Hard problems of the origin of life

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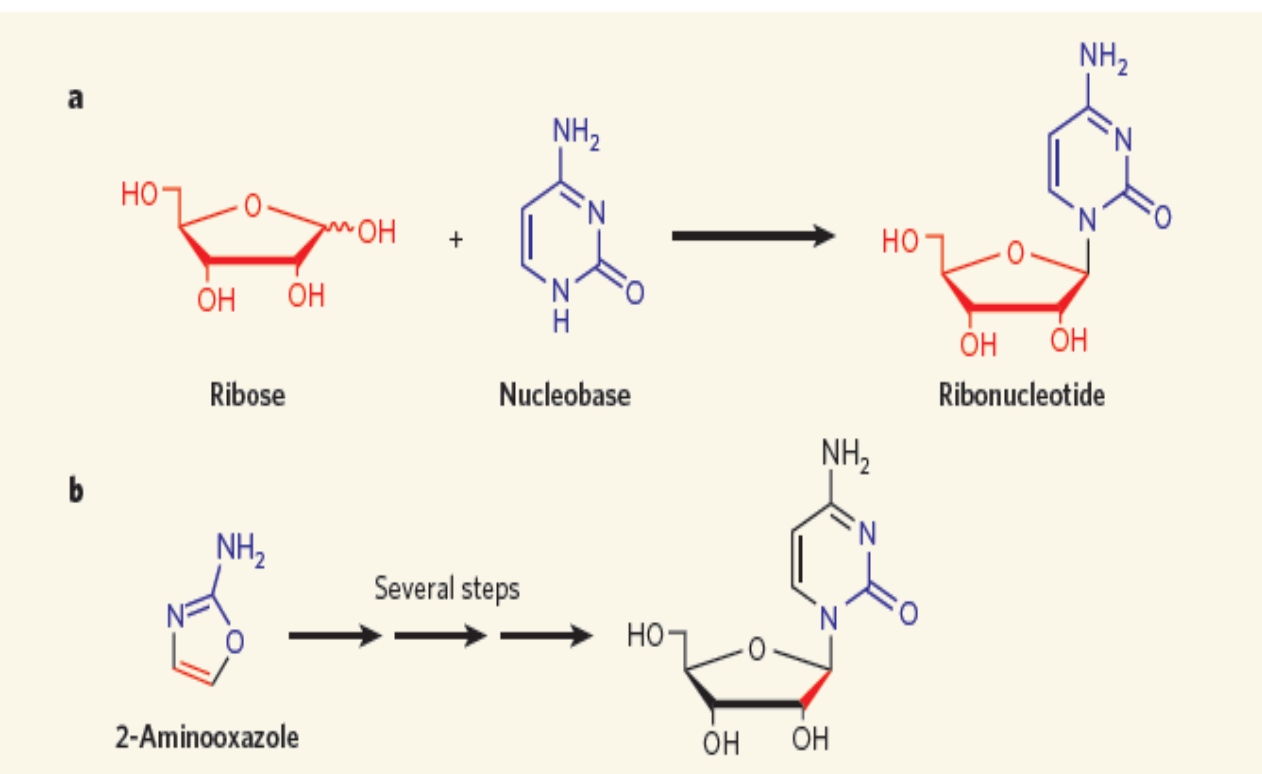
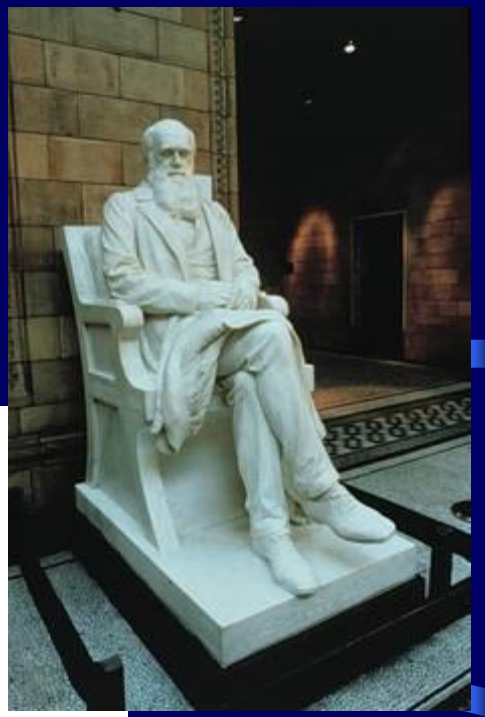
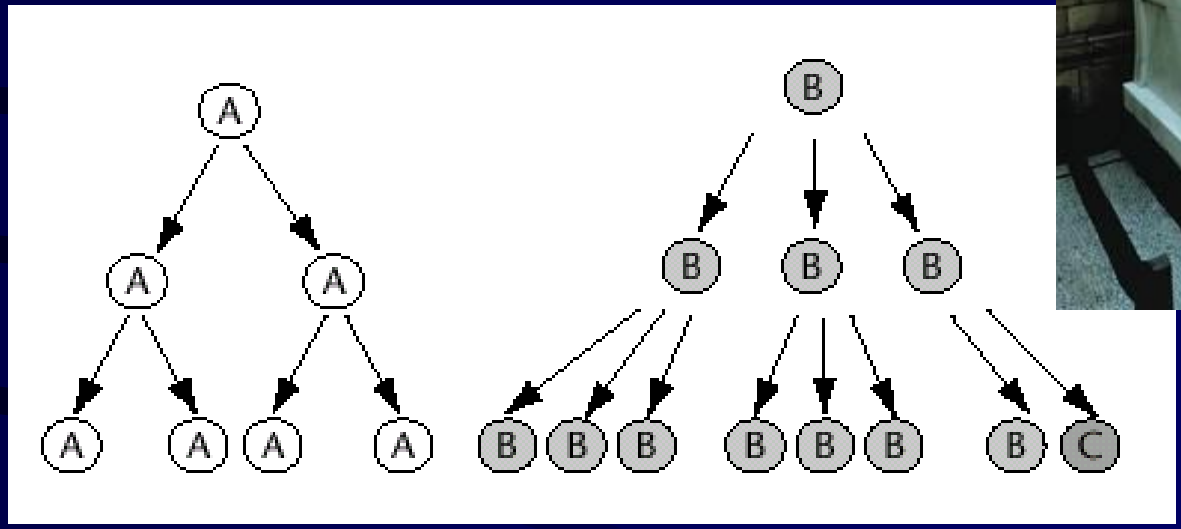
Chemical evolution



Units of evolution





1. multiplication
2. heredity
3. variation

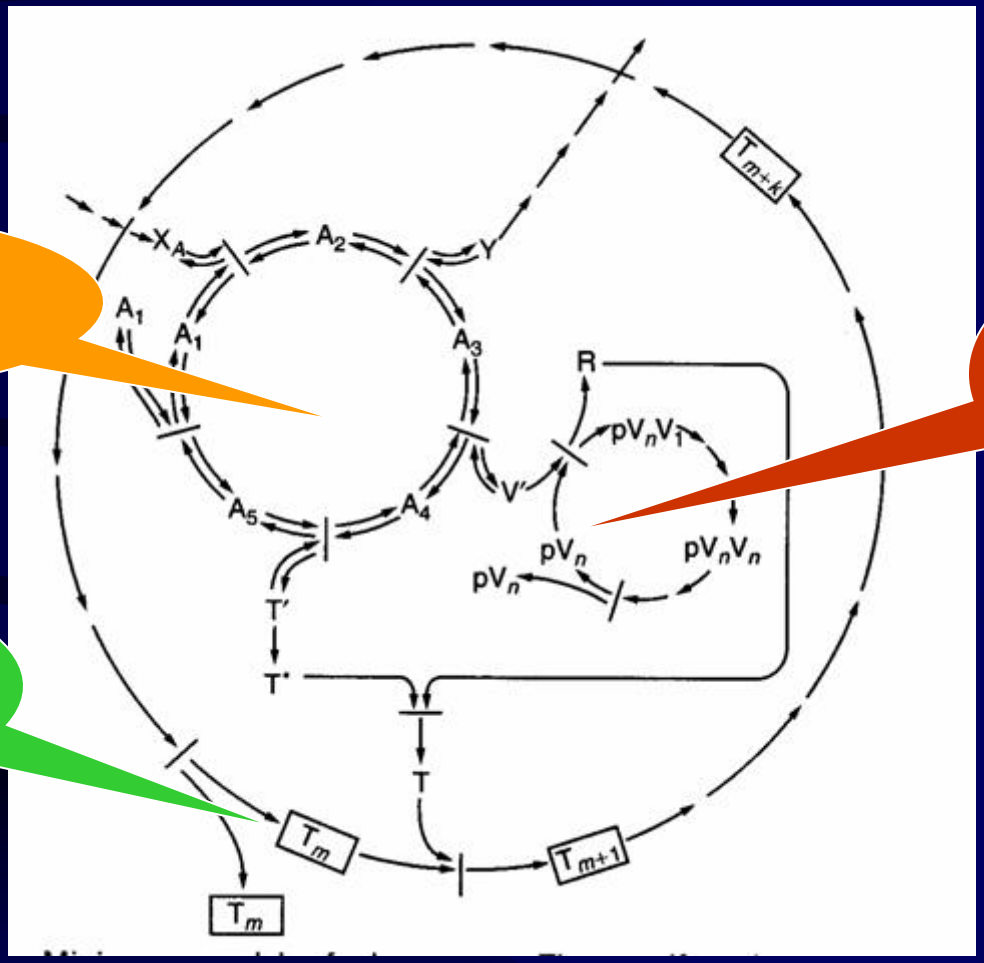
hereditary traits affecting survival and/or reproduction

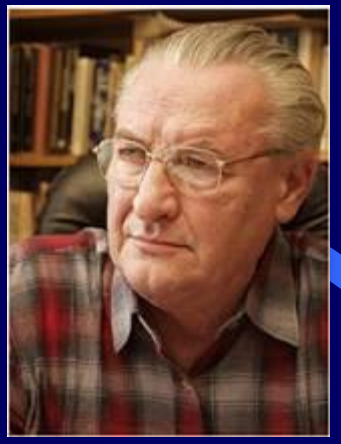
Gánti's chemoton model (1974)

metabolism

membrane growth

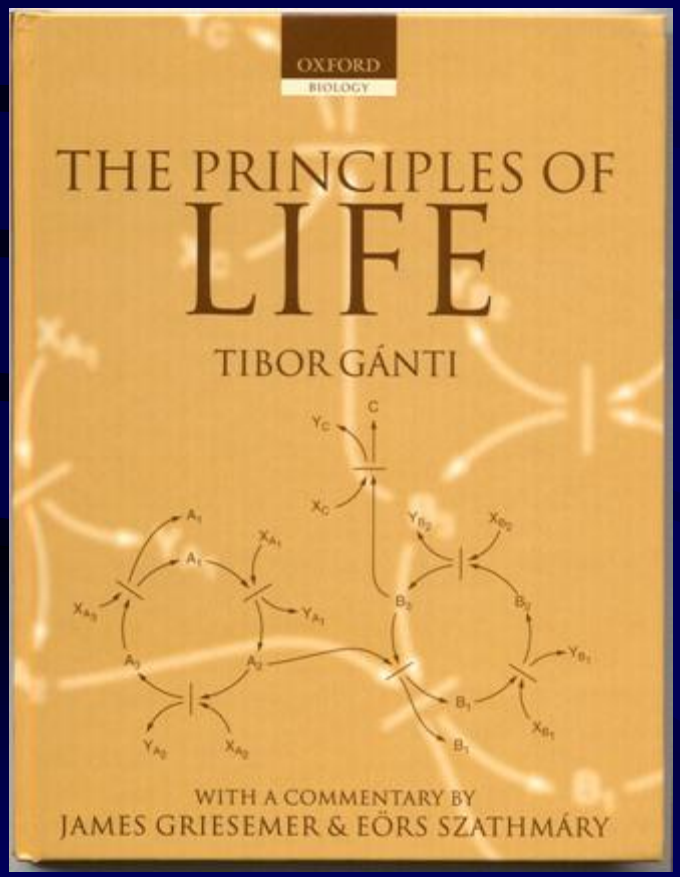
template copying





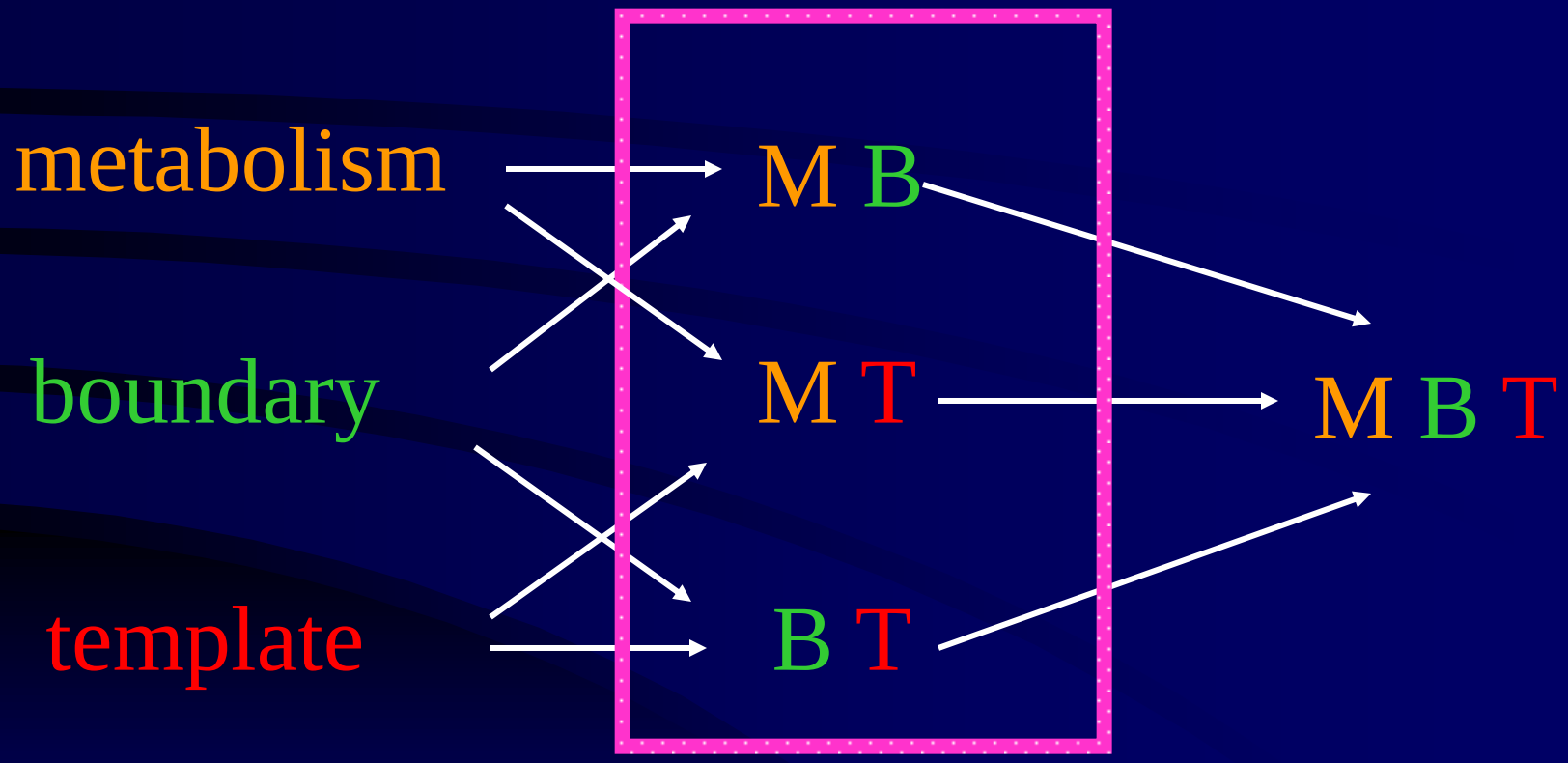
ALL THREE SUBSYSTEMS ARE AUTOCATALYTIC

The latest edition: OUP 2003



- After several editions in Hungarian
- Two previous books (the *Principles* and *Contra Crick*) plus one essay
- Essays appreciating the biological and philosophical importance

Pathways of supersystem evolution



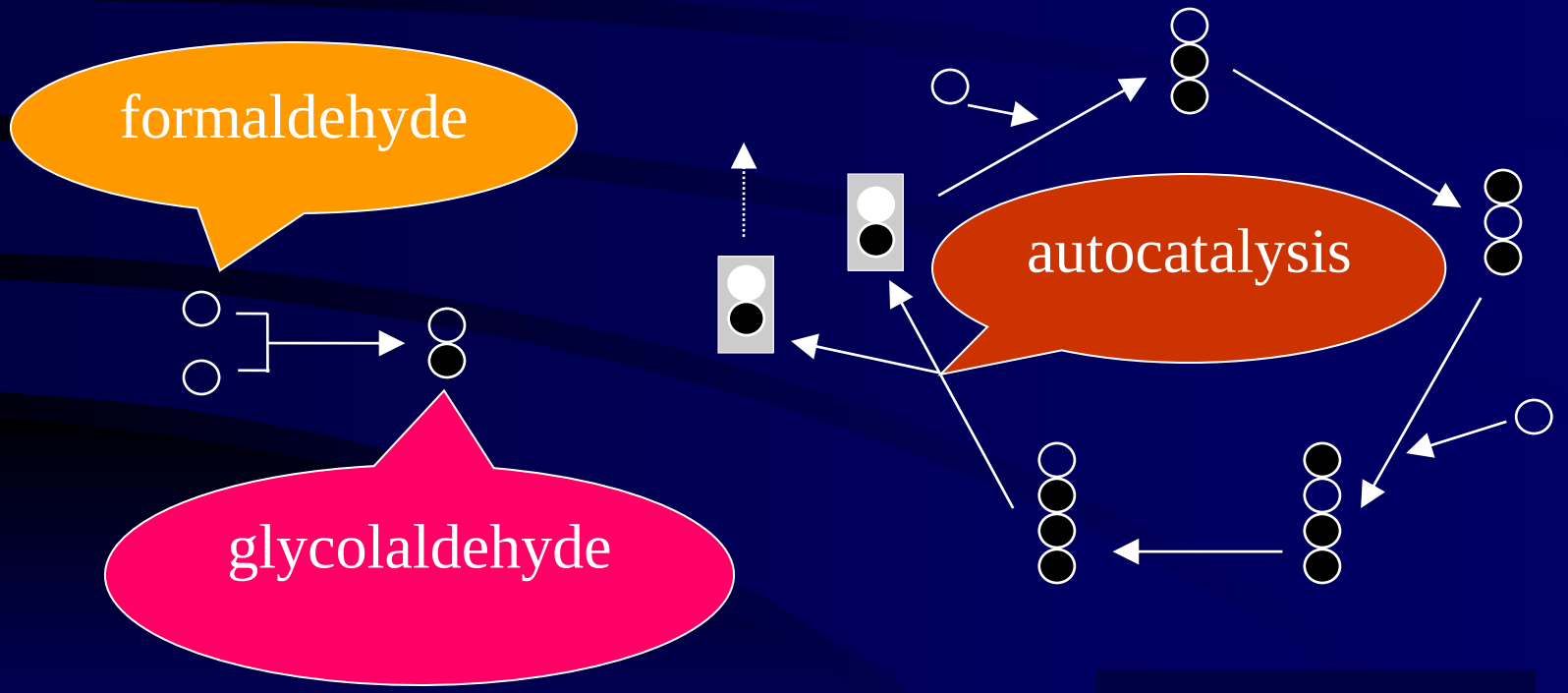
What about replication?

- Replication from a chemical point of view always rests on autocatalysis
- The basic form is

$$A + X \rightarrow 2\ A + Y$$

- very important for biology
- Much more general than DNA

The formose ‘reaction’

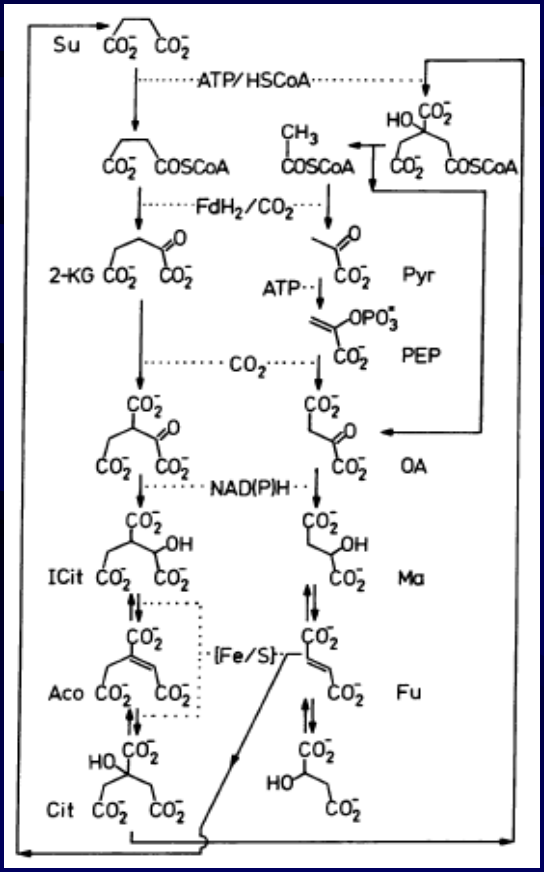


Butlerow, 1861

Replication in the formose reaction

- Replication is non-informational
- Autocatalysis – YES
- Heredity – NO
- Good for metabolism
- Not good for genetics
- Butlerow was born on the 15th Sept, 1829
- He was regarded as one of the best lecturers of his time. His lectures were lucid and thorough, yet his language was colourful. Local society often preferred his lectures to the theatre

Primitive ancestry of the reverse citric acid cycle



- Was proposed by Günter Wächtershäuser (1990)
- Coupled to CO_2 fixation and pyrite formation around deep-sea hydrothermal vents

The main problem of the origin of life is metabolite channelling

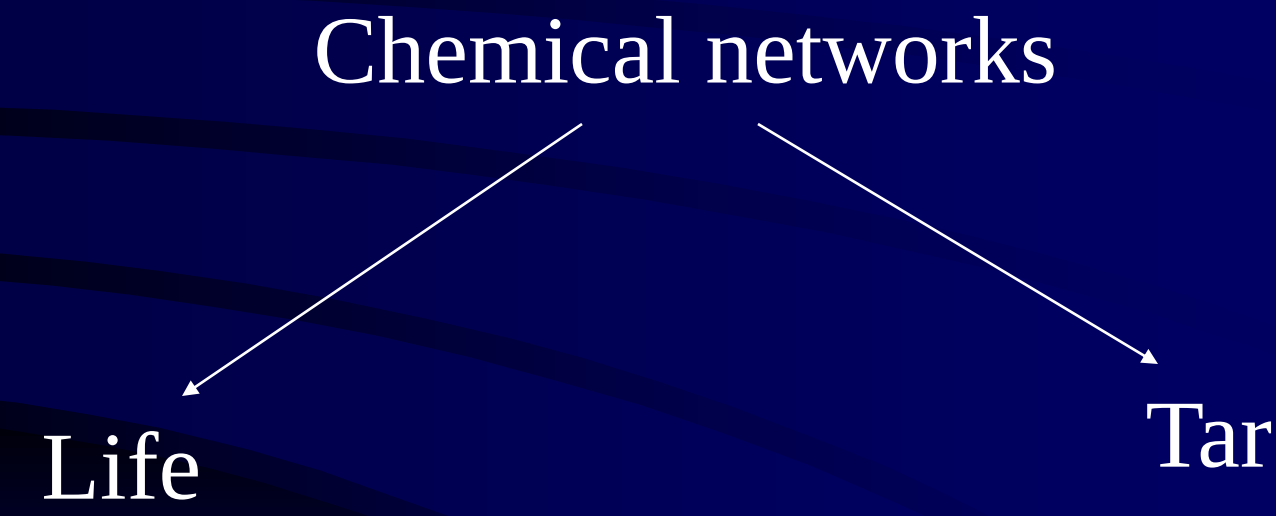
- Enzymes speed up reactions *relative to* the unwanted reactions
- Spontaneous decay reactions abound
- Maintenance, not only reproduction, requires autocatalysis

$$\mathrm{d}x/\,\mathrm{d}t = k\,x - d\,x = 0$$

All network models neglecting side reactions were seriously incomplete

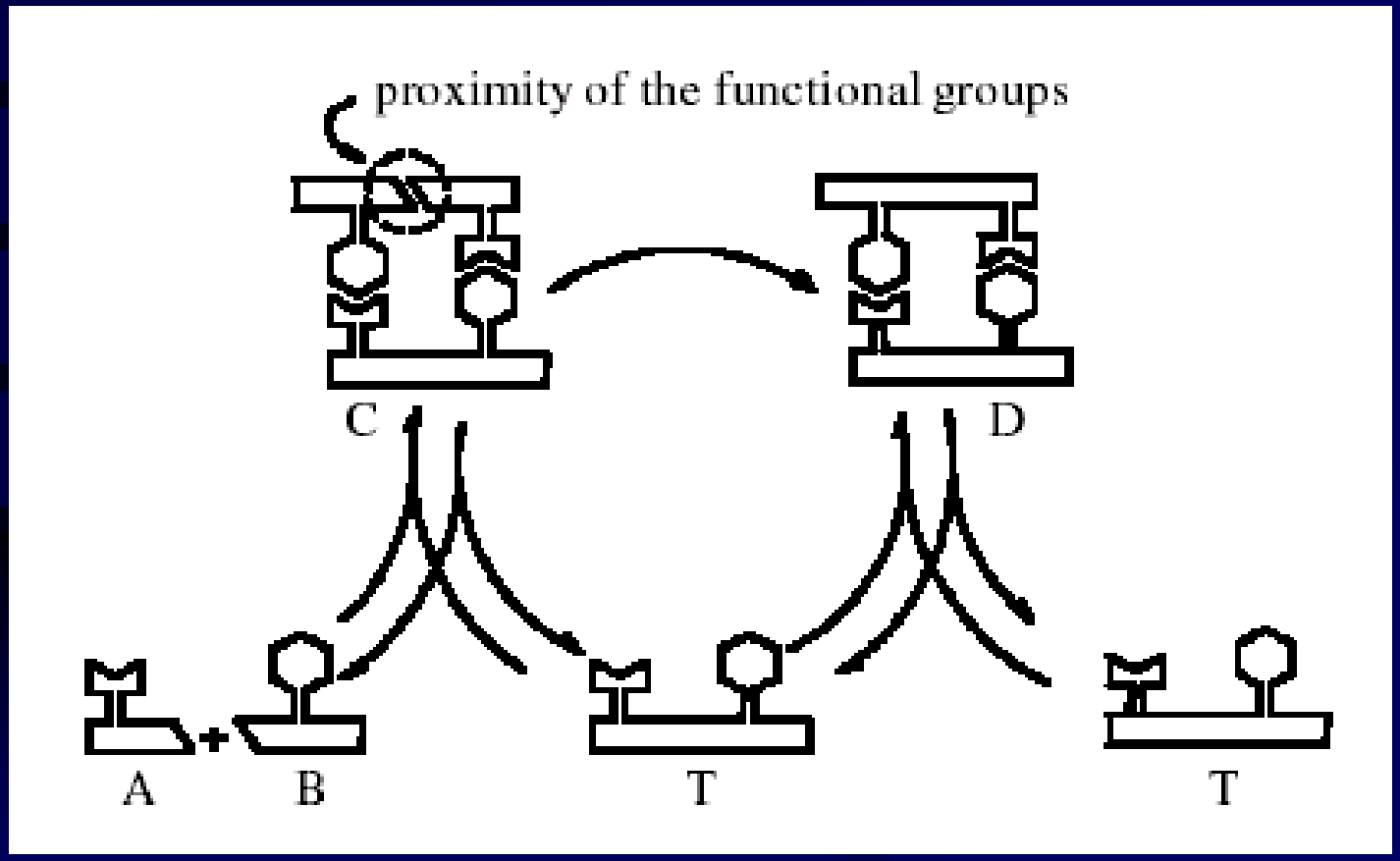
- E.g. protein networks
- In model assumptions, a reaction is either good or neutral for the system – but the number of harmful transformations is in fact much higher
- Did life emerge from a chemical canyon?

Chemical evolution was a race between tar formation and life formation

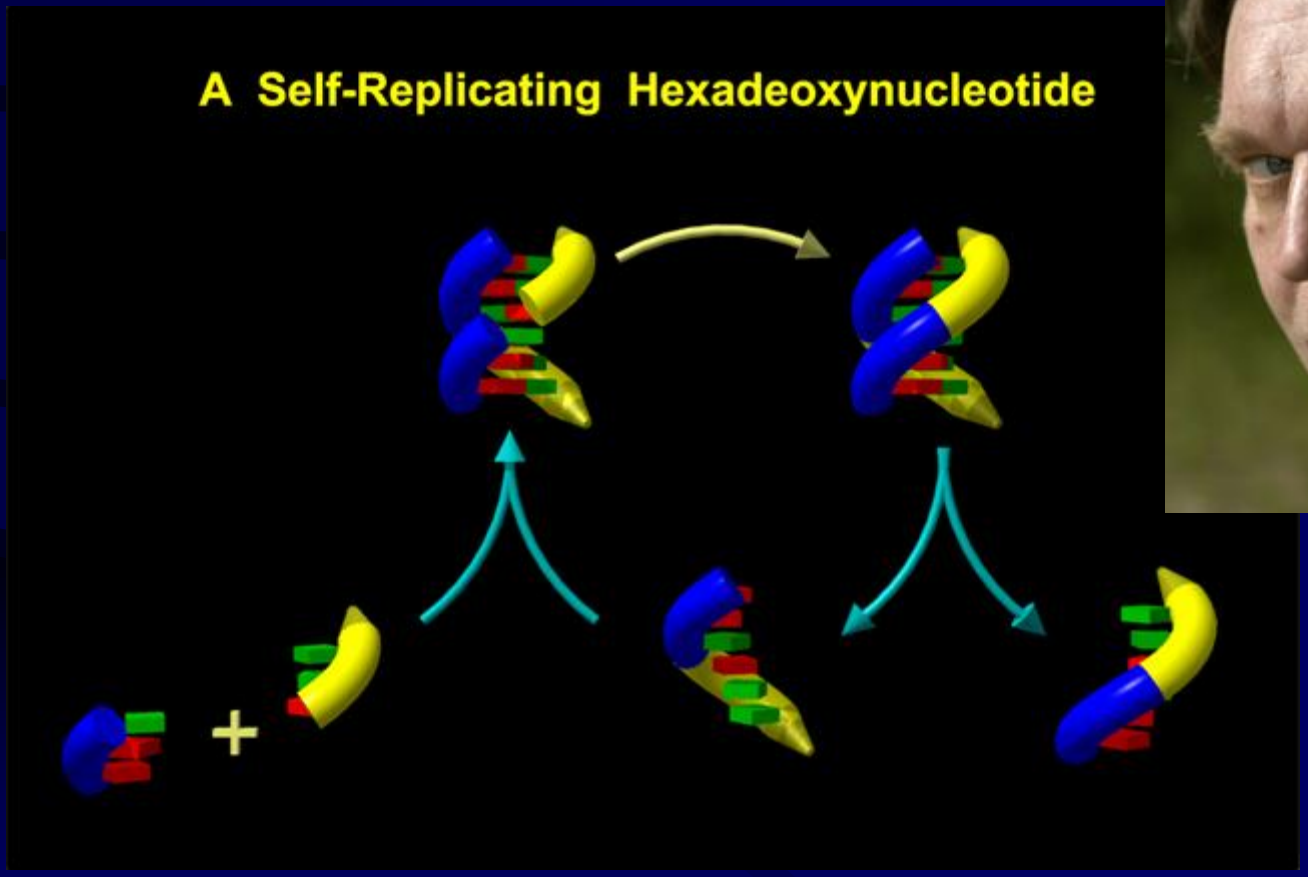


What fraction of planets would end up with just tar?

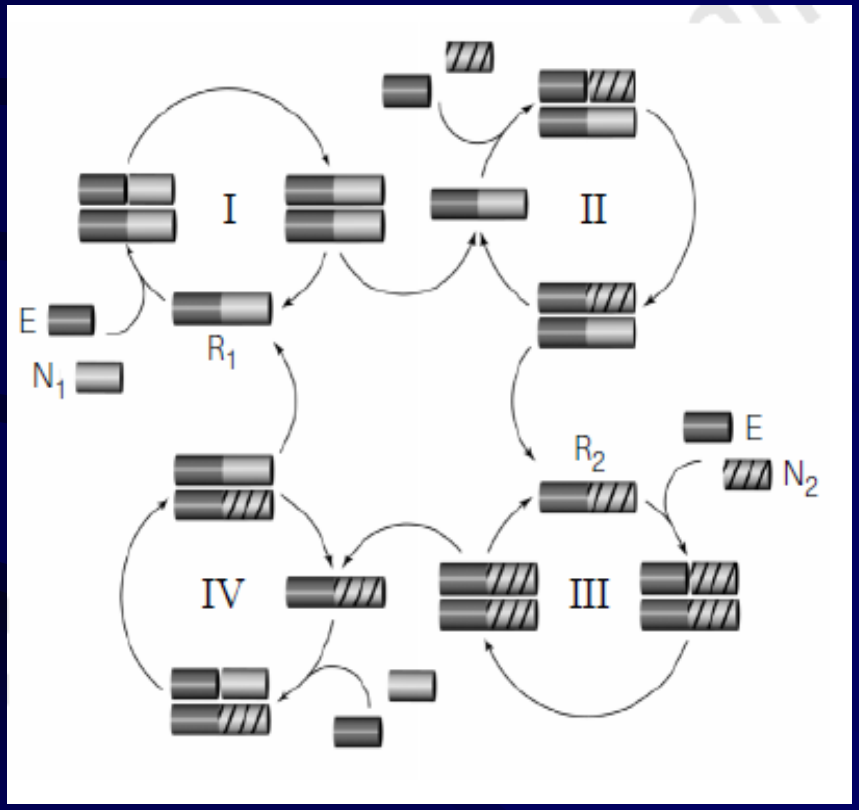
Another case: von Kiedrowski's replicators



Von Kiedrowski's replicator

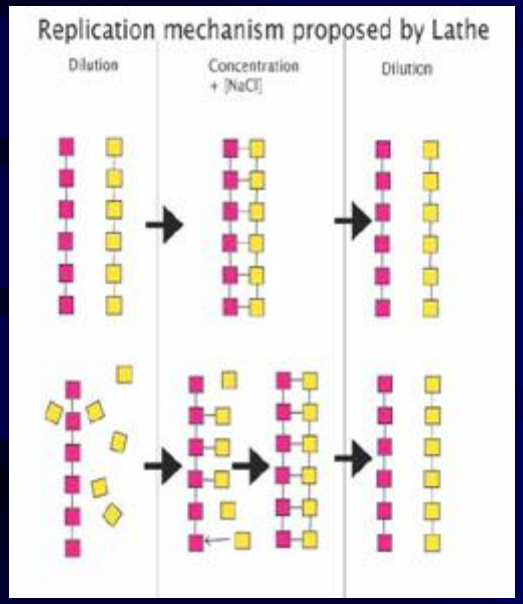


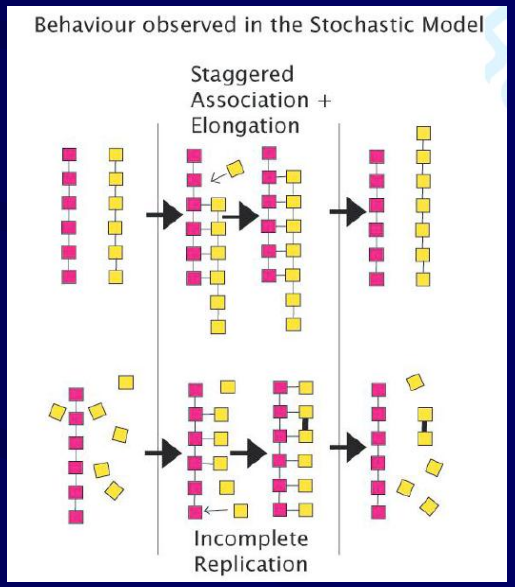
Peptide replicator networks



A Stochastic Model of Non-Enzymatic Nucleic Acid Replication: 'Elongators' Sequester Replicators

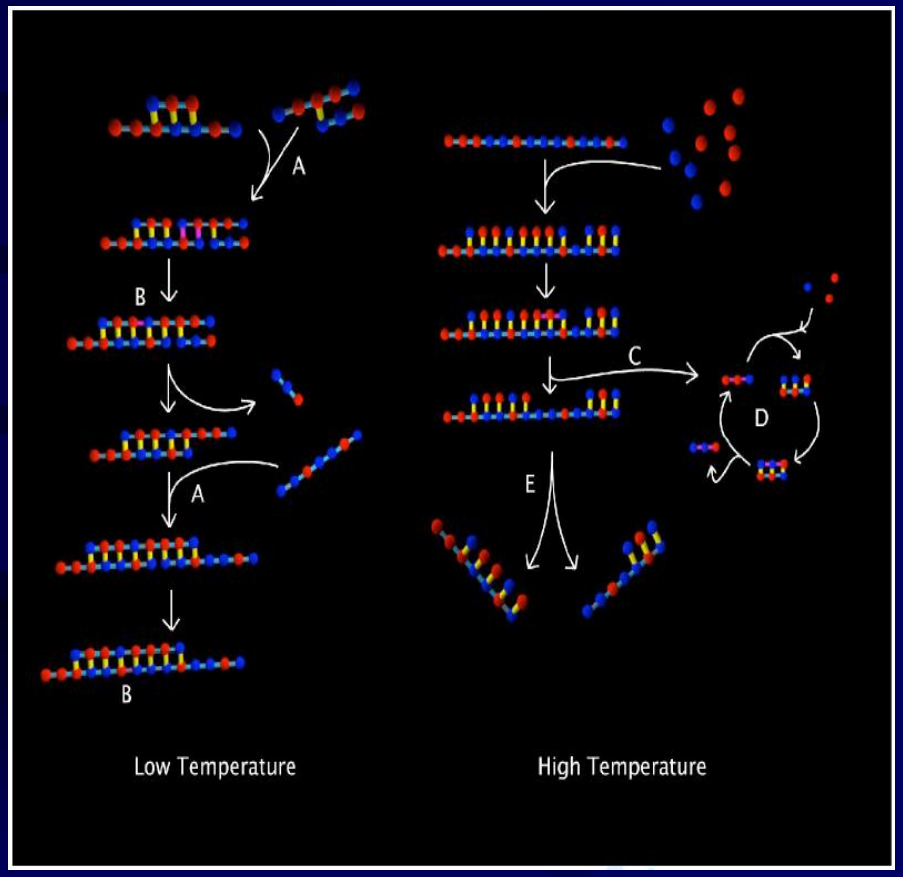
Chrisantha Fernando[1,2,3], Günter Von Kiedrowski[4], Eörs Szathmáry[2]



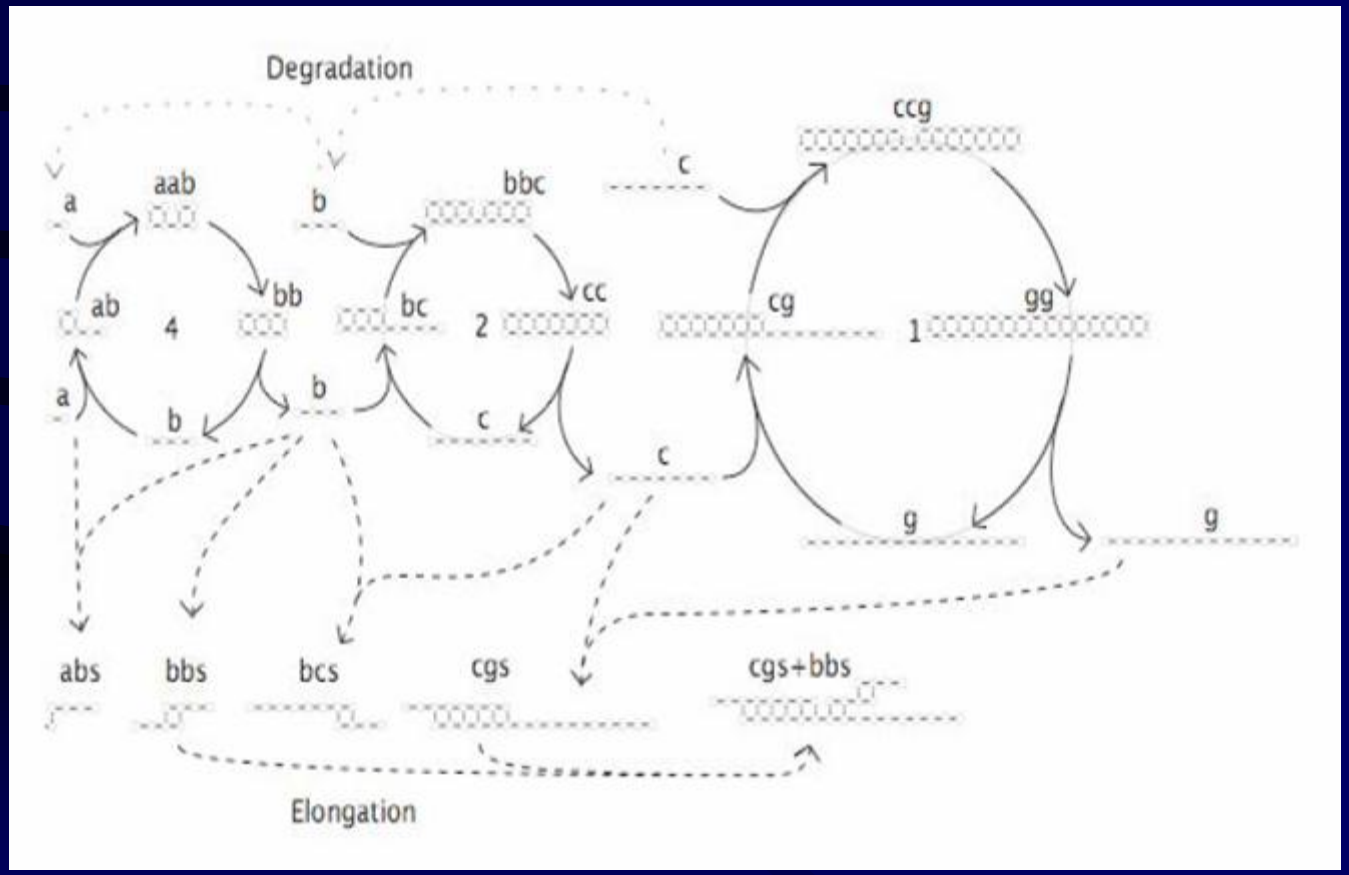


- Theory with experiment
- *J. Mol. Evol.*,

Does temperature cycling work?



Elongation taxes the system badly



Classification of replicators

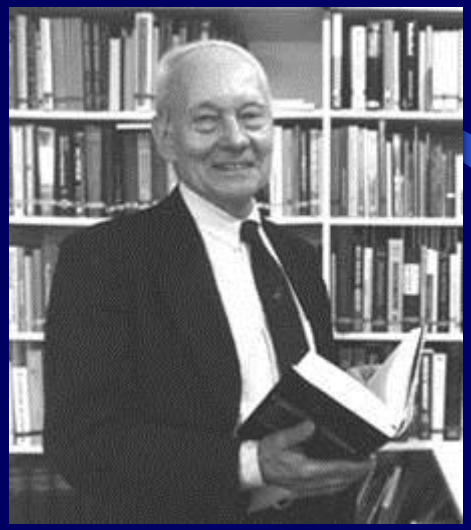
	Limited heredity	Unlimited heredity
Holistic	formose	
Modular	Von Kiedrowski	genes

Limited (number of individuals) > (number of types)

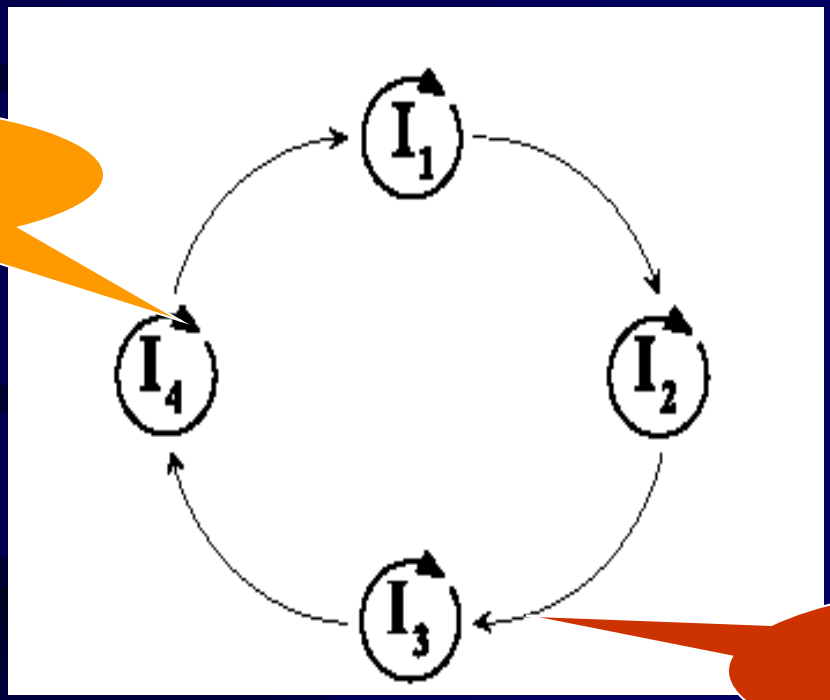
Unlimited (# of individuals) << (# of types)

A crucial insight: Eigen's paradox (1971)

- Early replication must have been error-prone
- Error threshold sets the limit of maximal genome size to <100 nucleotides
- Not enough for several genes
- Unlinked genes will compete
- Genome collapses
- Resolution???



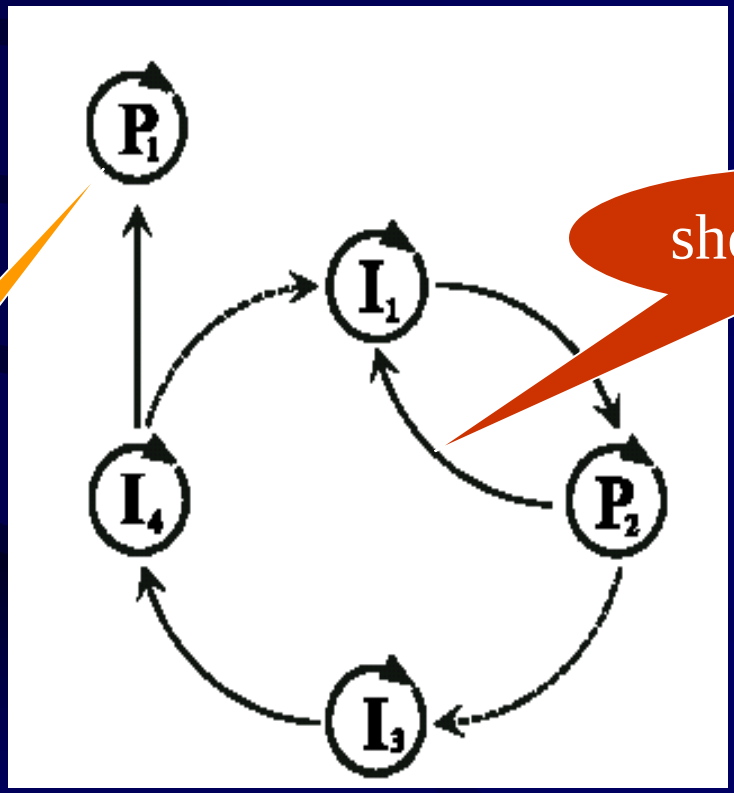
Molecular hypercycle (Eigen, 1971)



autocatalysis

heterocatalytic aid

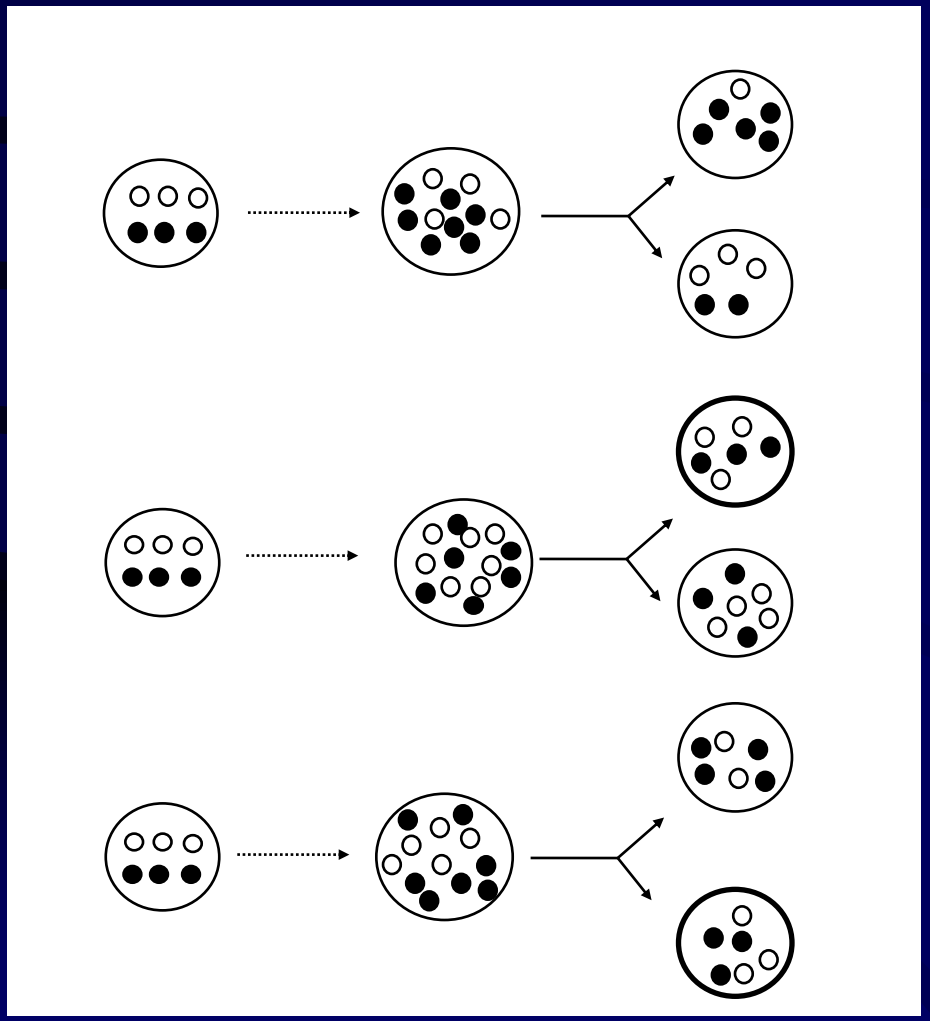
Parasites in the hypercycle (JMS)



short circuit

parasite

The stochastic corrector model for compartmentation



Szathmáry, E. & Demeter L. (1987) Group selection of early replicators and the origin of life. *J. theor Biol.* **128,** 463-486.

Grey, D., Hutson, V. & Szathmáry, E. (1995) A re-examination of the stochastic corrector model. *Proc. R. Soc. Lond.* B **262,** 29-35.

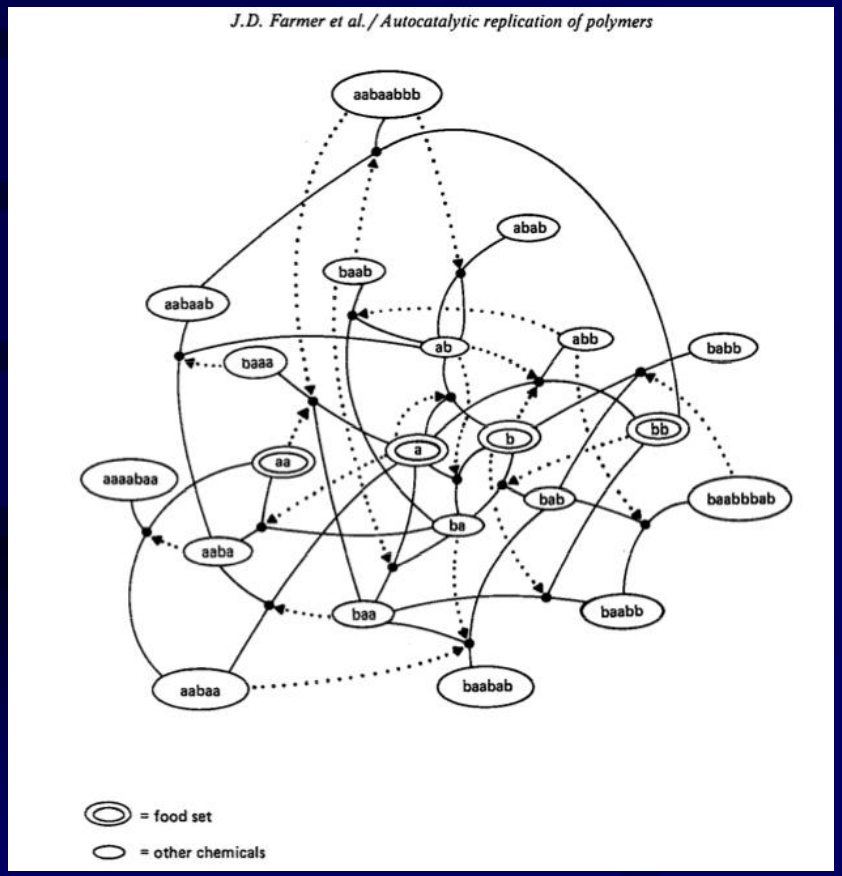
Dynamics of the SC model

- Independently reassorting genes
- Selection for optimal gene composition between compartments
- Competition among genes within the same compartment
- Stochasticity in replication and fission generates variation on which natural selection acts
- A stationary compartment population emerges

Group selection of early replicators

- Many more compartments than templates within any compartment
- No migration (fusion) between compartments
- Each compartment has only one parent
- Group selection is very efficient
- Selection for replication synchrony → **Chromosomes!**

Kauffman: Reflexively autocatalytic protein networks (1986)



Current investigations

- Evolvability is possible only in compartments
- Occasionally new autocatalytic loops appear
- Can be inherited from one cell to the daugther
- Can be selected for, give some evolution
- GARD is shadow of protein networks is a shadow of template replicators

Open questions

- Origin of efficient replication
- Origin of full protocells
- Origin of transcription
- Origin of highly specific enzymes
- Origin of translation