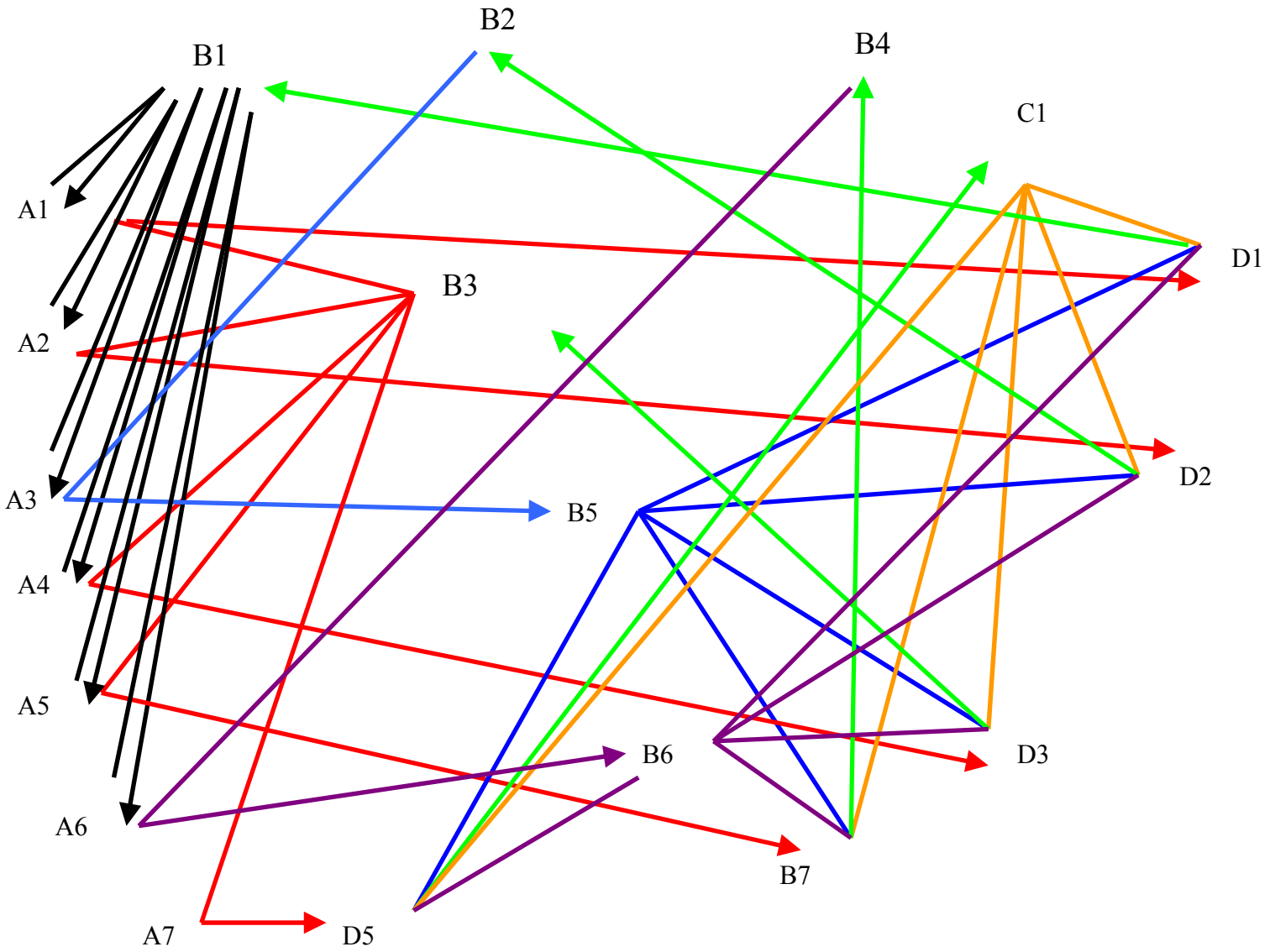
Amino acid	Hydrophilic or hydrophobic
Ala	hydrophobic
Val	hydrophobic
Leu	hydrophobic
Ile	hydrophobic
Pro	hydrophobic
Phe	hydrophobic
Trp	hydrophobic
Met	hydrophobic
Asp	hydorphilic
Glu	hydorphilic
Lys	hydorphilic
Arg	hydorphilic
His	hydorphilic
Gly	hydorphilic
Ser	hydorphilic
Thr	hydorphilic
Cys	hydorphilic
Tyr	hydorphilic
Asn	hydorphilic
Gln	hydorphilic

広義の魔法数:
黄金比に近い2:3 と 1:1以外は？？

Then, a higher-order of analysis also reveals the other specific ratios such as those for the various amino-acids.

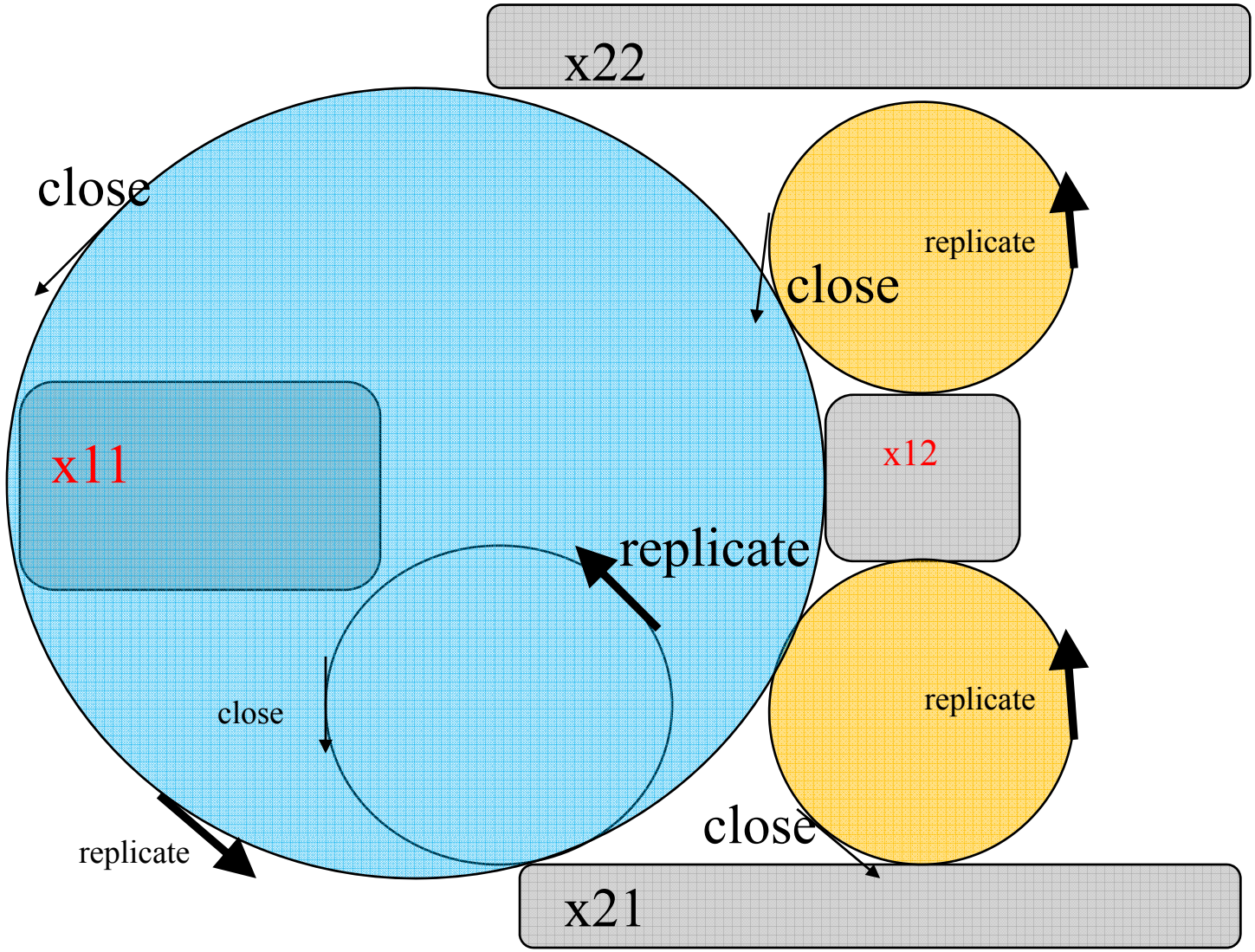


分子群のネットワークは？？



Reaction network for increasing all the molecules (accelerator):

Information groups (x11 and x12) and function groups (x21and x22) work as accelerator, Naitoh, Artificial Life & Robotics, 2008.

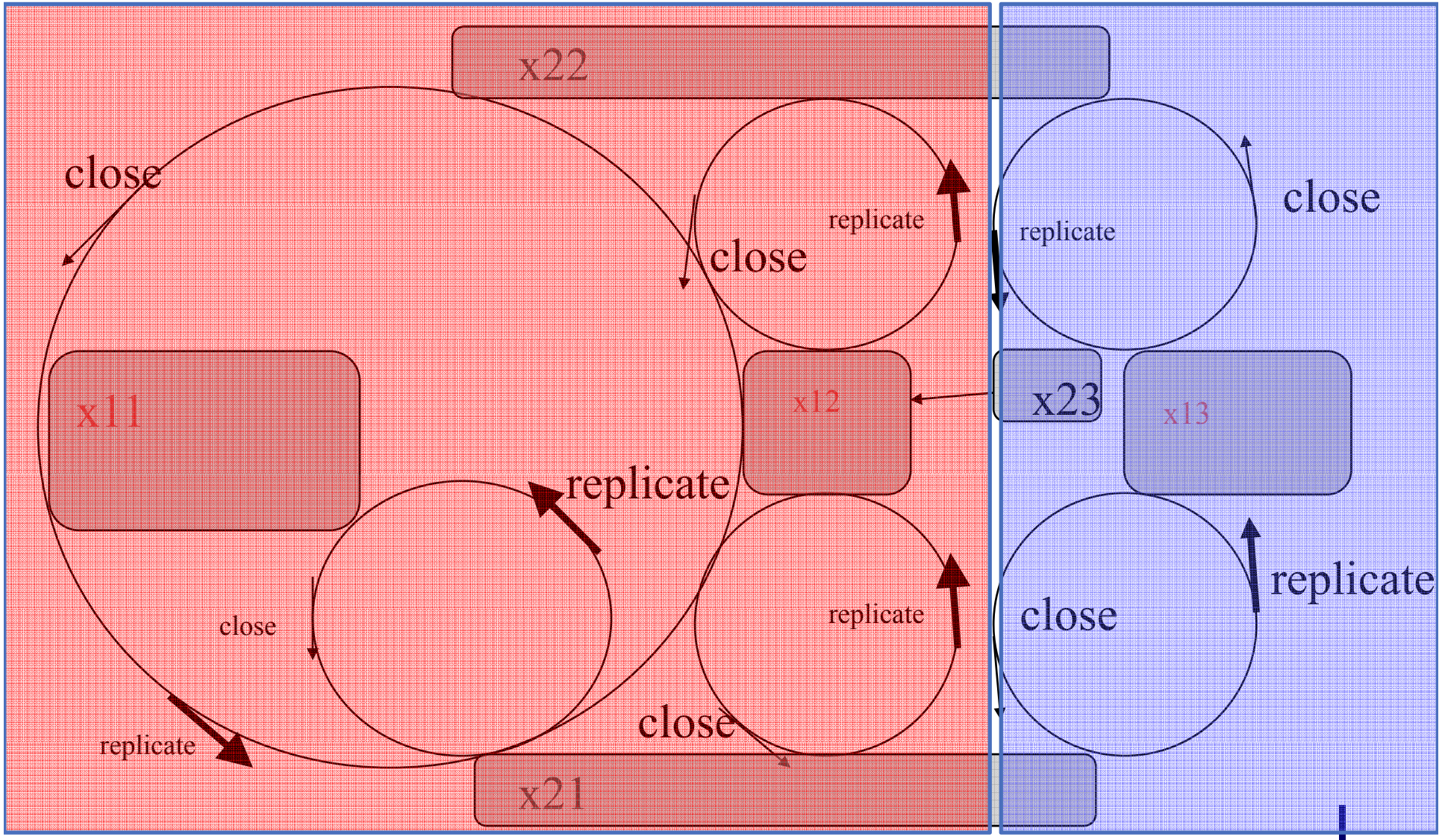


生命の定義

- 対称・非対称ネットワーク混在の4分子群：
  生命の最低必要条件

Reaction network of bio-oscillator: Naitoh, 2008, 2011.

Information groups (x11 and x12) and function groups (x21and x22) work as accelerator, while x13 and x23 work as brake (depression).



The macroscopic model for several bio-oscillations

(Naitoh, Proc. of the 13rd Int. Conf. on BioMedical Eng., Springer, 2008 & JJIAM 2011.)

Density increase of molecular group ij

Information group for subgroup j

Function group for accelerating maingroup i

$$x_{ij}^{N+1} - x_{ij}^{N} = \alpha_{ij} \left(x_{1j}^{N} - b_{ij} x_{23}^{N} \right) * x_{2i}^{N}, \qquad x_{ij} \geq 0$$

Depression

- i: 2 major groups of information and function
  (i=1 for information molecular group / i=2 for functional molecular group)
- j: 3 subgroups of information production, function production, and depression
  (j=1 for information / j=2 for function generation / j=3 for depression)
- N: generation

発生過程

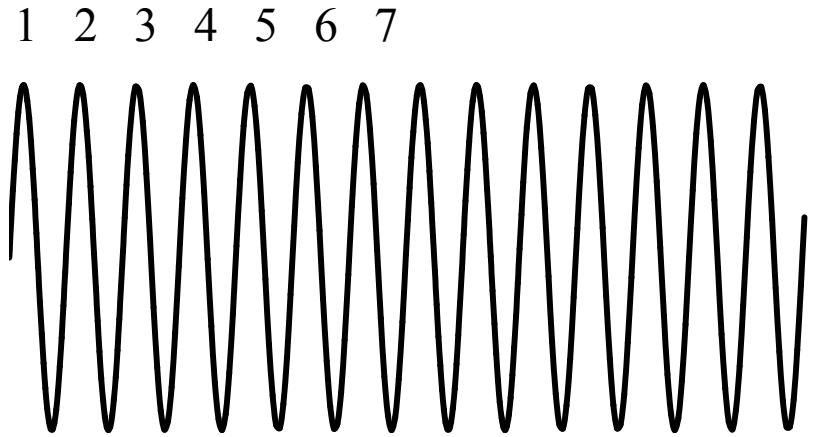
胚や臓器は6-7回の細胞分裂の周期で発生する

Phase	Fertile egg	Blast cyst	Ectodermal, Endoderm	Mesoderm	Heart	Hand,Leg, Eye,Ear	Unborn Baby	Neonate:
The number of divisions	0	6	13	20	26	32	37	40−45

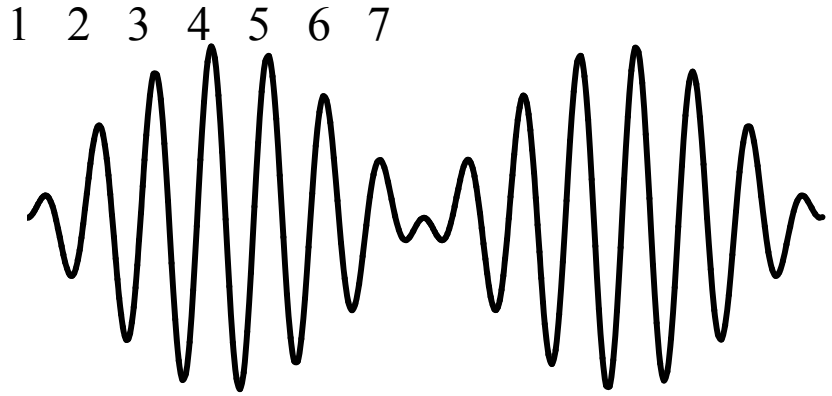
受精卵　胚盤葉　外胚葉内胚葉　中胚葉　心臓　手足目耳　胎児　新生児

Braking system (depression molecule) such as OCT4 is also necessary for stem cell cycles.

Basic rhythm



Seven-fold beats



Circadian Clock

- 約3.5時間周期の濃度変化を起こす分子系ユニットが存在し、その6－7回の繰り返しで、24時間程度のリズムを形成していることに一致

まとめ

- 情報・構造・機能にまたがる「生命起源からヒトに至る生命の新たな設計原理」(Onto-biology)。
- 生命では、非対称性と対称性の混在(双極性)が見られ、それが、構造と機能を生成している。
- 素粒子・核子・原子・分子・生命細胞・液粒・恒星の分裂現象の統合理論提示。
- 計算機実験と思考実験と実験の3つの実験の組み合わせの重要性。
- そろそろ、応用へ。