NORCIA LUGLIO 2005:

SELF-REPRODUCTION OF SYNTHETIC SYSTEMS (AS MODELS FOR BIOLOGICAL SELF-REPLICATION)

THE INCREASE OF COMPLEXITY TOWARDS THE EMERGENCE OF LIFE PROCEEDS

VIA THE INTERPLAY BETWEEN SELF-ORGANIZATION AND EMERGENCE

SELF-ORGANIZATION: THE ACQUISITION OF HIGHER STRUCTURAL ORDER-AS DETERMINED BY THE SYSTEM'S RULES

…under thermodynamic or kinetic control

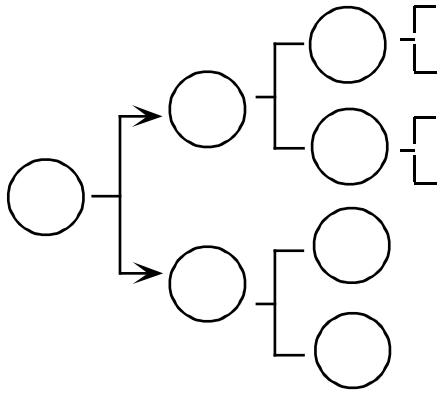
Emergence:
the formation of a higher complexity level brings about NOVEL properties that are not present in the basic components

..the whole is more
than the sum of
the parts
...holism

ORIGIN OF SELF - REPRODUCTION

↓

ORIGIN OF LIFE

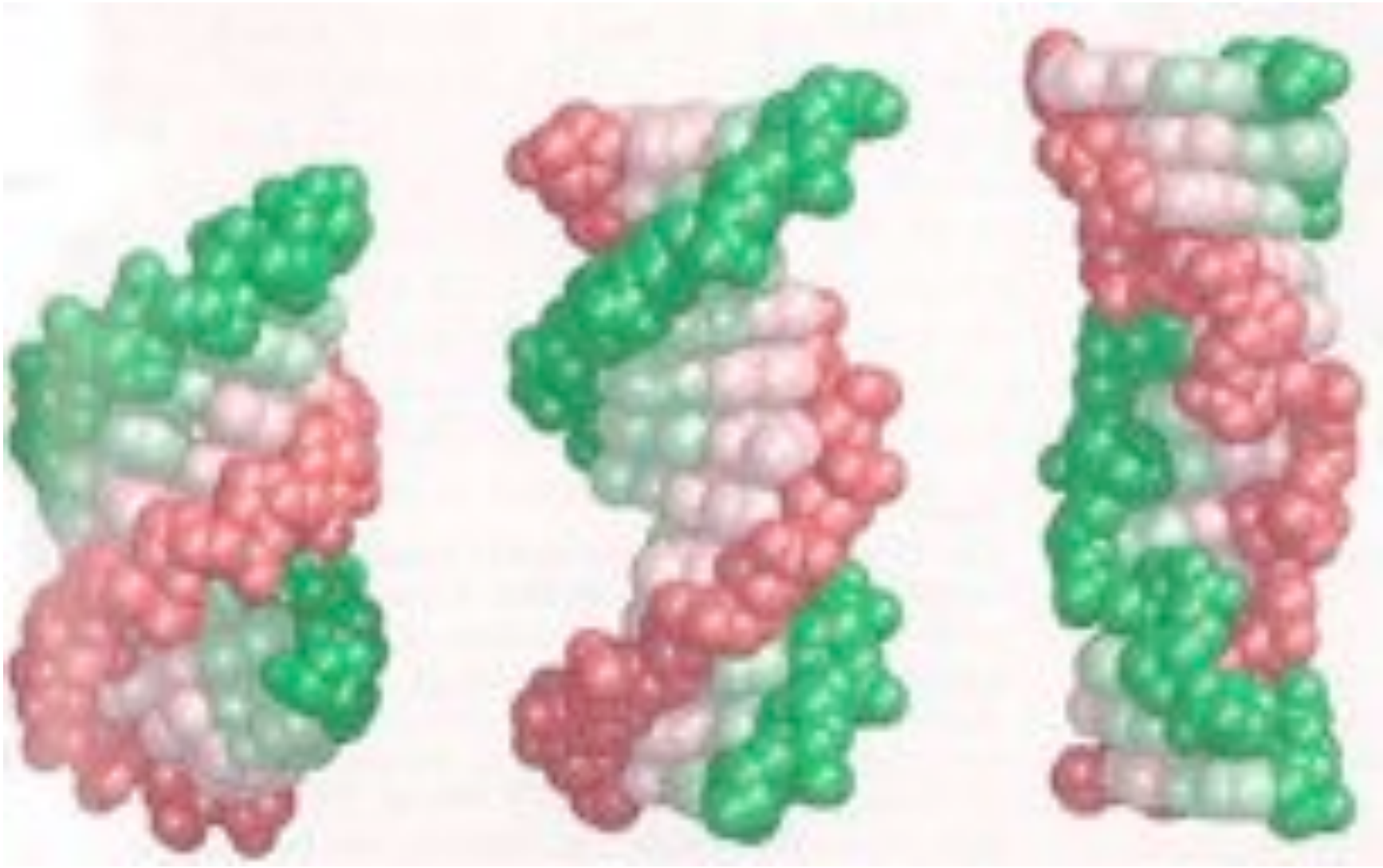


" self " means
that the structure itself does it
i. e. , the process is autocatalytic

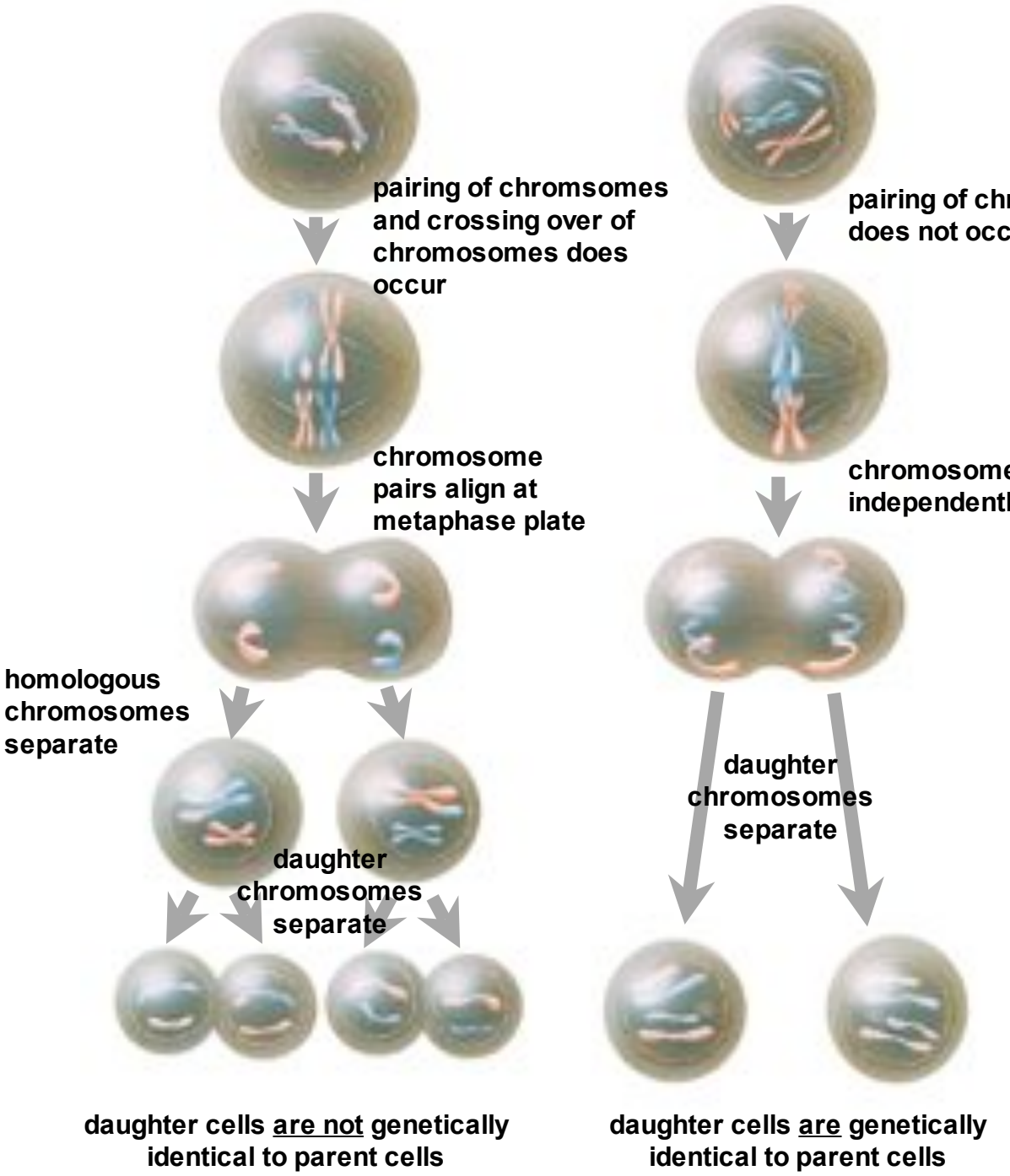
self - reproduction = autocatalysis

AND : **IF THE STRUCTURE CARRIES INFORMATION (A) ,**
THEN WE HAVE
→ **REPRODUCTION & INFORMATION AT A TIME**

AND : **IF DURING SELF-REPRODUCTION**
ALSO STRUCTURAL (→ FUNCTION) CHANGES OCCUR,
WE ALSO HAVE EVOLUTION
NOVEL CATALYSIS
↳ **.....everything else**



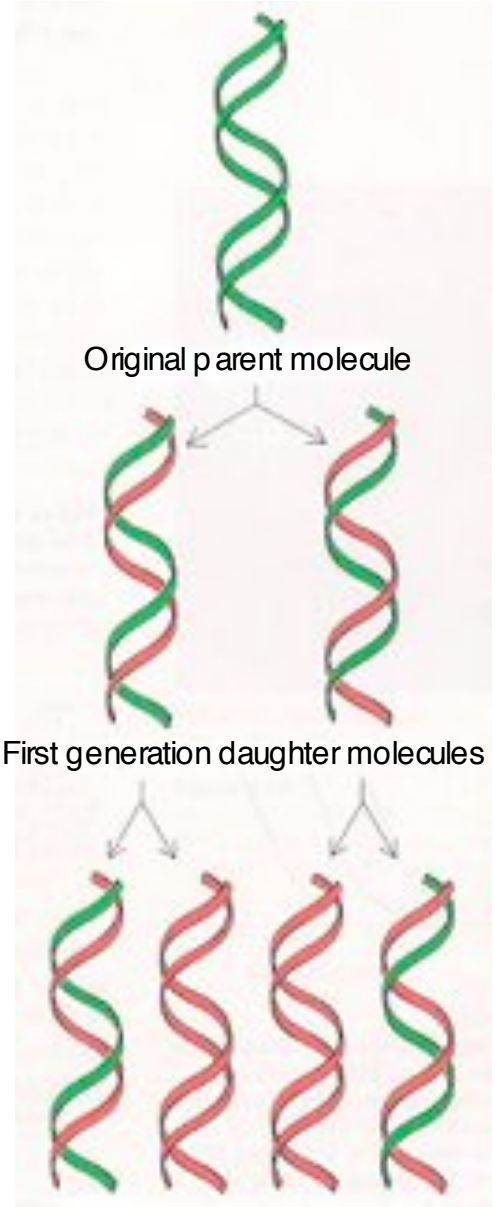
A-DNA B-DNA Z-DNA



Comparison of meiosis and mitosis.

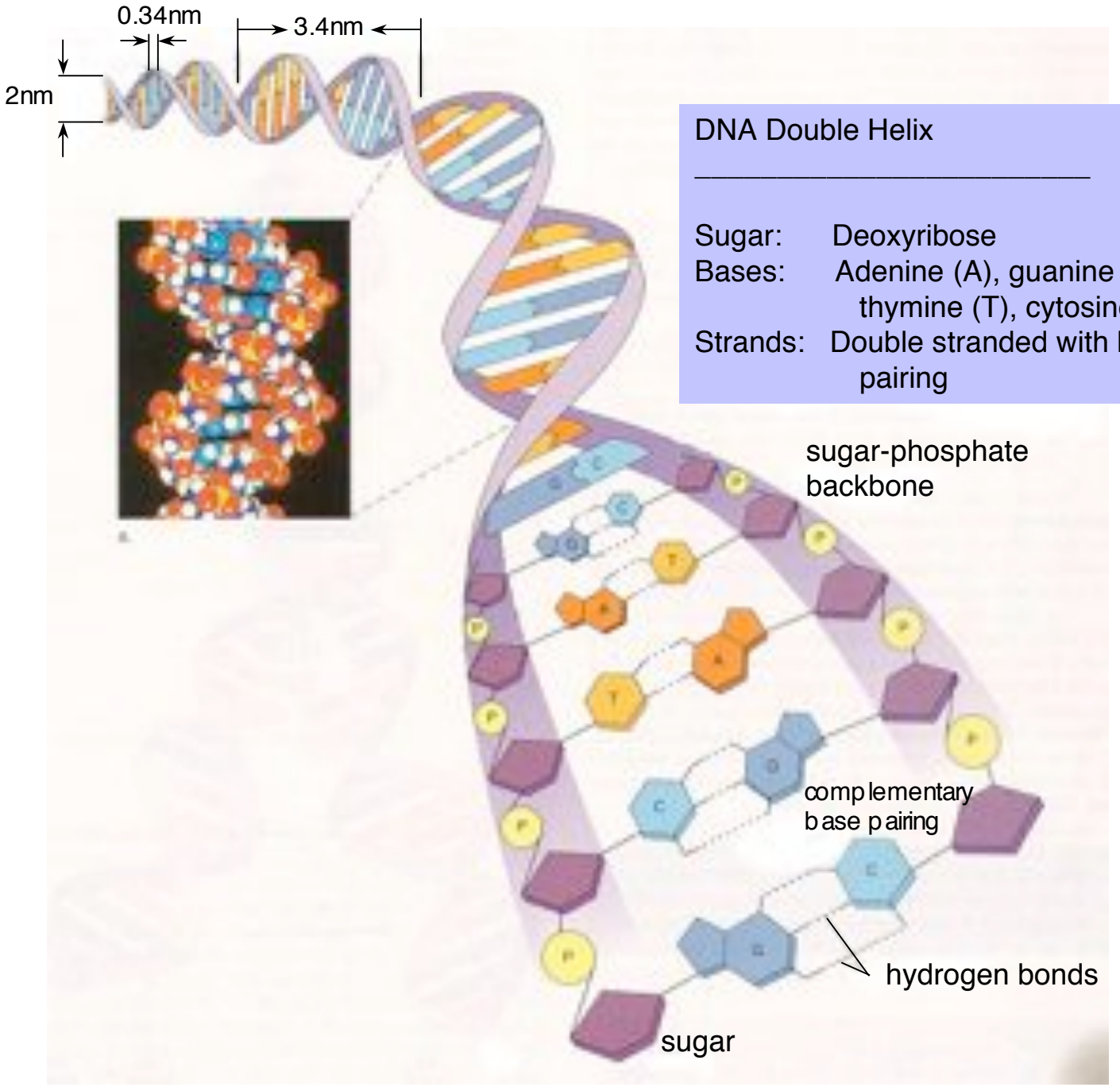
(The blue chromosomes were inherited from one parent, and the red chromosomes were inherited from other parent.)

(from Biology / S.Mader, 5th ed.)



Schematic diagram of semiconservative replication. Parental DNA is shown in green and newly synthesized DNA in red. [After M. Meselson and F.W. Stahl. *Proc. Nat. Acad. Sci.* 44(1958):671.)


parent molecule
old strand
new strand
daughter molecule
new strand
old strand
daughter molecule


0.34nm
3.4nm
2nm
DNA Double Helix
Sugar: Deoxyribose
Bases: Adenine (A), guanine (G) thymine (T), cytosine (C)
Strands: Double stranded with base pairing
sugar-phosphate backbone
complementary base pairing
hydrogen bonds
sugar

In particular research focusses on

SELF-REPLICATION SYSTEMS

Self means that the process is spontaneous, i.e., determined by the internal rule of the system

(generally self-replication corresponds to **autocatalysis, and generally the time process is exponential**)

A → 2A → 4A → 8A → 16A etc

Origin of life
from self-replicating molecules

(how it works on paper)

a) heterocatalysis

A ⋯⋯➤ B

One molecule per second, then 6.10^{23} sec. to make one mole of B

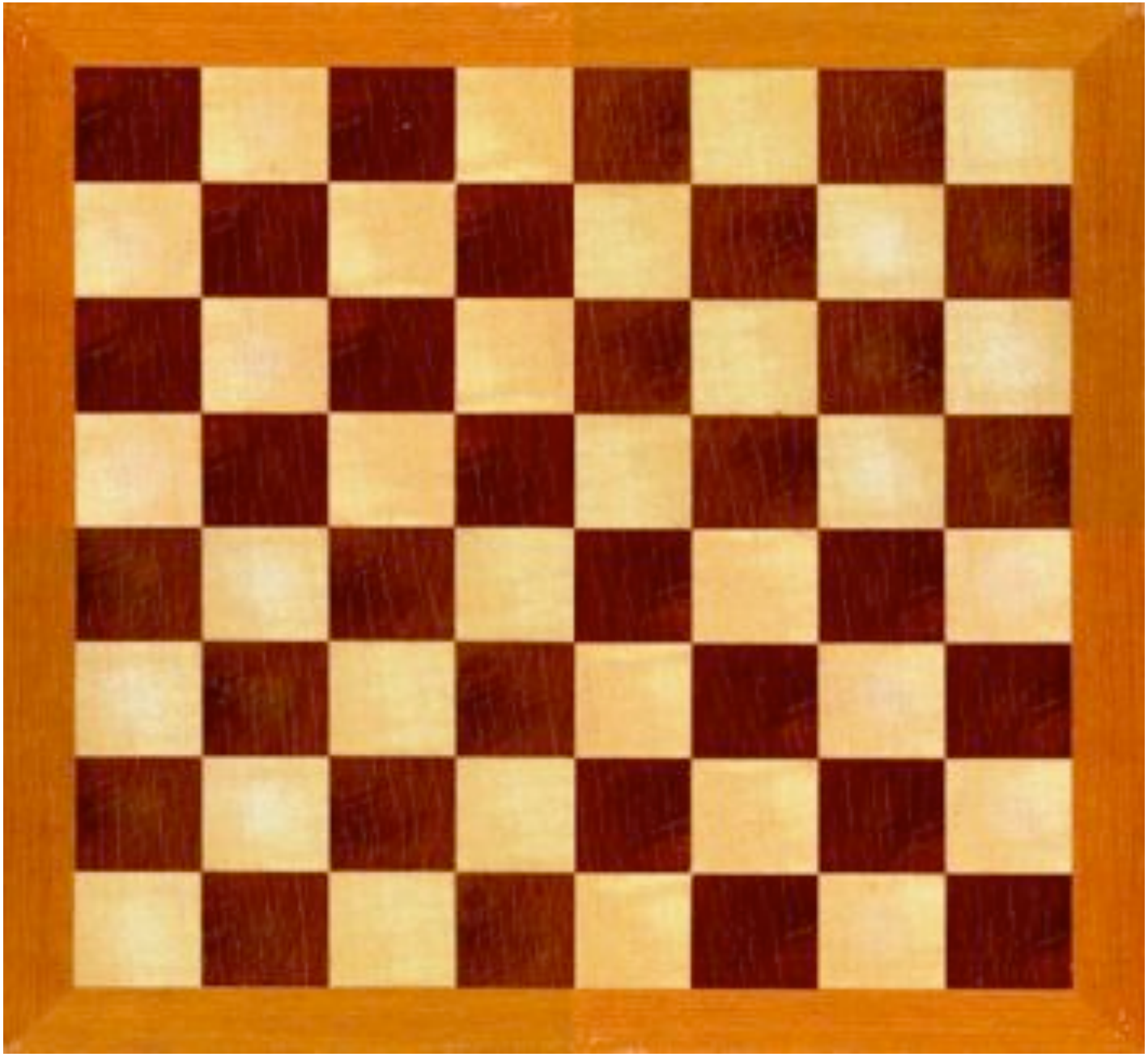
b) self-replication (autocatalysis)

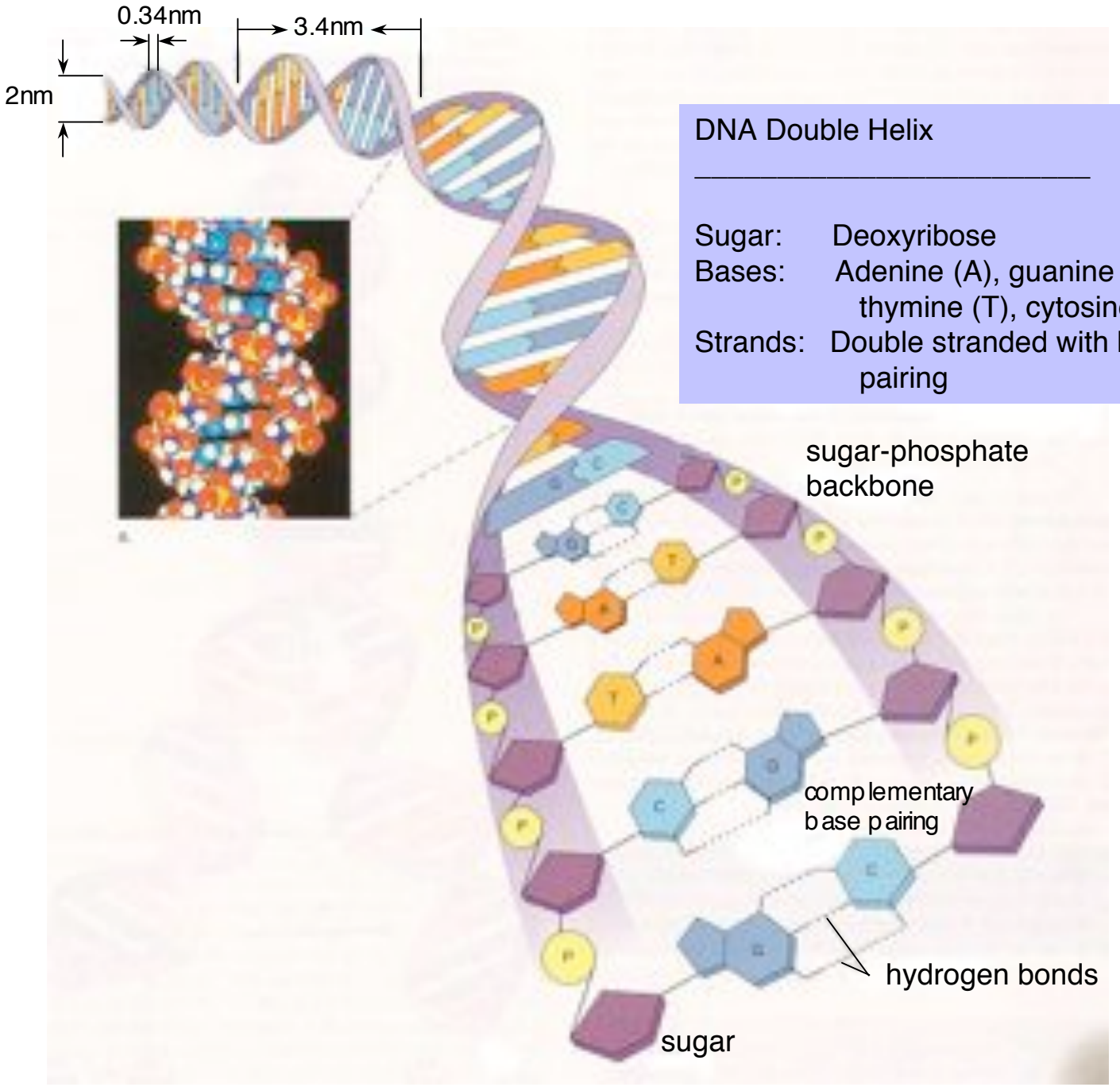
A ⋯⋯➤ A

Only 79 sec. to make one mole of A

2.....4.....8.....16.....32.....64.....128.....etc.


Museum of Fine Arts

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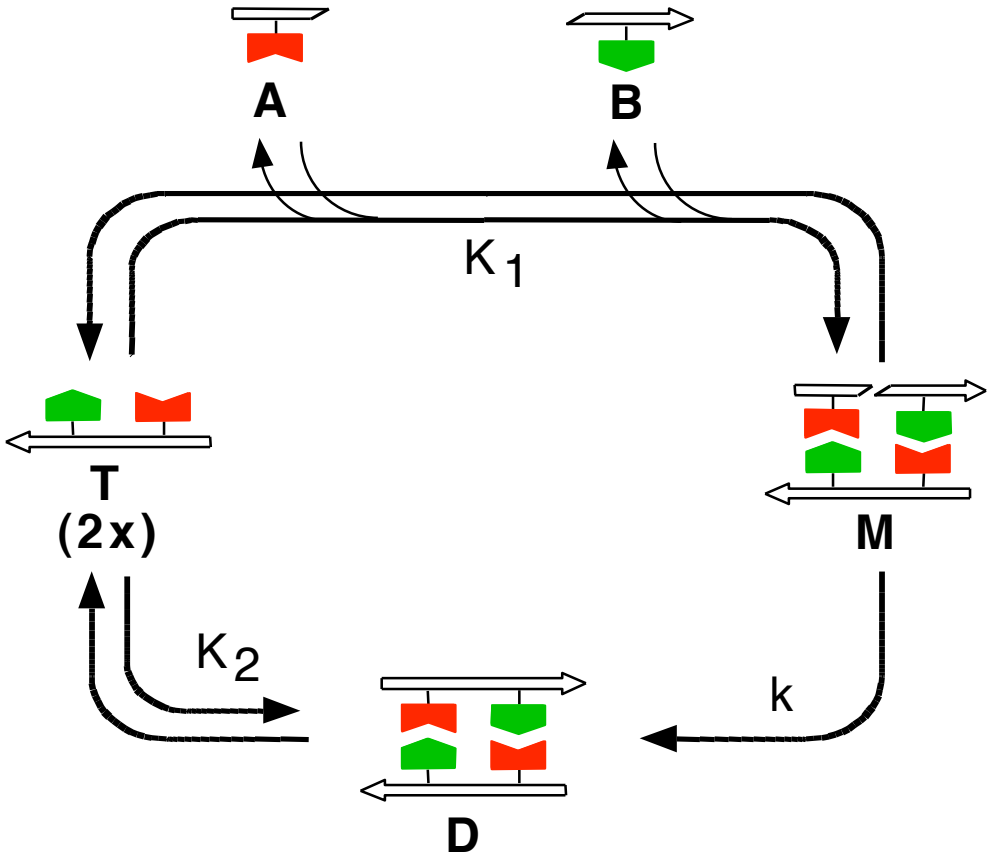


General mechanism for a minimal self-replicating system.
Constituent **A** represents the activated form of trimer $\mathbf{A^2}$ here.
Large arrowheads at the reaction arrows for the reversible reactions indicate the favored site of the equilibrium.

Kiedrowski, Angew.chem. (1986)10, 932

Rebek, JACS (1990)

the notion of *hypercycle*, originally developed by Eigen and collaborators (Eigen 1971, Eigen and Schuster 1977, 1979).

A simple rendering of an hypercycle,

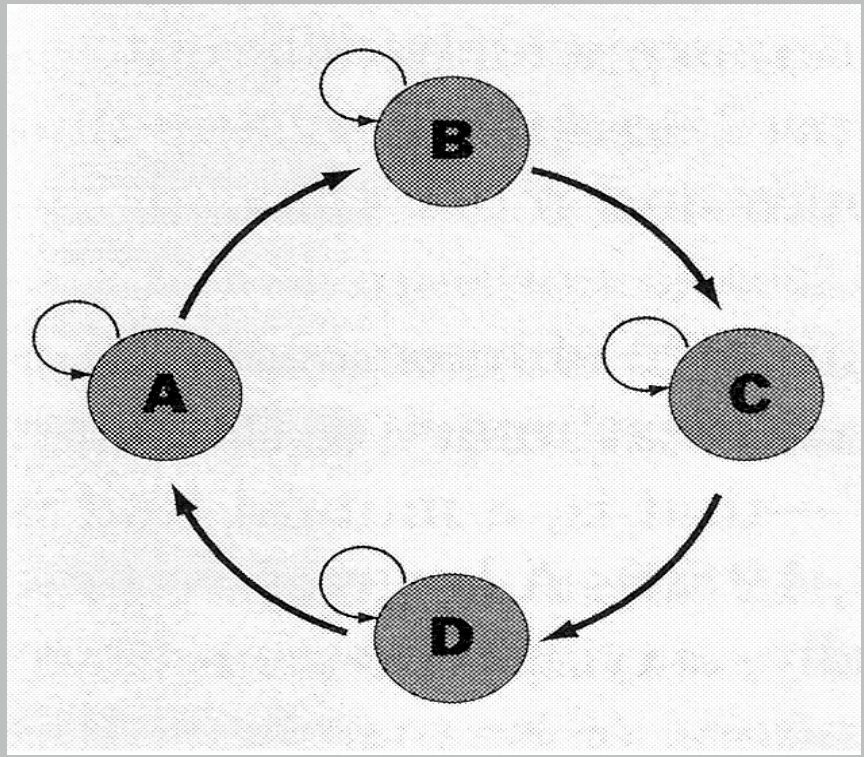
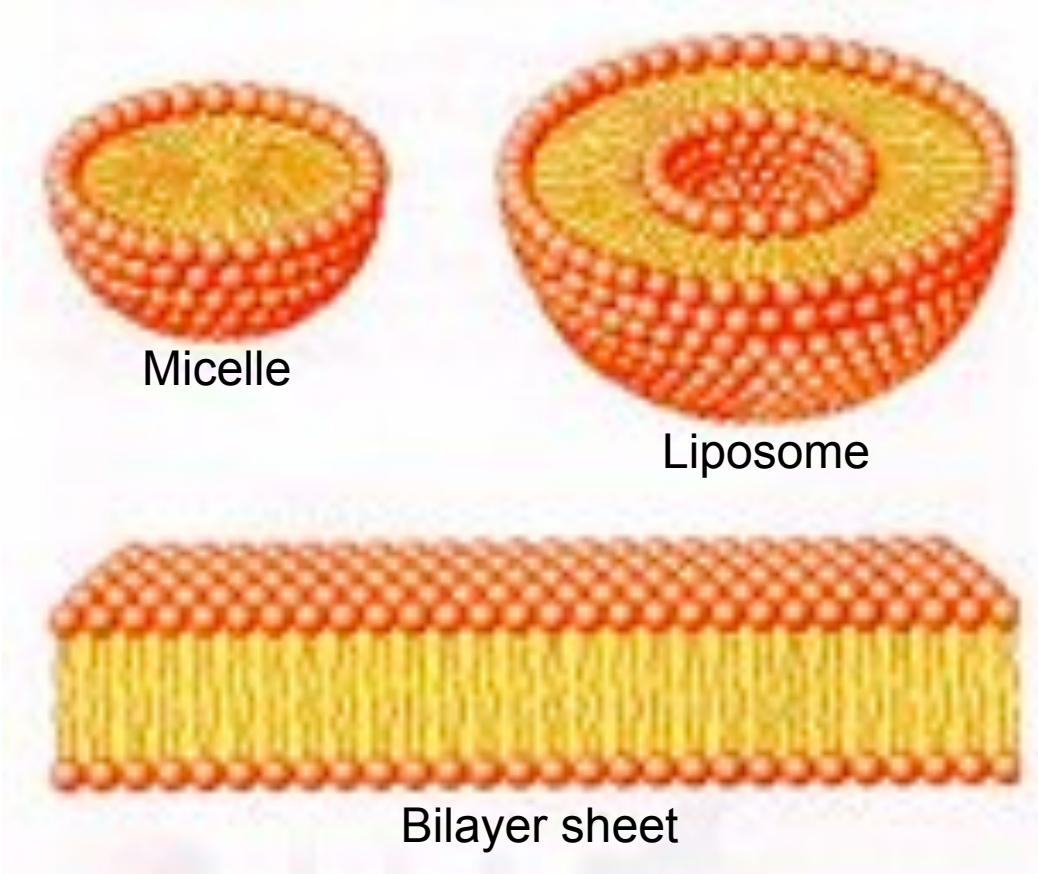
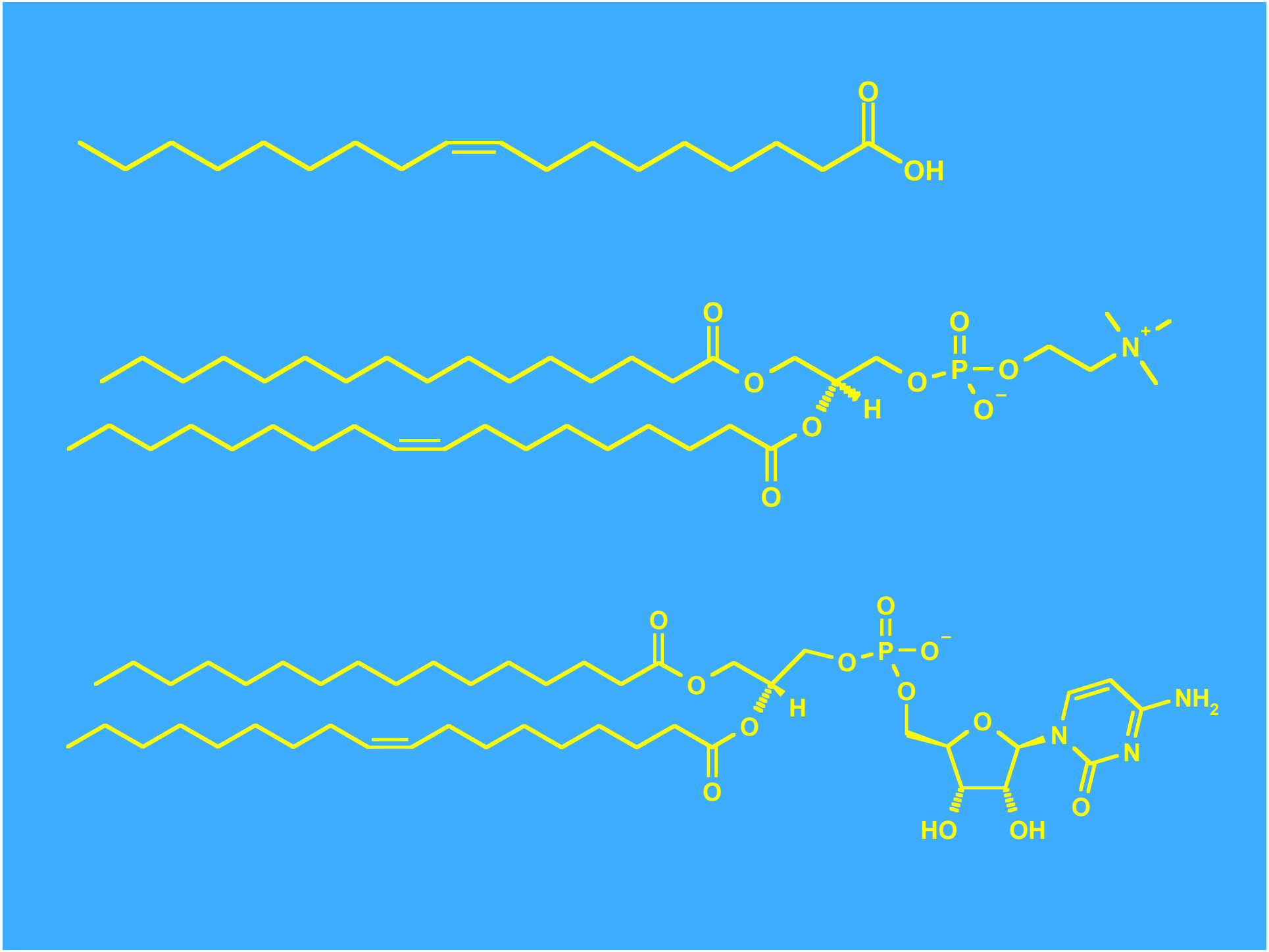


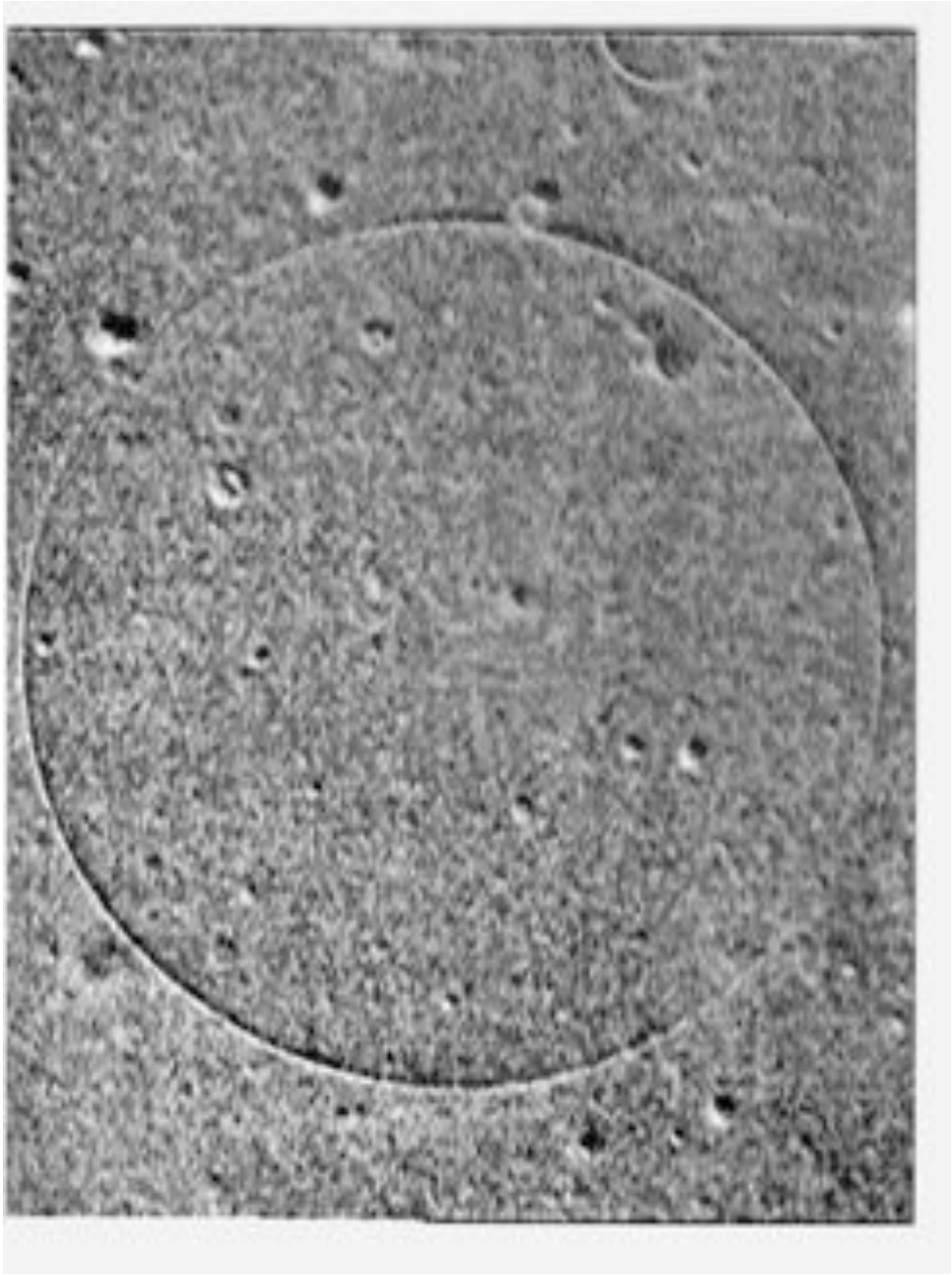
Fig. 4.6 The hypercycle. Each of the units A, B, C and D is a replicator. The rate of replication of each unit is an increasing function of the concentration unit immediately preceeding it. Thus the rate of replication of B is an increasing function of the concentration of A, and so on round the cycle.

Cross-sectional views of the three structures that can be formed by mechanically dispersing a suspension of phospholipids in aqueous solution



The red circles depict the hydrophilic heads of phospholipids, and the squiggly lines (in the yellow region) the hydrophobic tails.


O
OH
O
O
O
H
O
O
O
P
O
O
N+
O
O
O
O
H
O
O
P
O
O
O
O
N
N
NH2
O
HO
OH



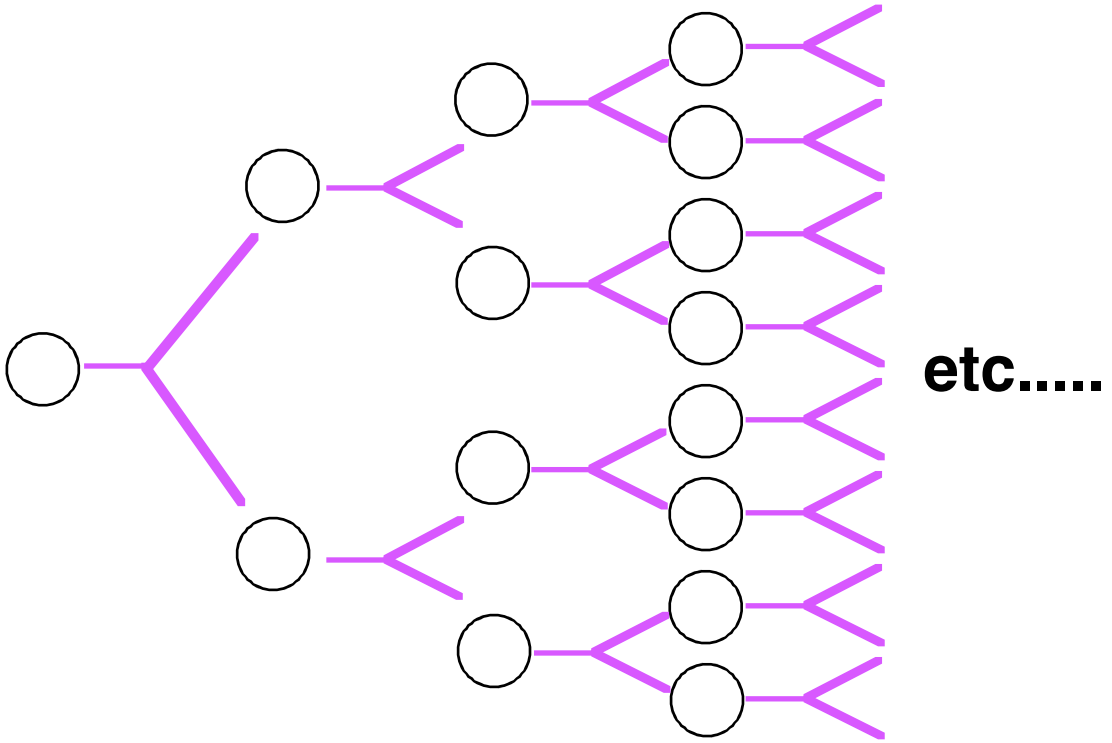
Oleic acid / oleat vesicles

Is it possible to mimick some of the properties of the living cells with micelles (or liposomes) ?

FOR EXAMPLE:

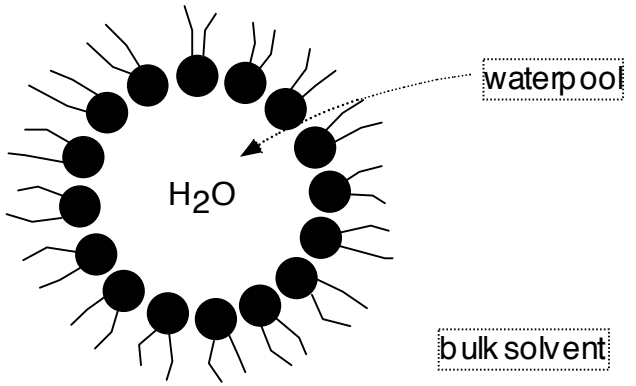
SELF–REPLICATION?

SELF-REPRODUCING MICELLES, LIPOSOMES & CHEMICAL AUTOPOIESIS

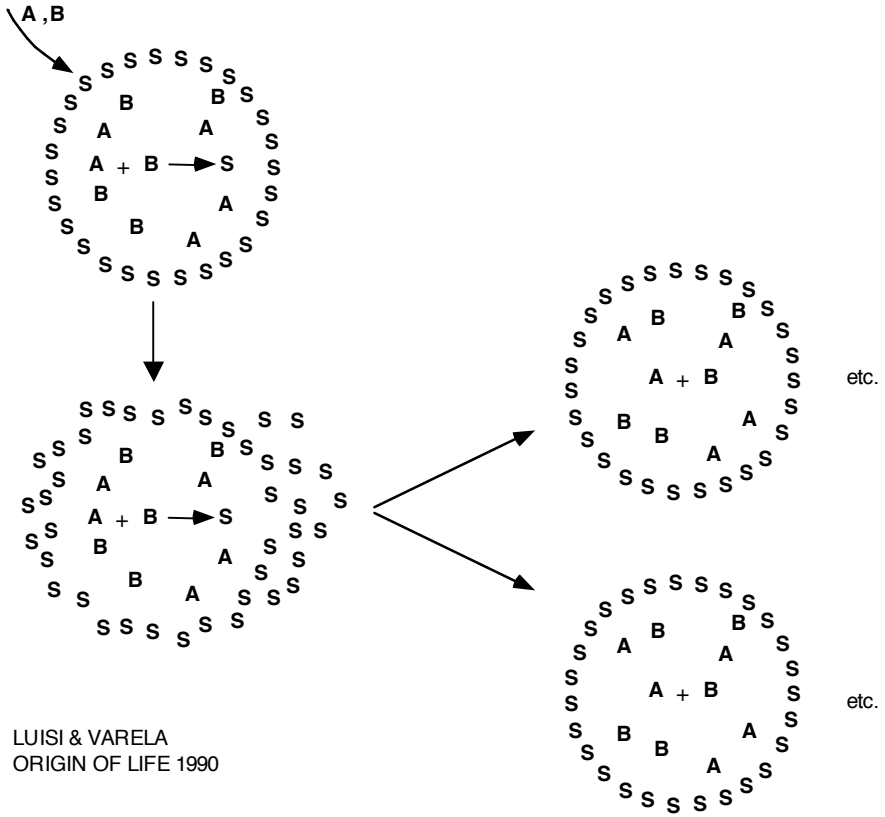


SELF - REPLICATING MICELLES

a



b



LUISI & VARELA
ORIGIN OF LIFE 1990

caprylate 

or

oleate $CH_3(CH_2)_7$ -CH = CH-$(CH_2)_7COO^-$

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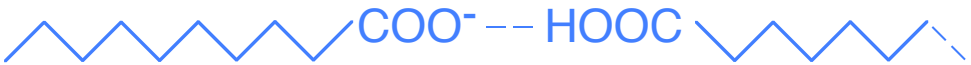
form micelles at alkaline pH

(Deamer, 1976)

vesicles at pH=7-8

(pH ≃ pk)



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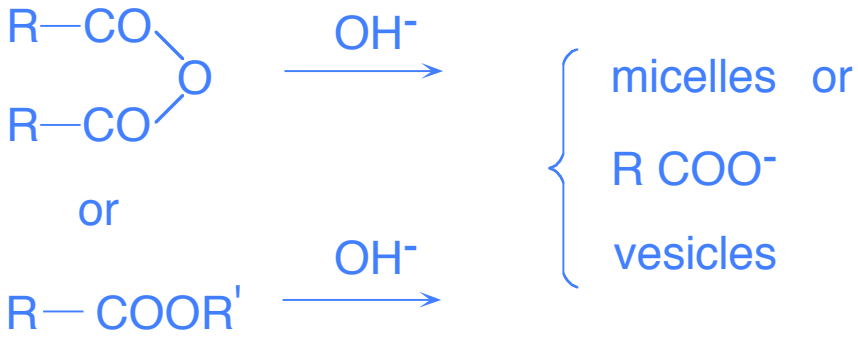
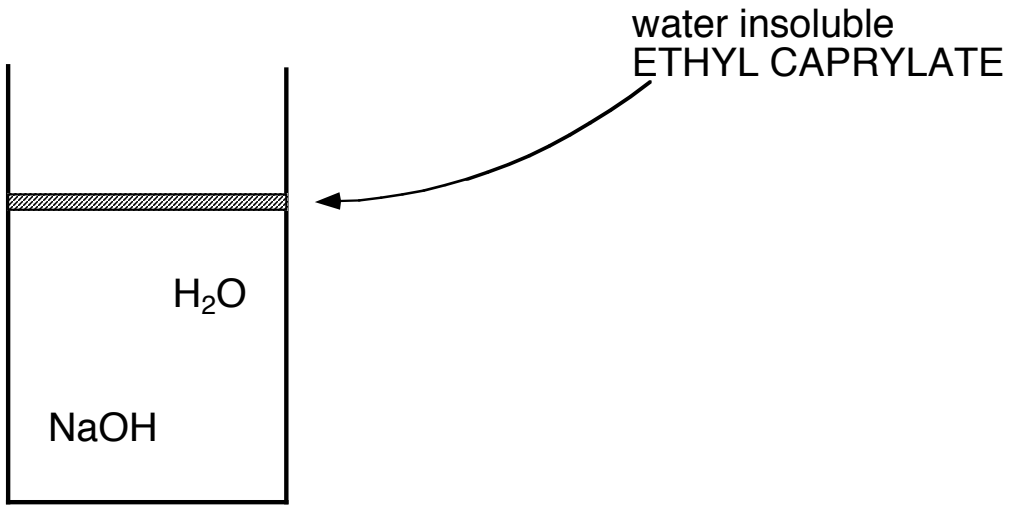
precursors (water insoluble!)

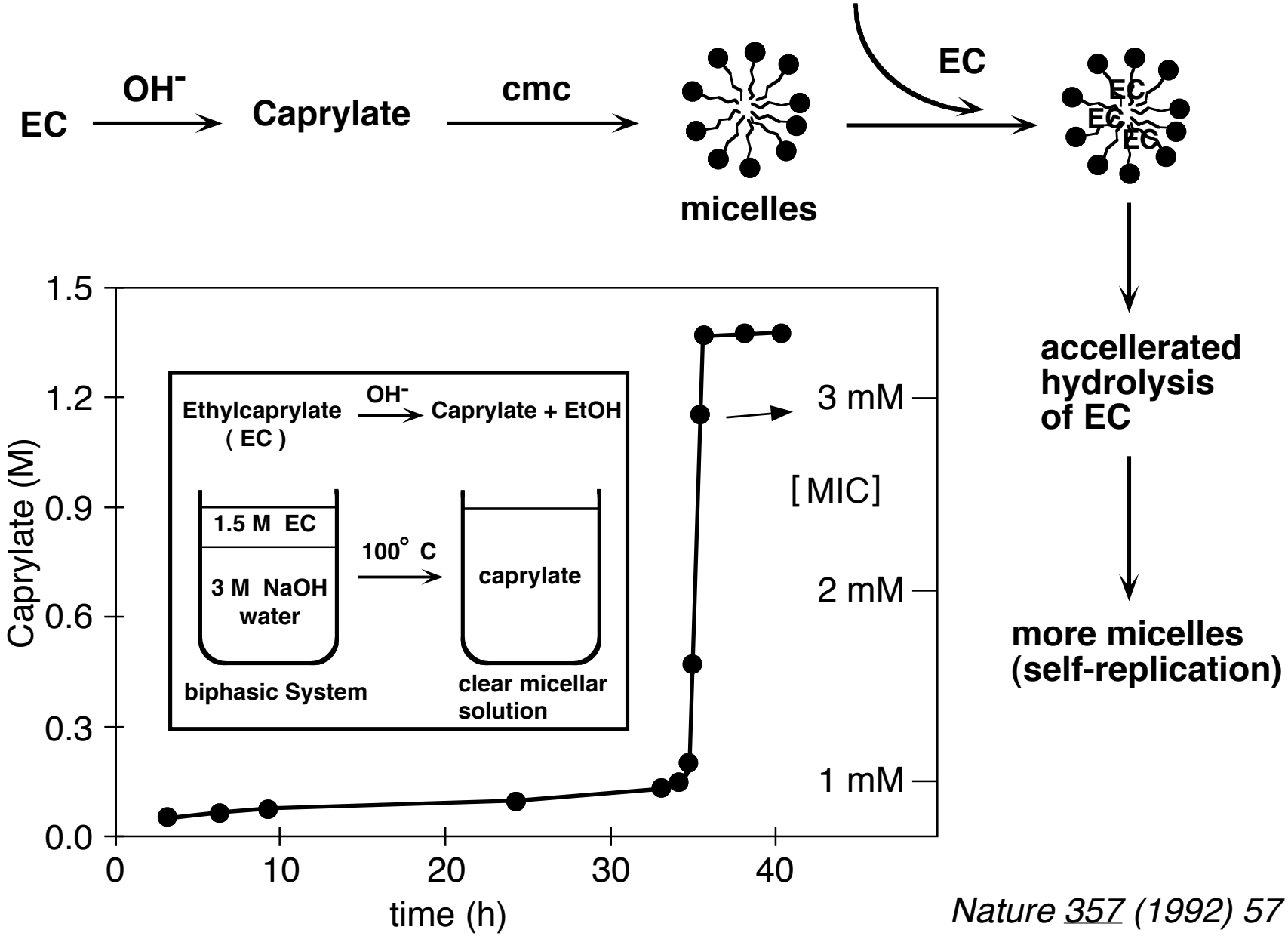


... a reaction which creates its own microenvironment for self-replication....



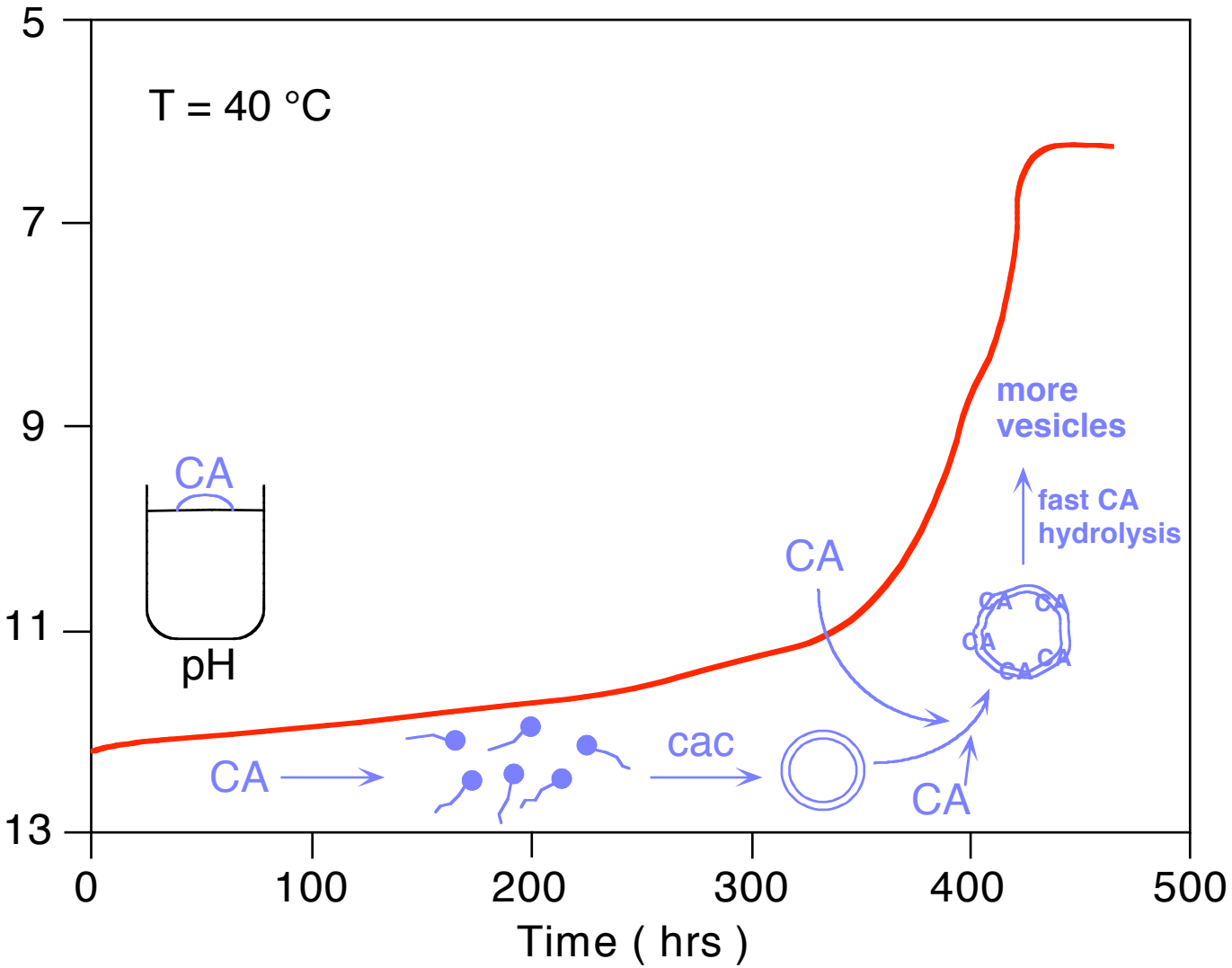
Ethylcaprylate $\xrightarrow{OH^-}$ caprylate $\xrightarrow{cmc}$ micelles in water (pH ~ 10)

or vesicles (pH ~ 7 - 8)
(start with anhydride)



Nature 357 (1992) 57

Hydrolysis of Caprylic anhydride

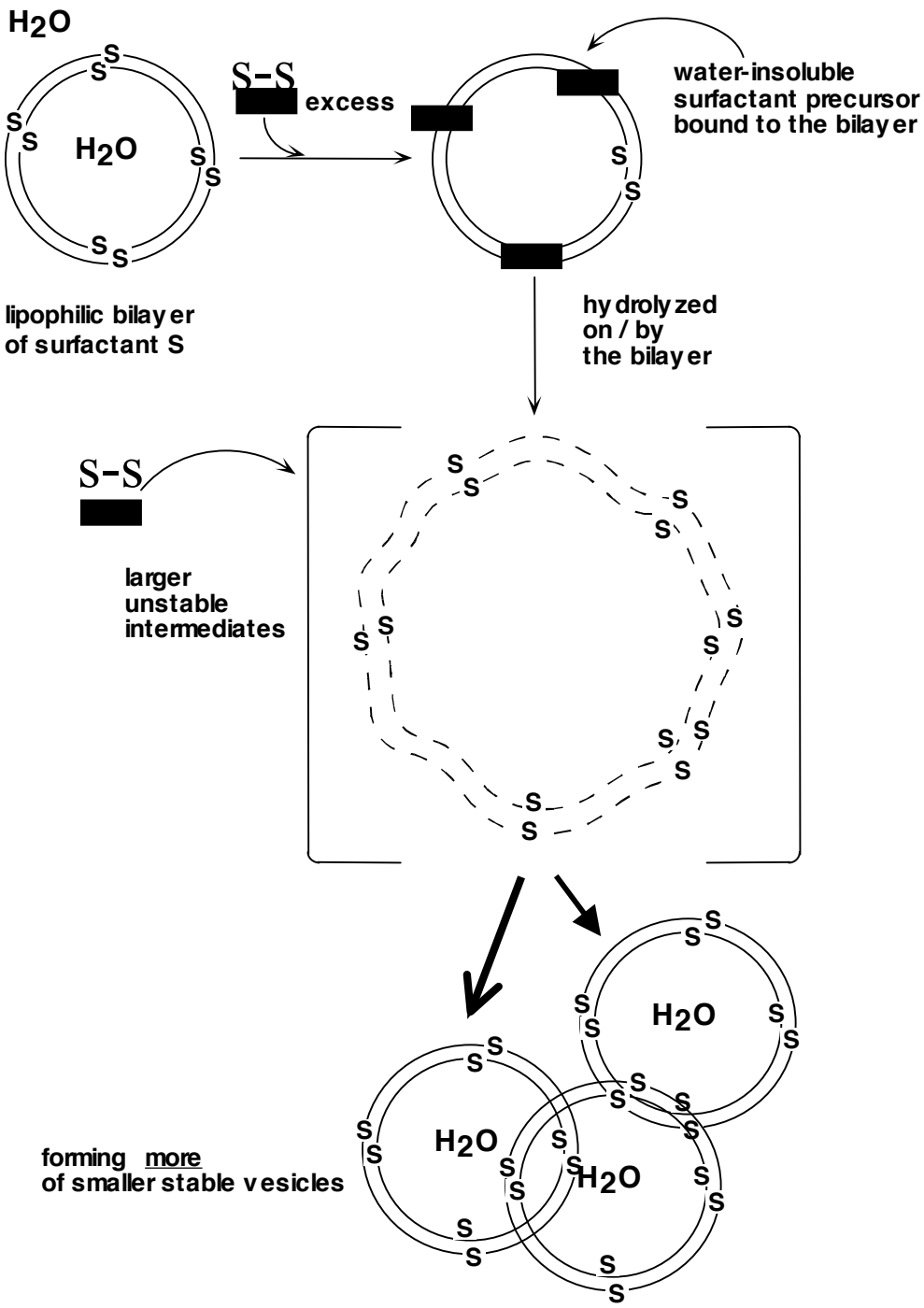


The hydrophobicity of the lipid bilayer

Is the main driving force for

The activity/reactivity and applications

Of liposomes


H2O
S-S
excess
water-insoluble
surfactant precursor
bound to the bilayer
lipophilic bilayer
of surfactant S
hydrolyzed
on / by
the bilayer
S-S
larger
unstable
intermediates
H2O
H2O
H2O
forming more
of smaller stable vesicles