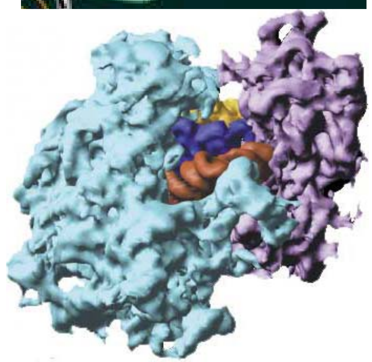
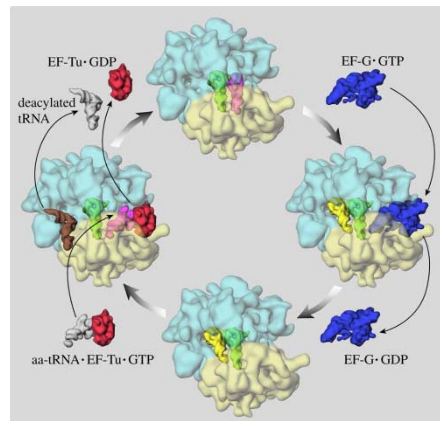
Biological Research (in the last 60 years)

From discoveries ⇄ **Mechanisms** ⇄ **Integration**

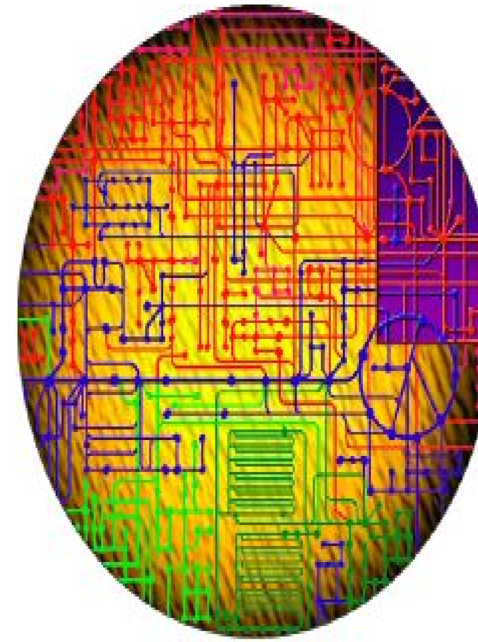
Molecular Biology



Reduction



Systems Biology



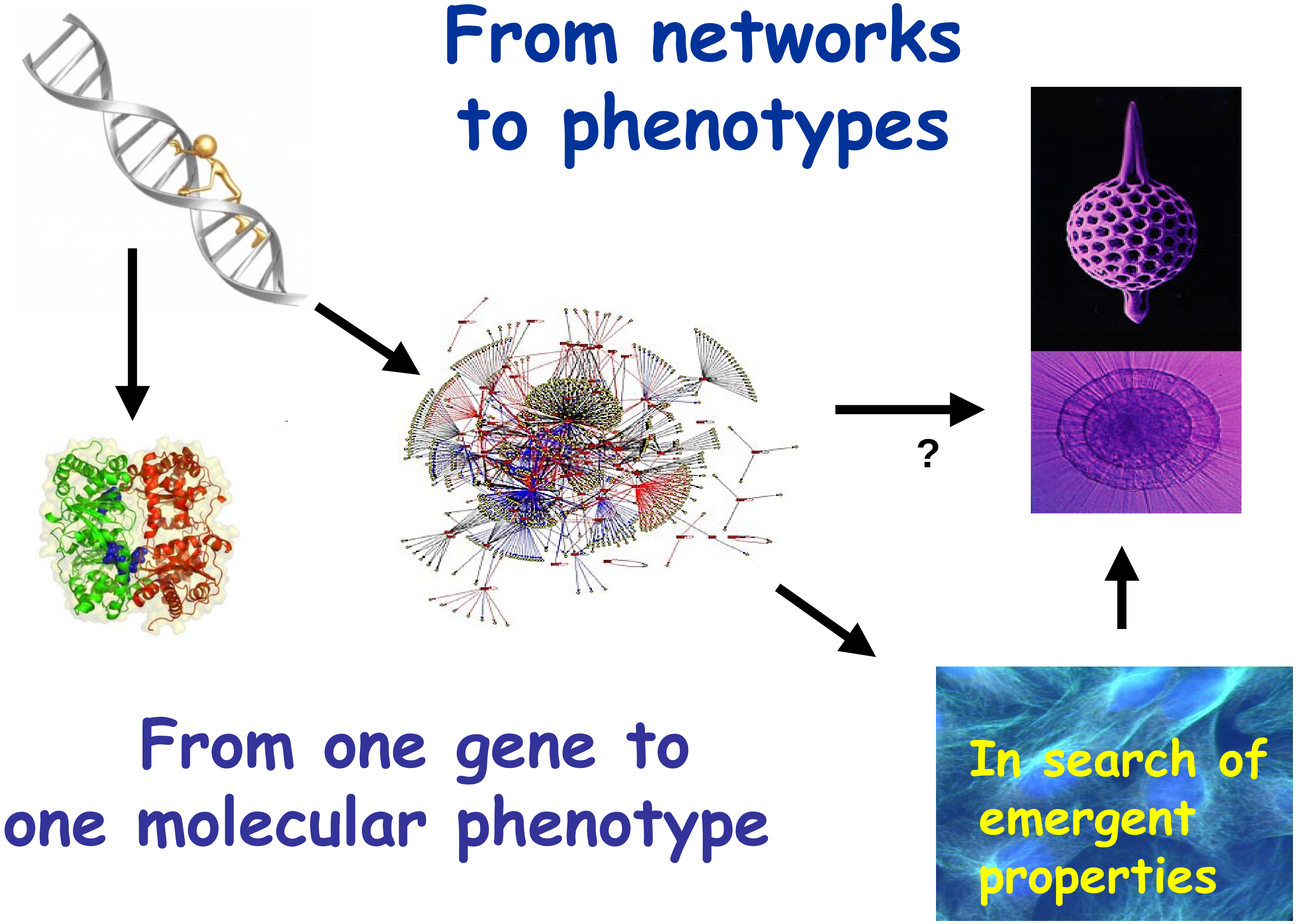
Biology as an information science

High throughput methodologies

Interdisciplinary approaches

Model organisms

The Ultimate Goal

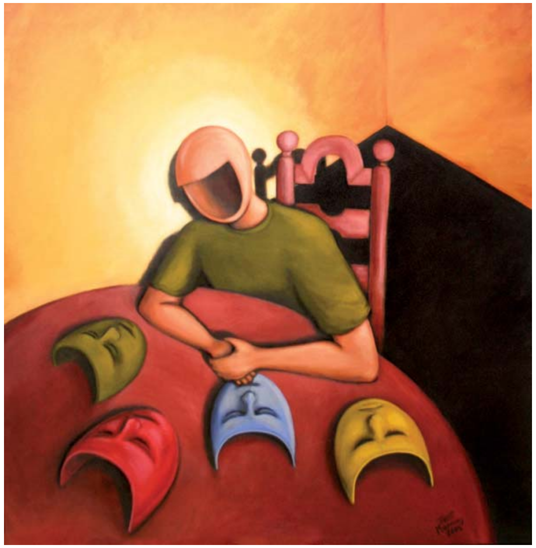

From networks
to phenotypes
?
From one gene to
one molecular phenotype
In search of
emergent
properties

The New Approach

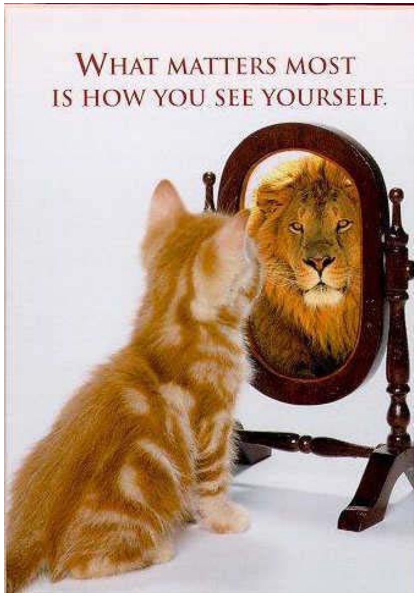
Systems Biology

N. Wiener 1946
Cybernetics – Control and Communication in the Animal and the Machine.

…explicitly considered technical as well as biological systems as objects for the same scientific approach



Identity Crisis



Systems Biology

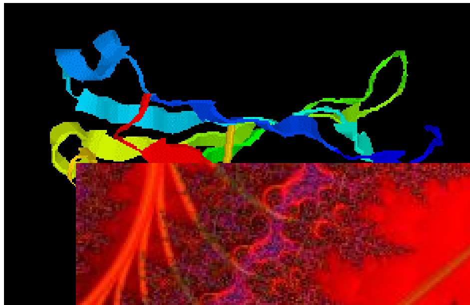
..is all about cycles of modeling-verifications and final simulations

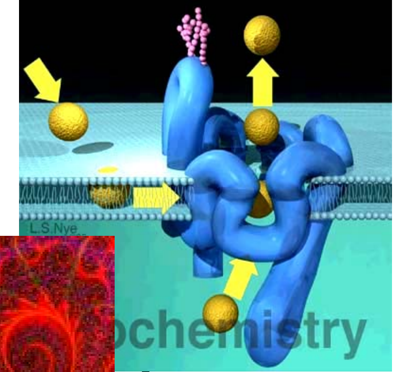
..is all about engineering

..is all about -omics

..is a paradigm shift

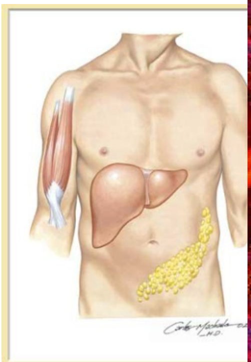
..is a multidisciplinary integrated approach

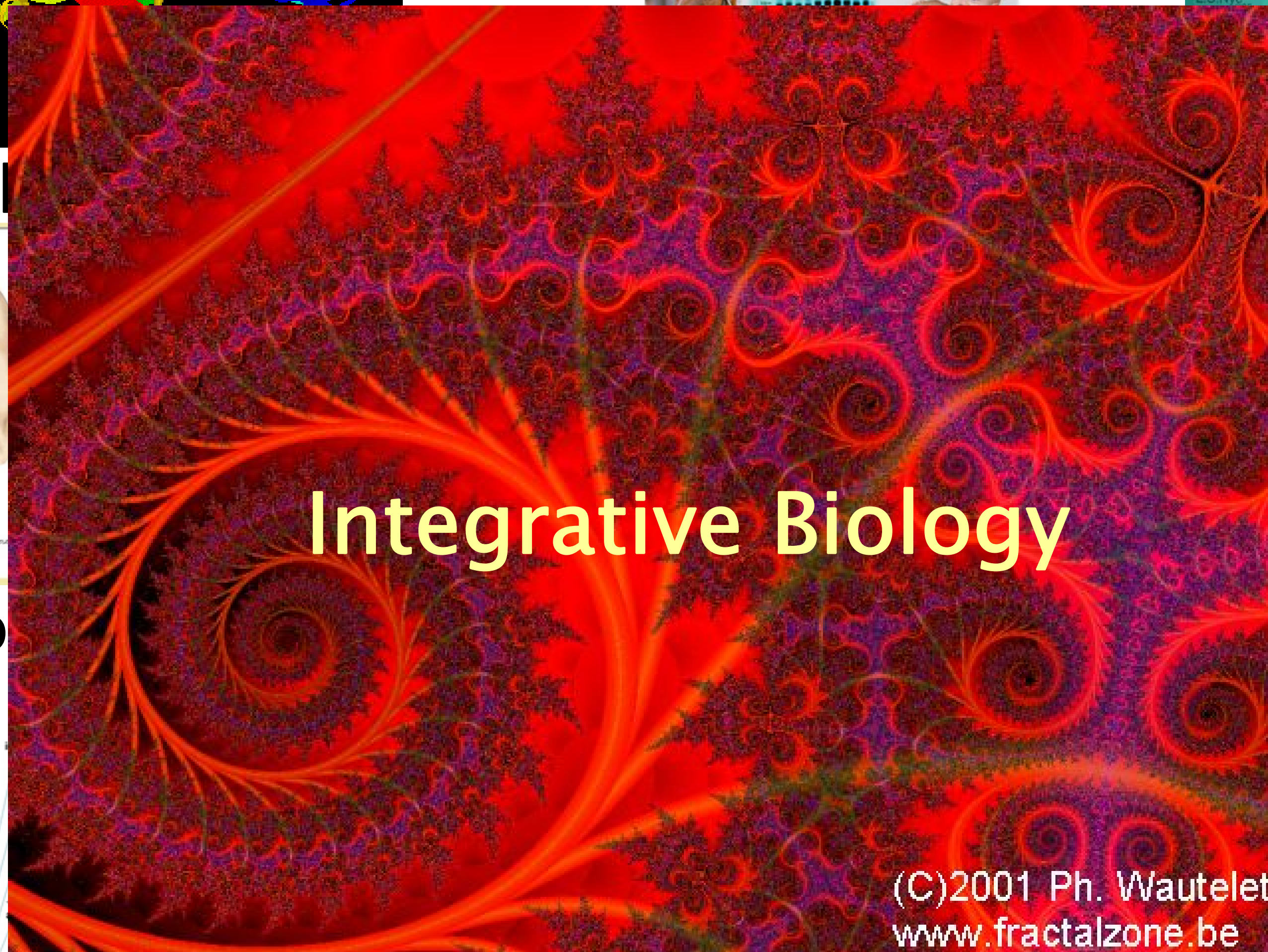


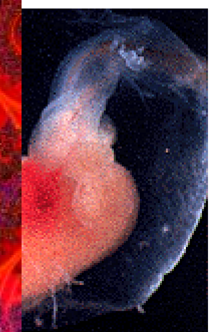


Mol

chemistry

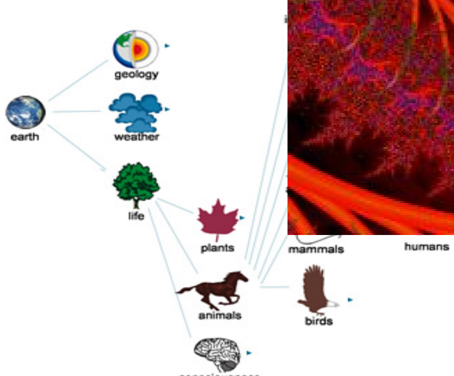






Physiolo

ment

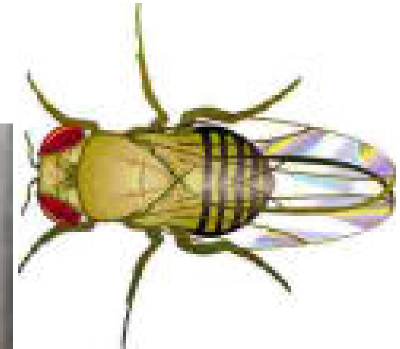


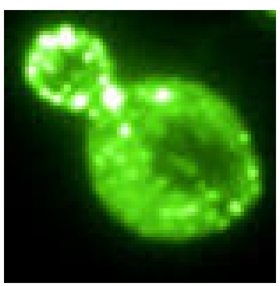
Taxonomy

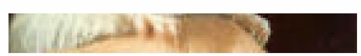
Evolution

Ecology

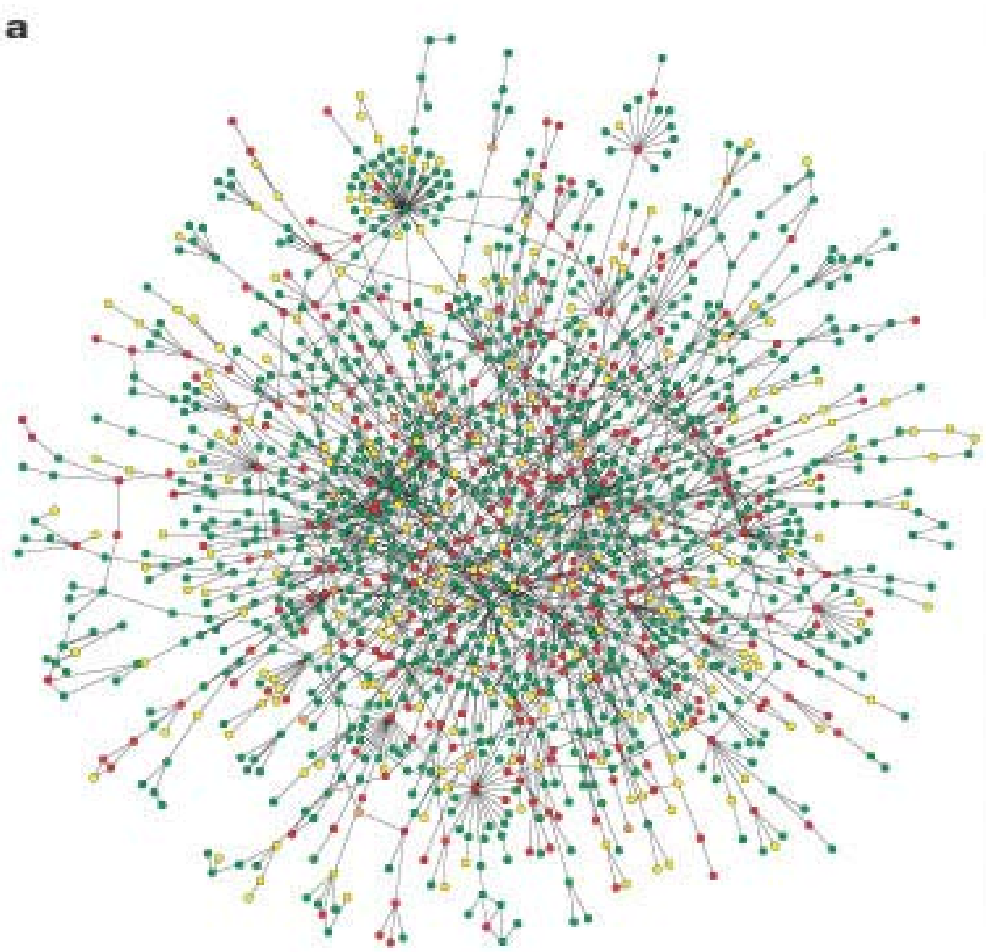
Traditional Top Models in Biological research

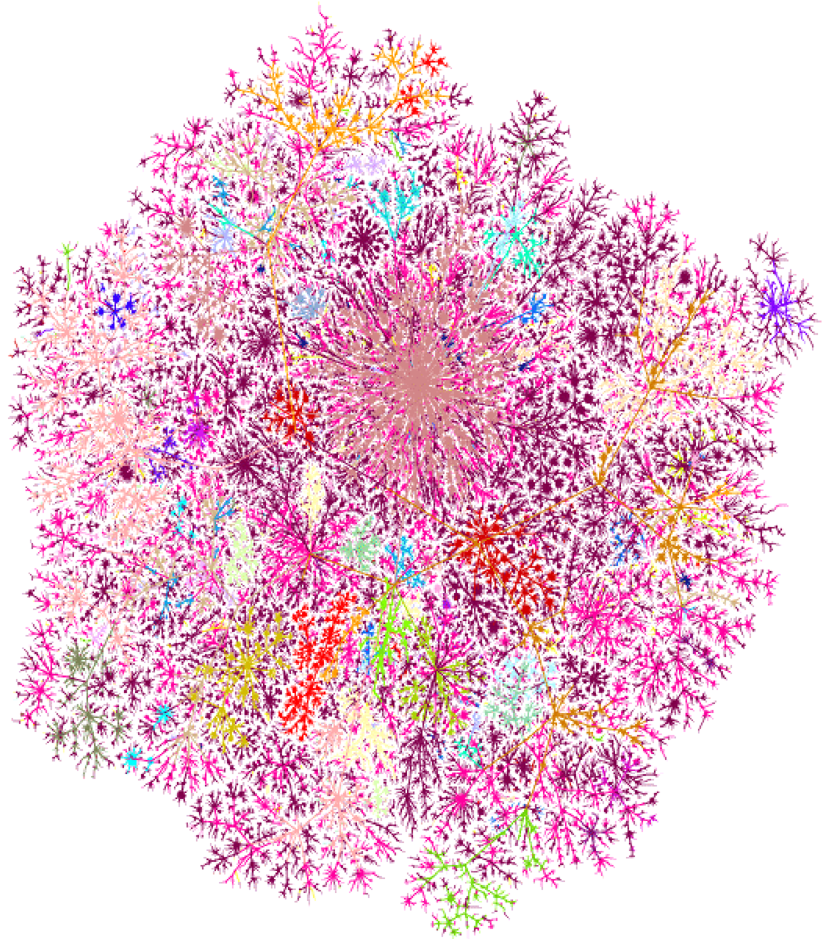




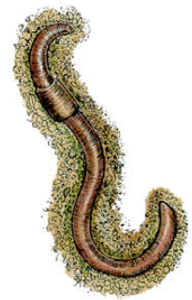
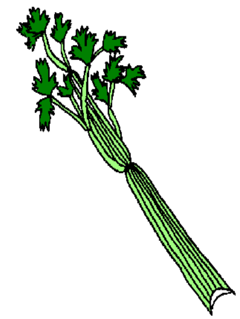


The ultimate model organism





From models to genomes

Complete Published Genome Projects: 961

A **Archaeal:56** B **Bacterial:801** E **Eukaryal:104**

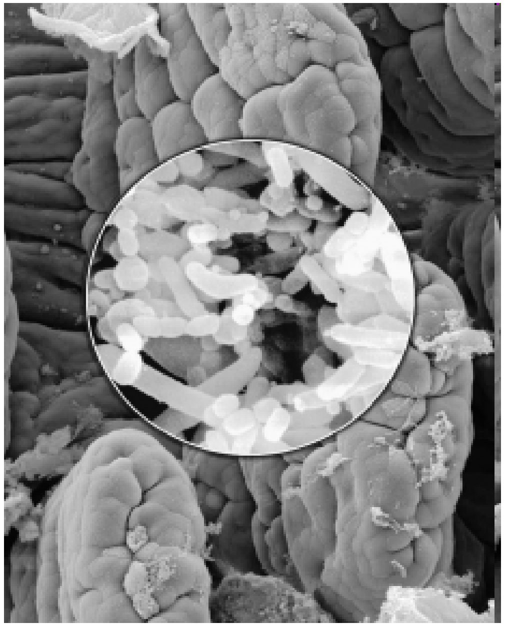
Ongoing Genome Projects: 3,541

A **Archaeal:100** B **Bacterial:2422** E **Eukaryal: 1029**

From genomes to organisms
Metagenomics

Sargasso sea

Antarctic



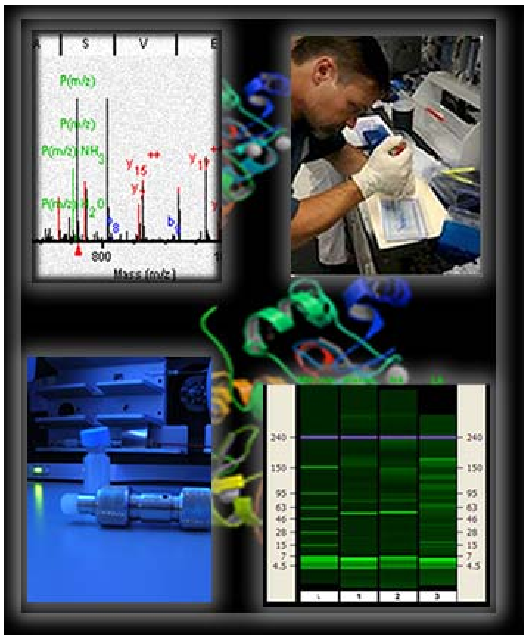
Human gut
Microbes:human 10:1

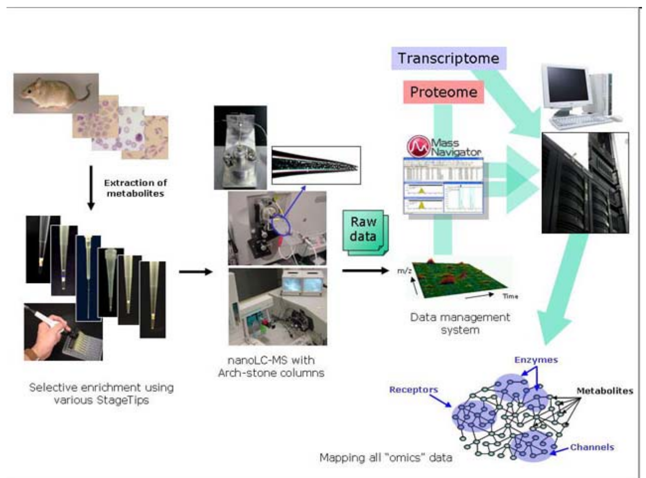
Exploring the bacterial fauna

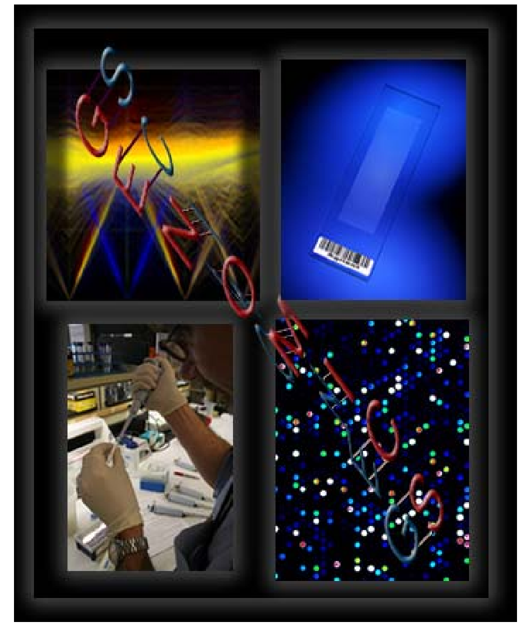
Less than 1% of the species are known

152 metagenomes completed

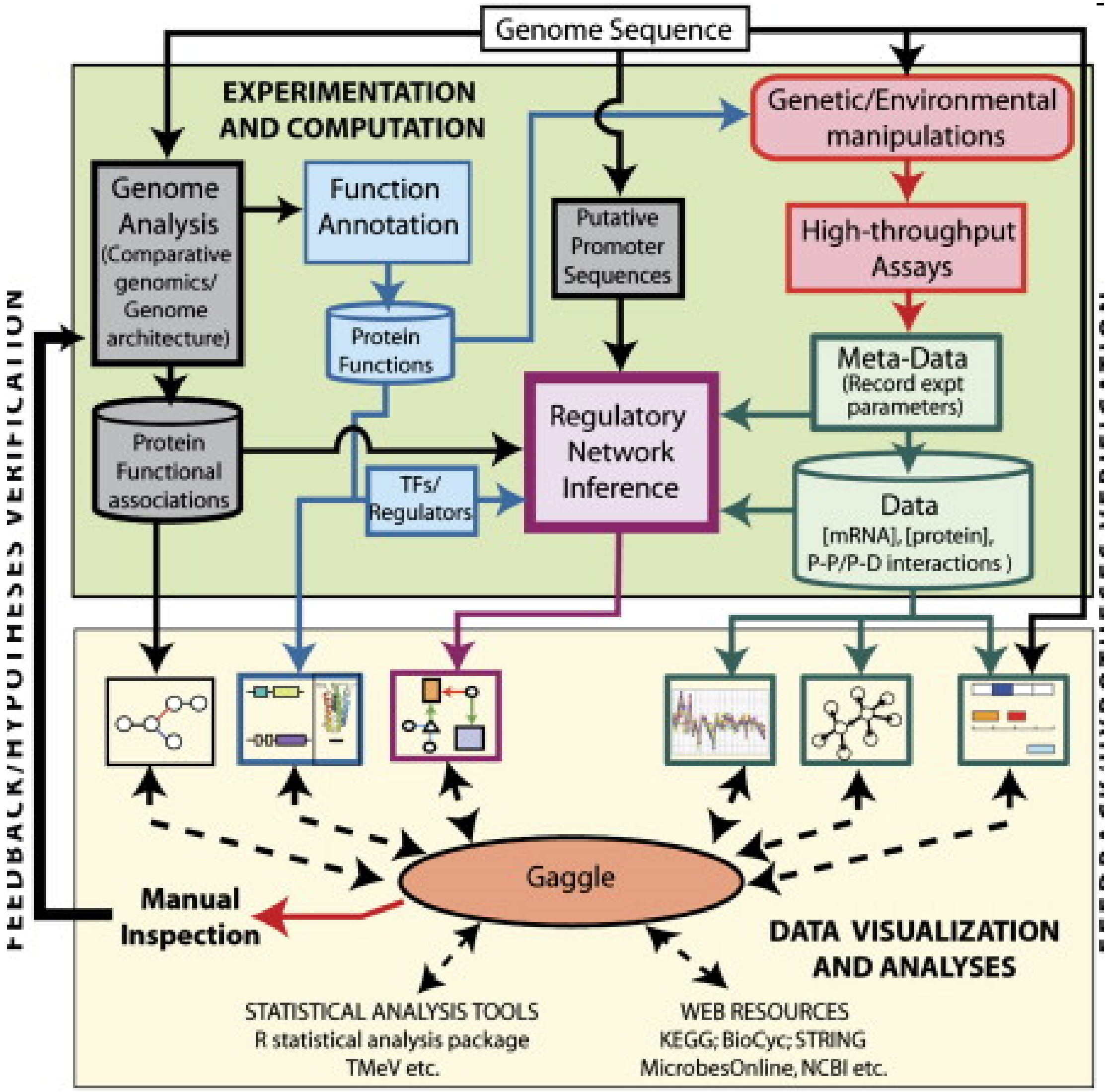
-omics or more comics?





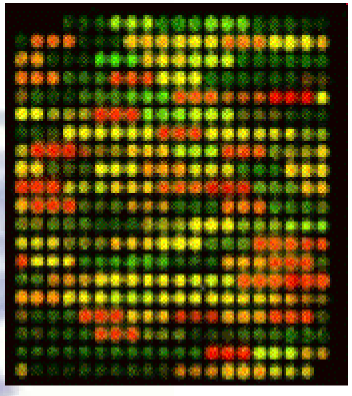


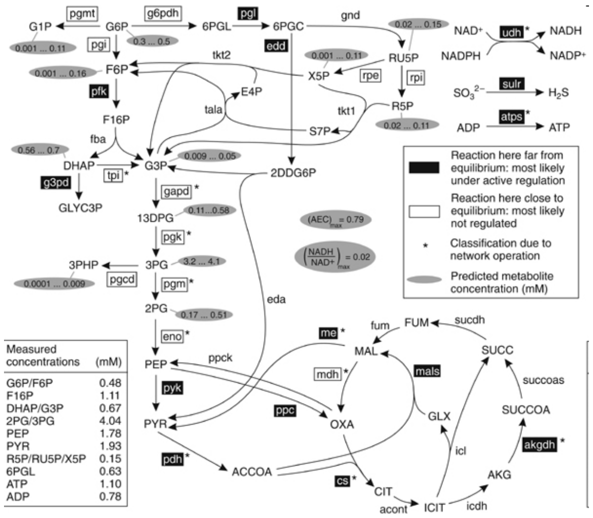
Transform information to knowledge



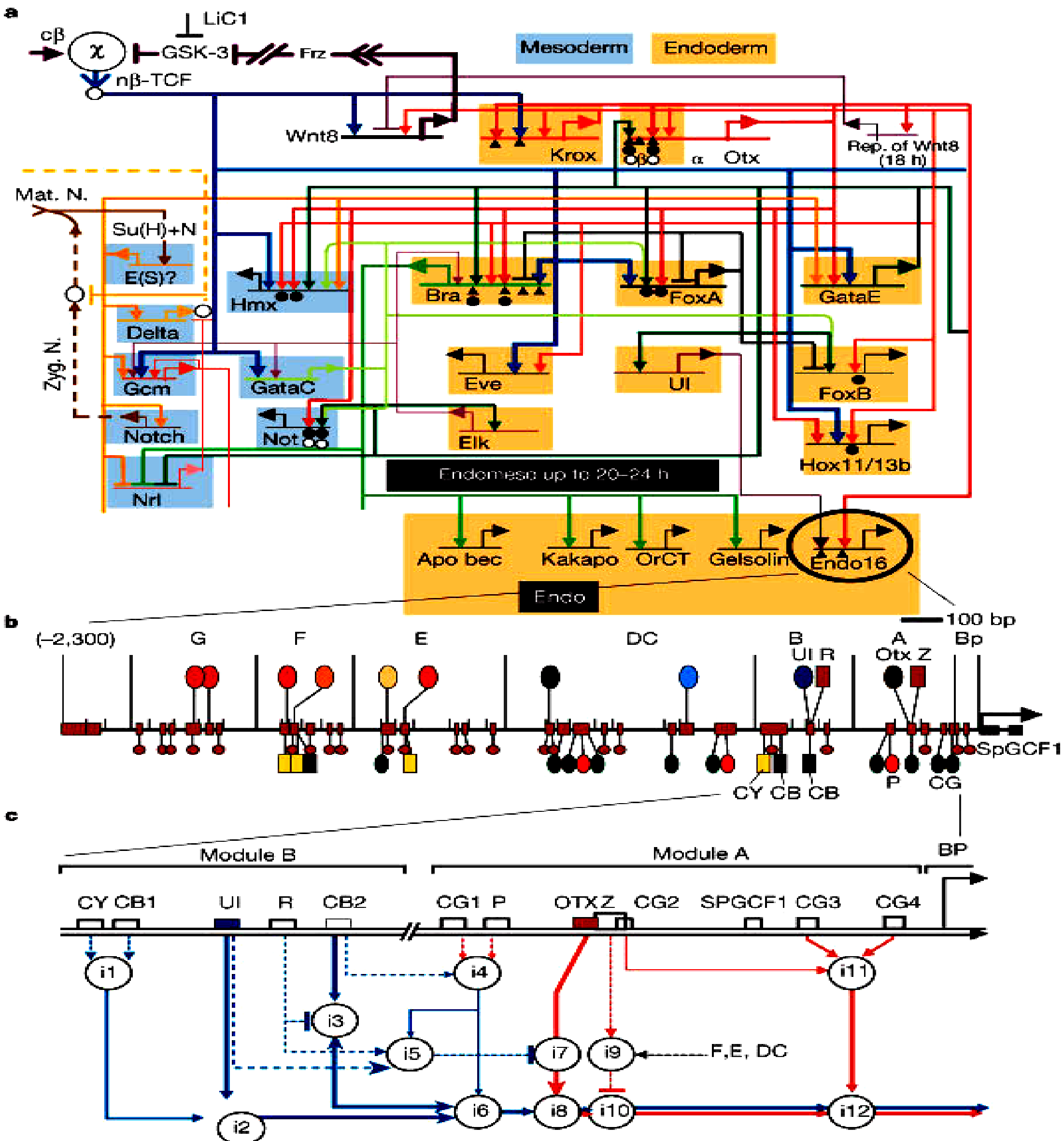
Systems Biology
Defining the components

Systems Biology
Defining the components



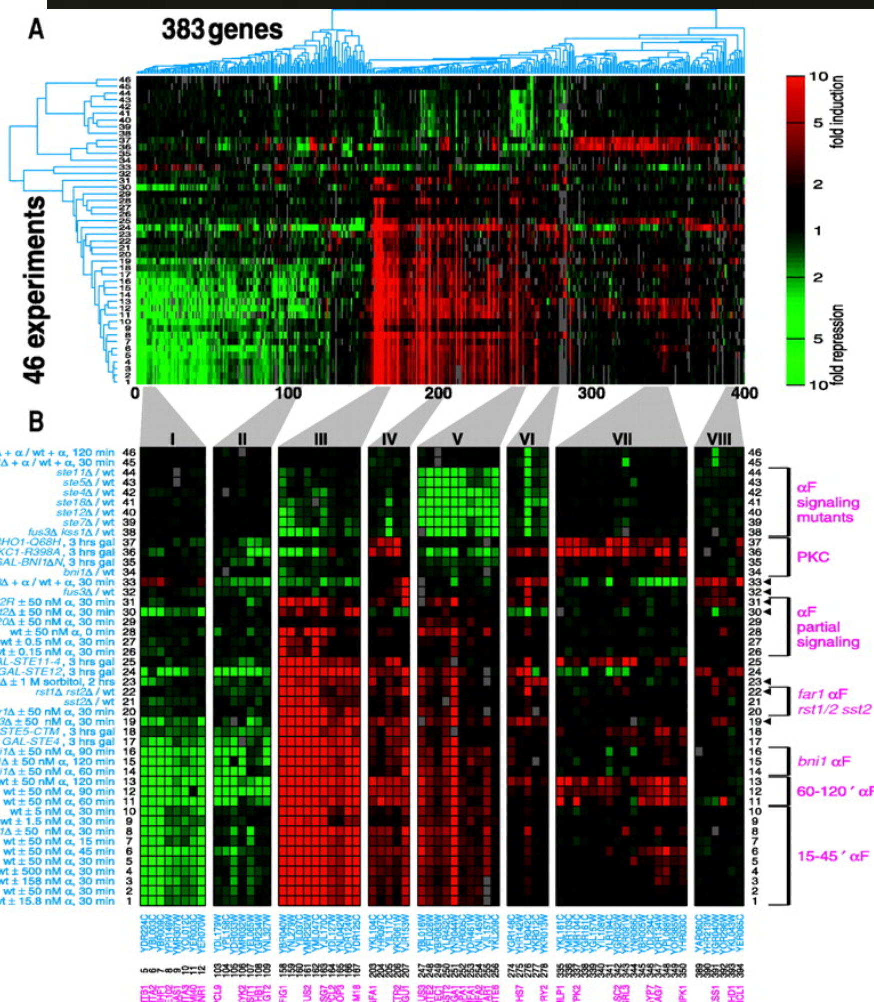


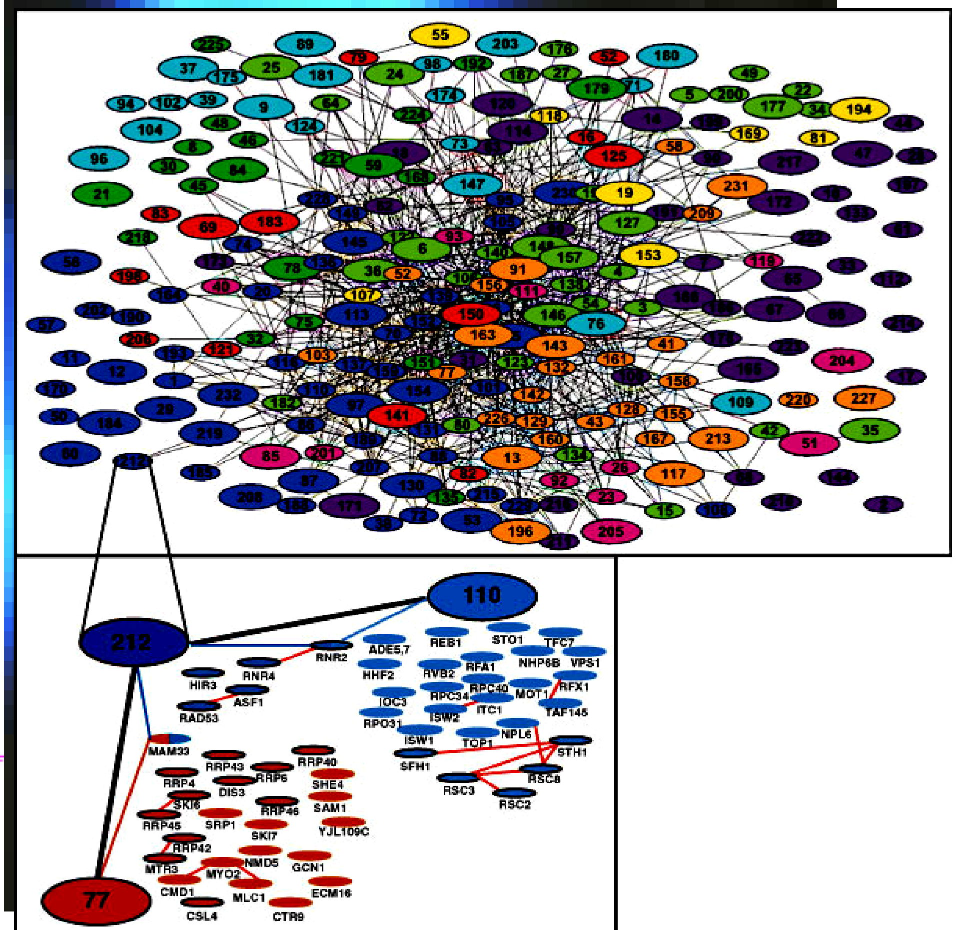
Systems Biology
Defining how the components are related



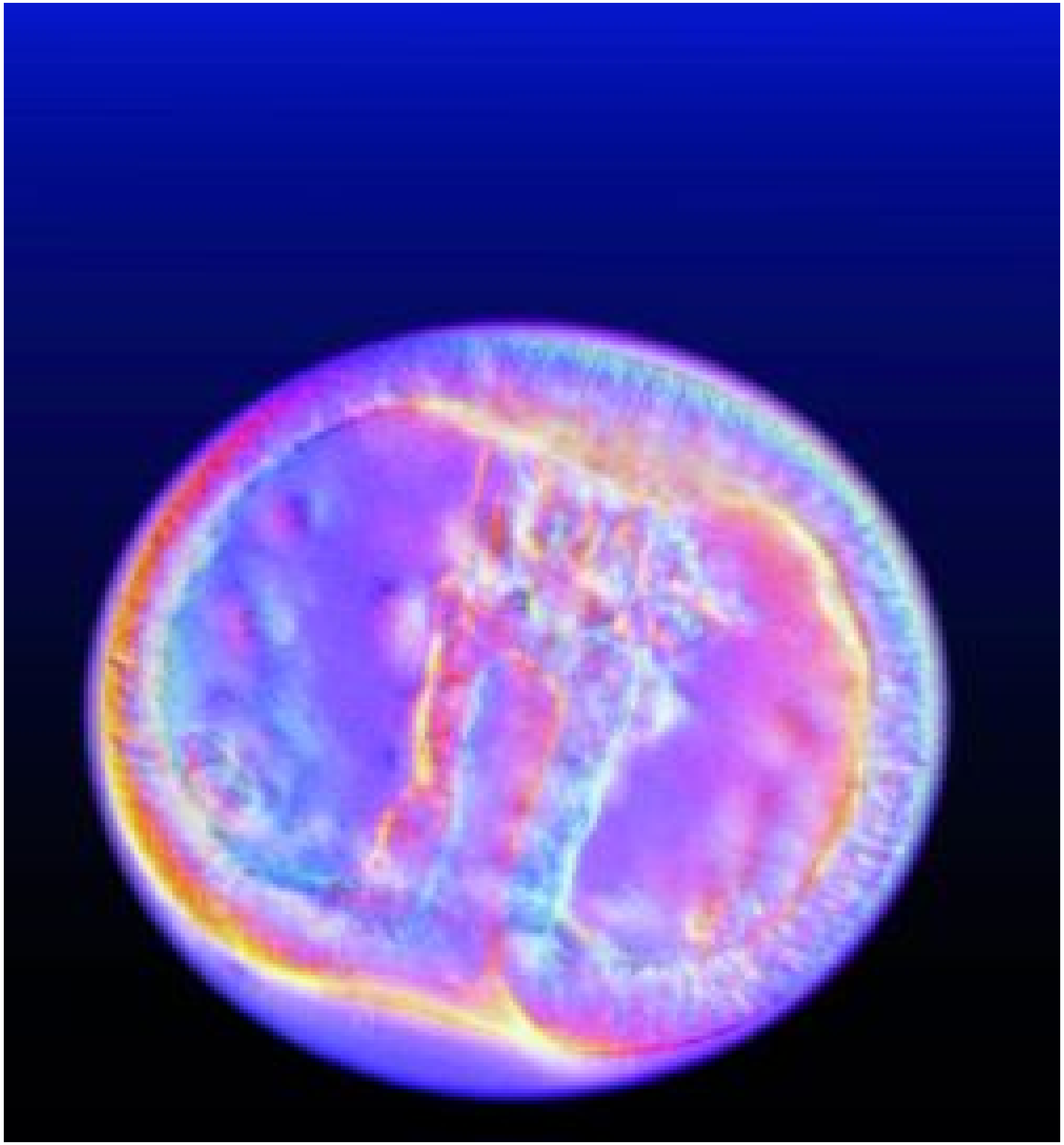
Systems Biology

Integrated representations
or perhaps the ultimate reduction?

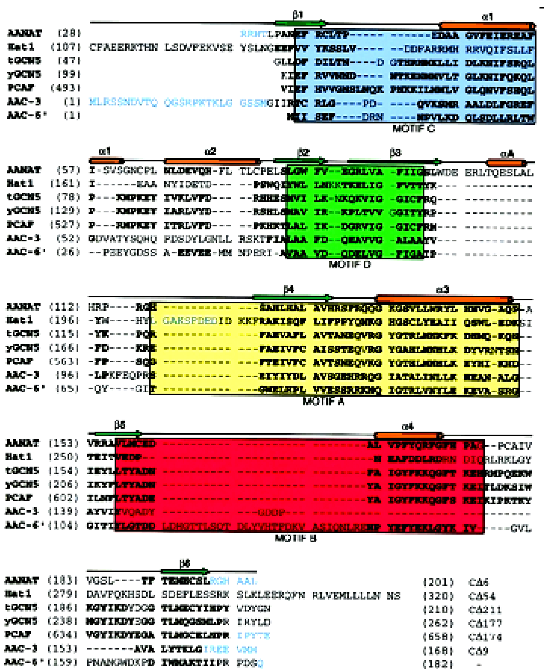


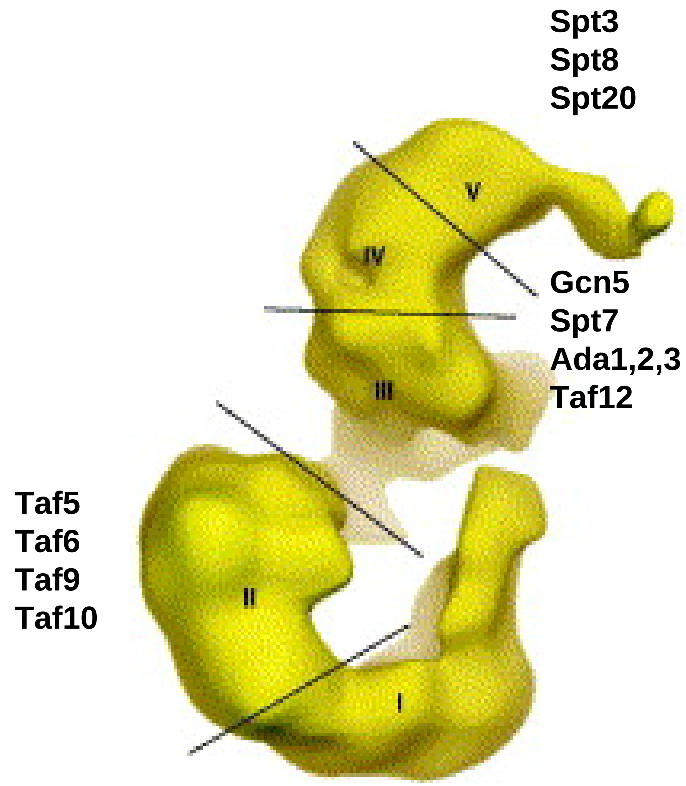


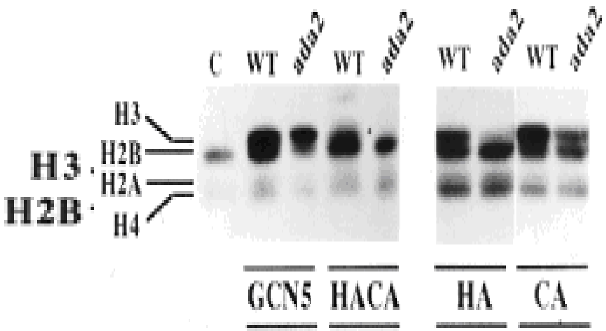
Can we go to phenotypes?



Emergence and Robustness

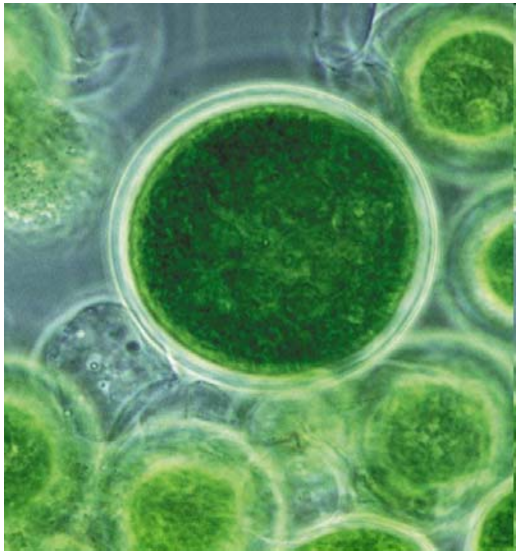






Green Biotechnology

Food



Energy

Environment

The problem with Green Biotechnology

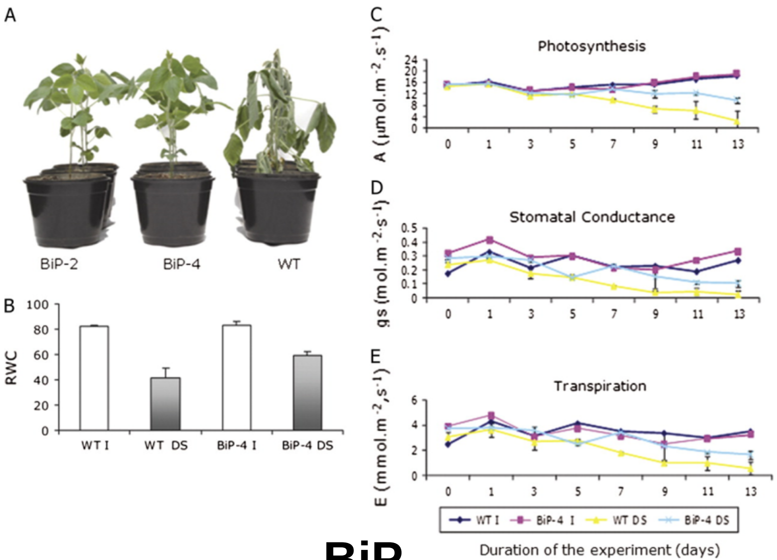
The future of green biotechnology

Safety through

1. Genomics/metagenomics
2. Systems biology
3. Synthetic life

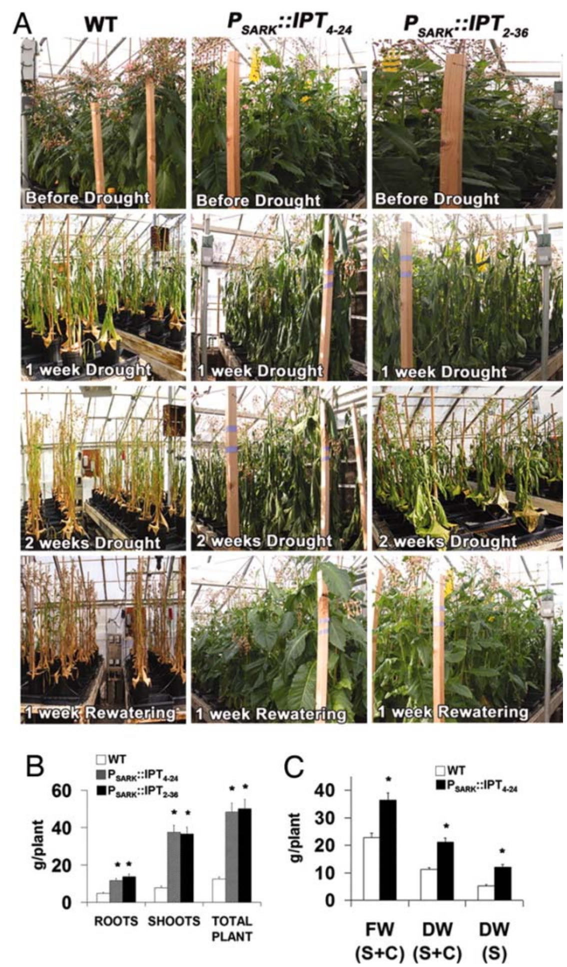
One example
(towards safe
food and sound environment)

Delayed leaf senescence and drought resistance



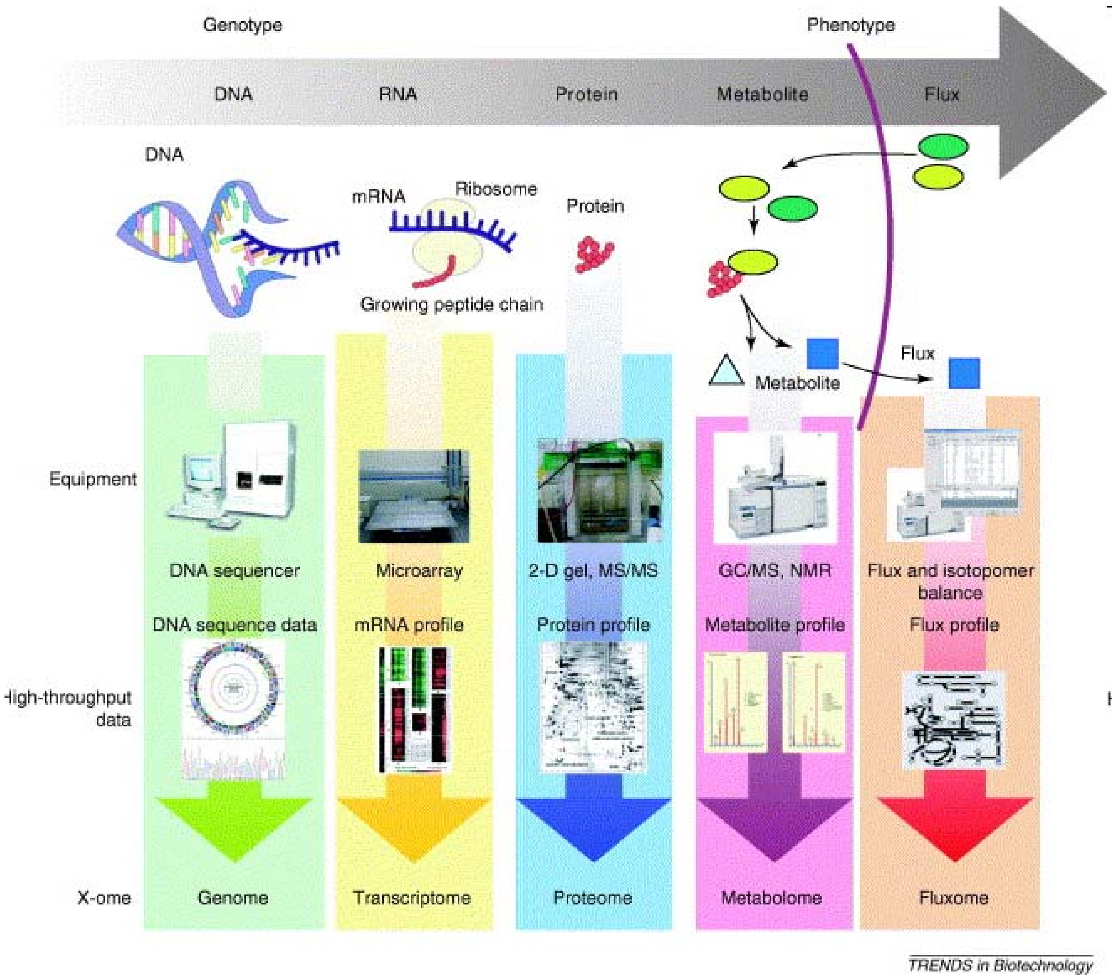
BiP

Aldehyde dehydrogenase

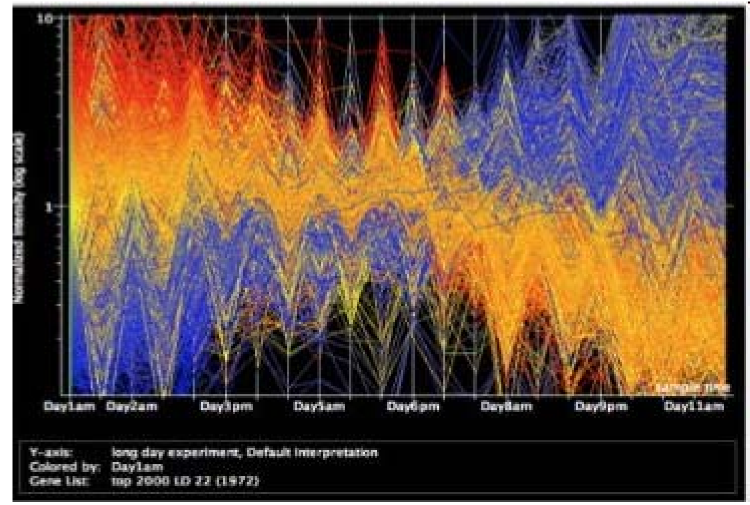


Cytokinin

Genomics and Post-genomics



Systems Biology of leaf senescence



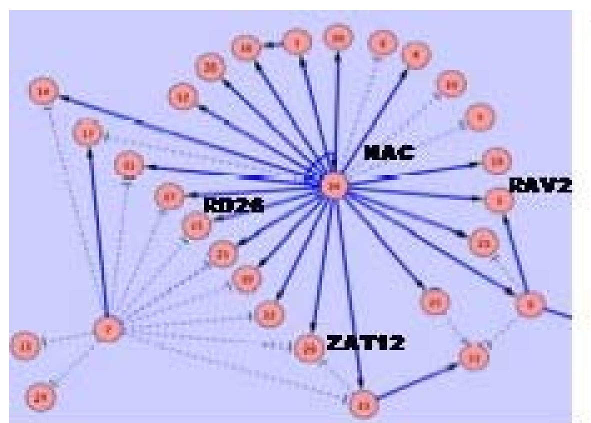
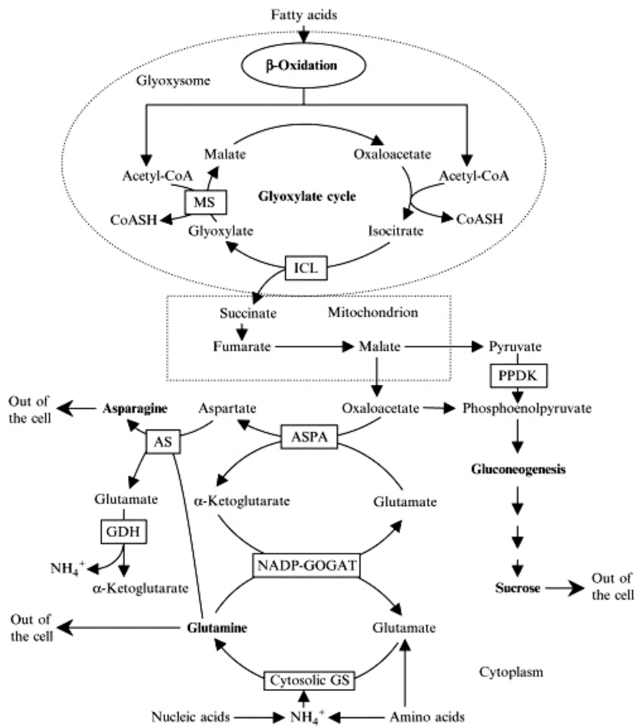
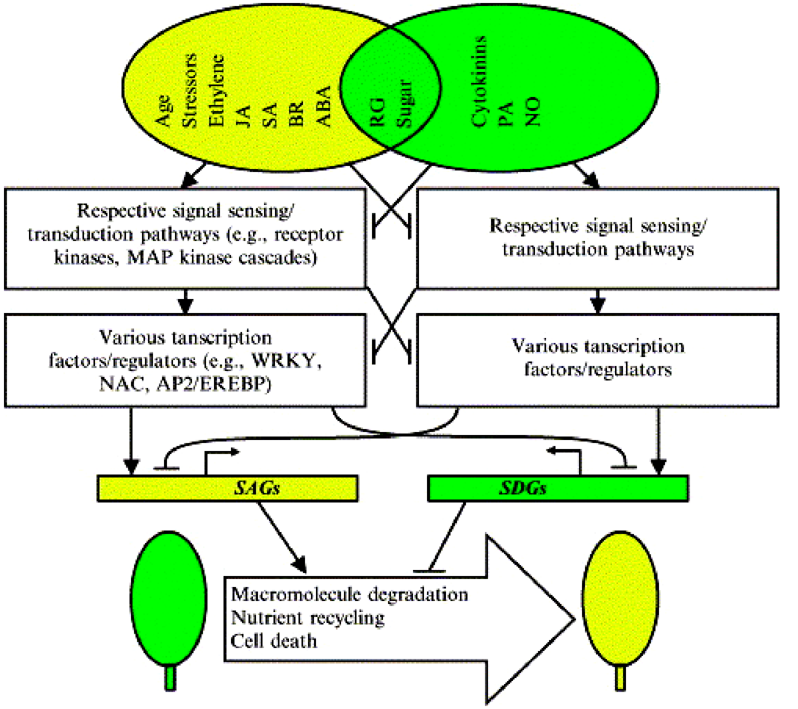


Fig 3. Network model derived from developmental time series microarray data for selected senescence-enhanced genes. Solid lines indicate positive and dotted lines indicate negative influences.

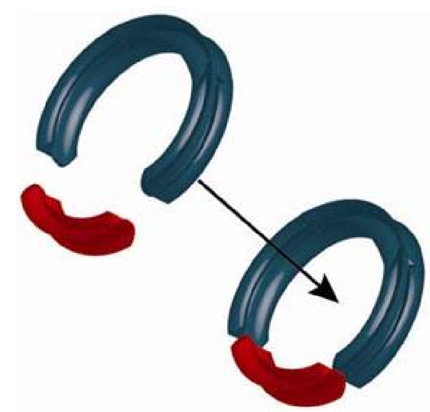
Metabolomics and transcriptomics of leaf senescence

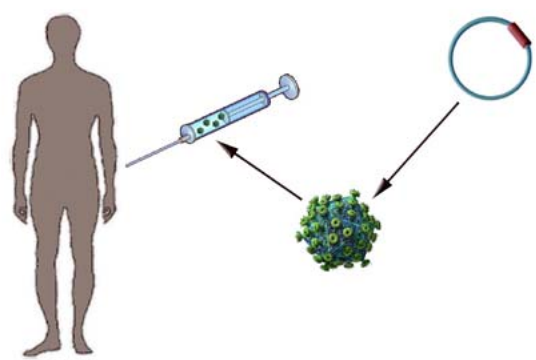




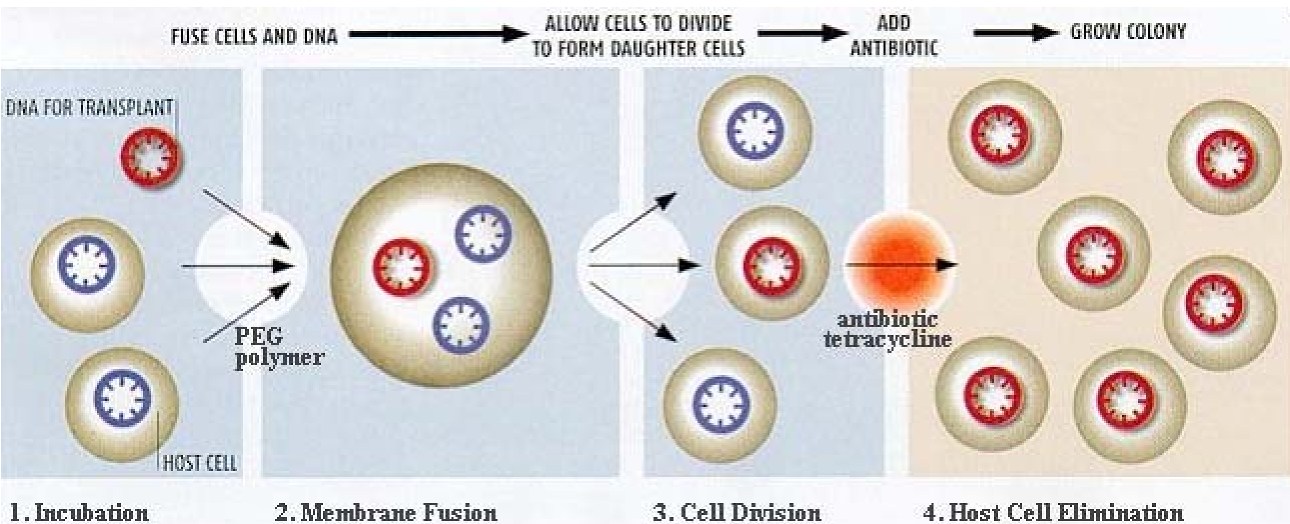
From systems analysis to systems engineering

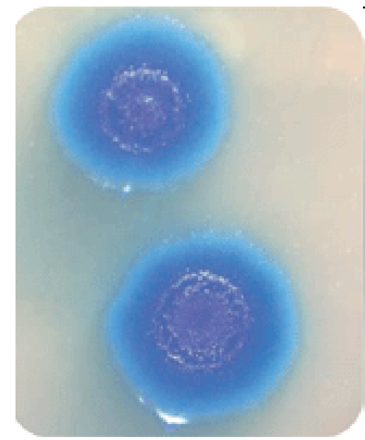
Synthetic Life
Recombinant DNA



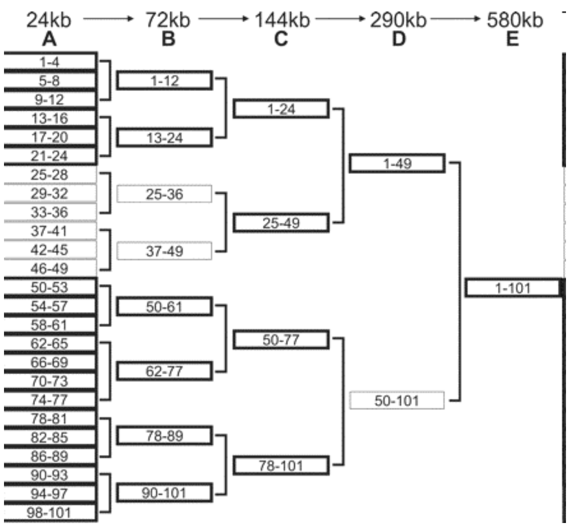


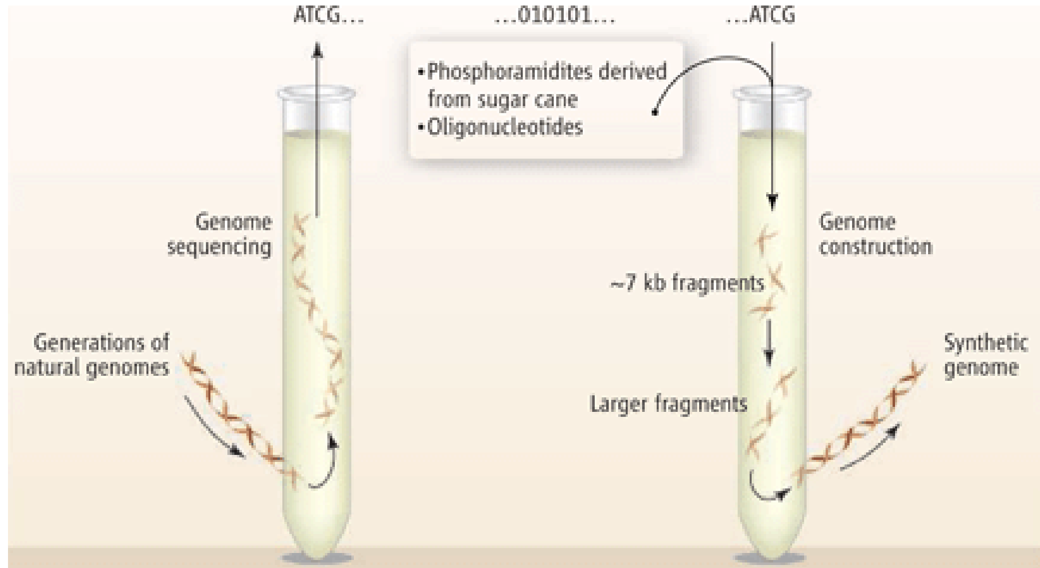
Synthetic Life
New species

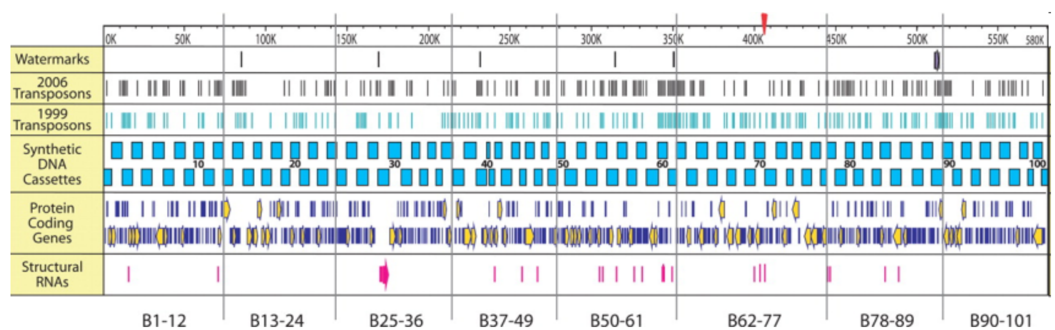




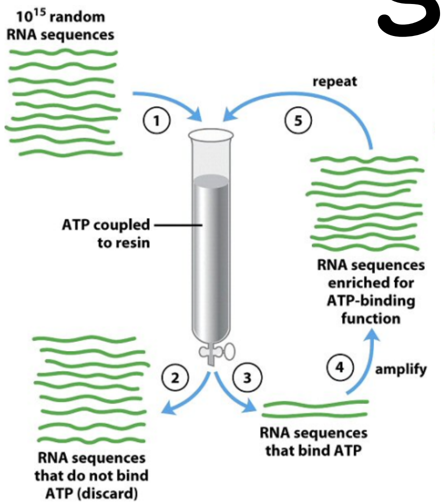
Synthetic Life
Synthetic chromosomes



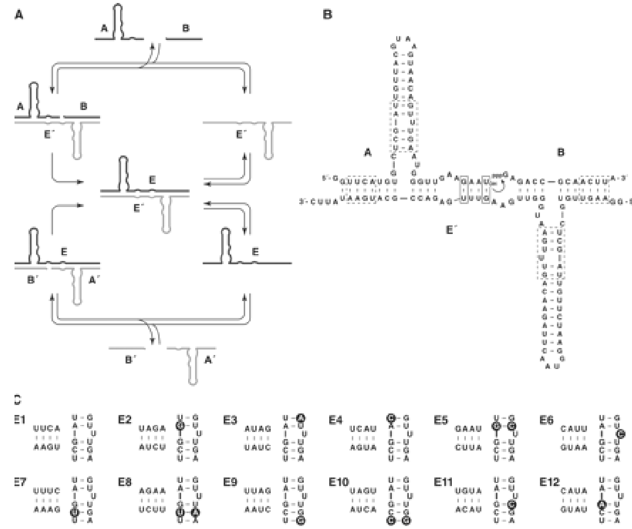


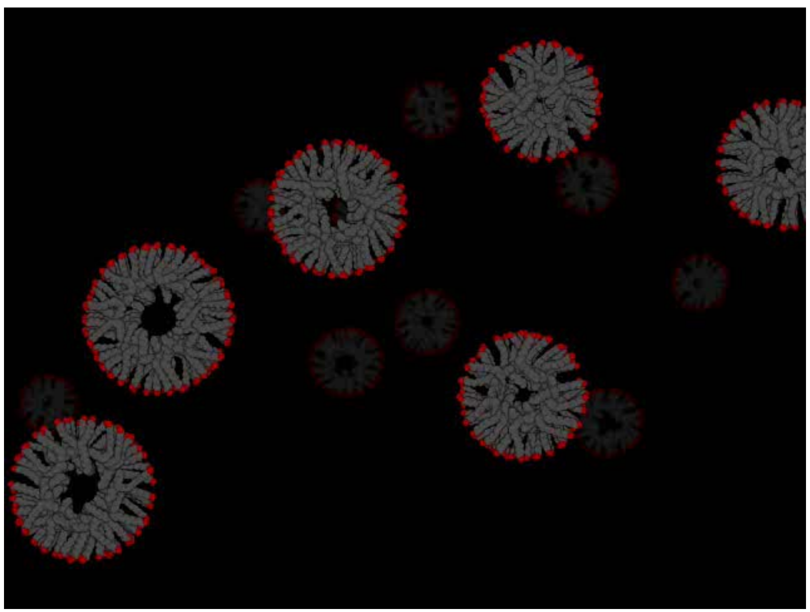


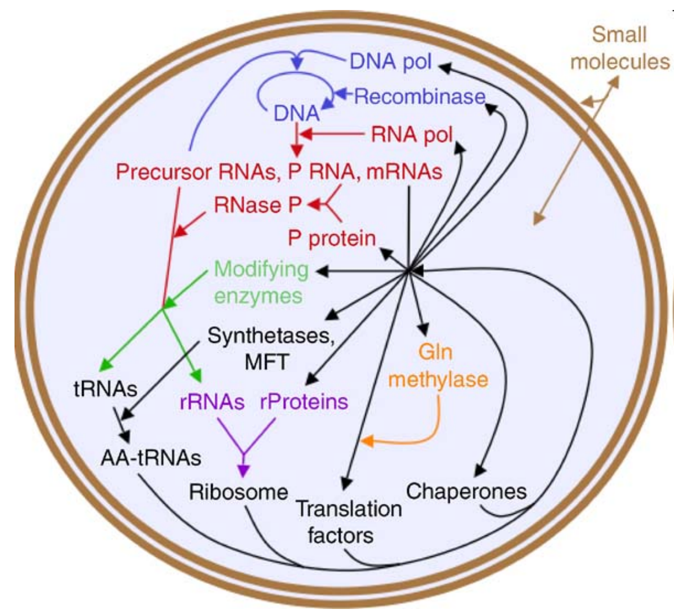
Synthetic life
Synthetic cell



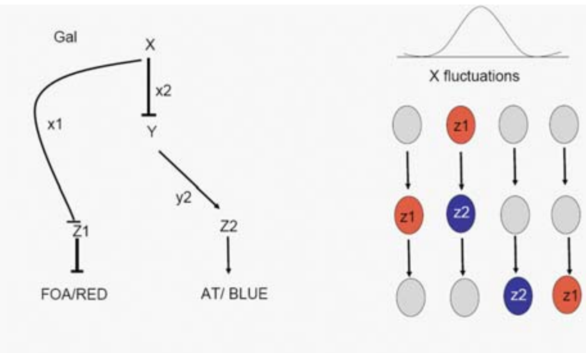
Box 26-3 figure 1
Lehninger Principles of Biochemistry, Fifth Edition

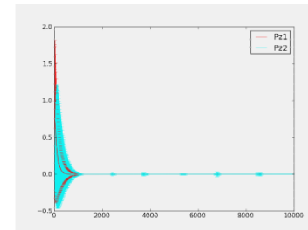






Synthetic stochastic binary cell fates





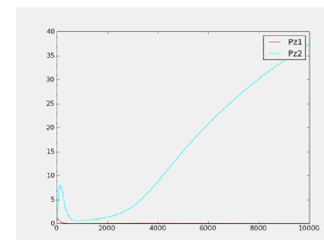
$$X \xrightarrow{r} X + P_X$$

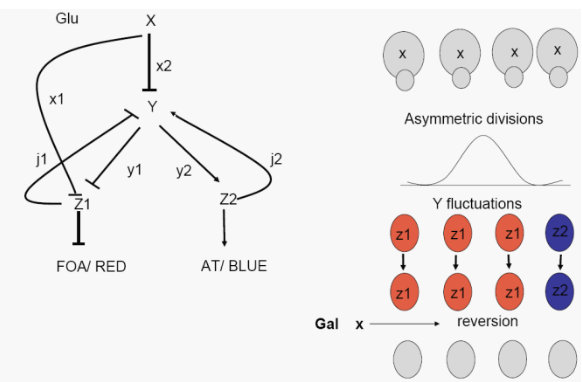
$$Y \xrightarrow{r} Y + P_Y$$
$$Y + P_X \xrightarrow{x2} Y' + P_X$$
$$Y + P_{Z1} \xrightarrow{j1} Y'' + P_{Z1}$$
$$Y + P_{Z2} \xrightarrow{j2} Y''' + P_{Z2}$$
$$Y' \xrightarrow{\eta 1} Y$$
$$Y'' \xrightarrow{\eta 1} Y$$
$$Y''' \xrightarrow{\eta 2} Y + P_Y$$

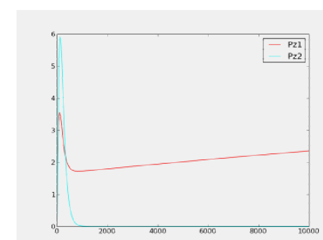
$$Z1 \xrightarrow{r} Z1 + P_{Z1}$$
$$Z1 + P_X \xrightarrow{x1} Z1' + P_X$$
$$Z1 + P_Y \xrightarrow{y1} Z1'' + P_Y$$
$$Z1' \xrightarrow{\eta 1} Z1$$
$$Z1'' \xrightarrow{\eta 1} Z1$$

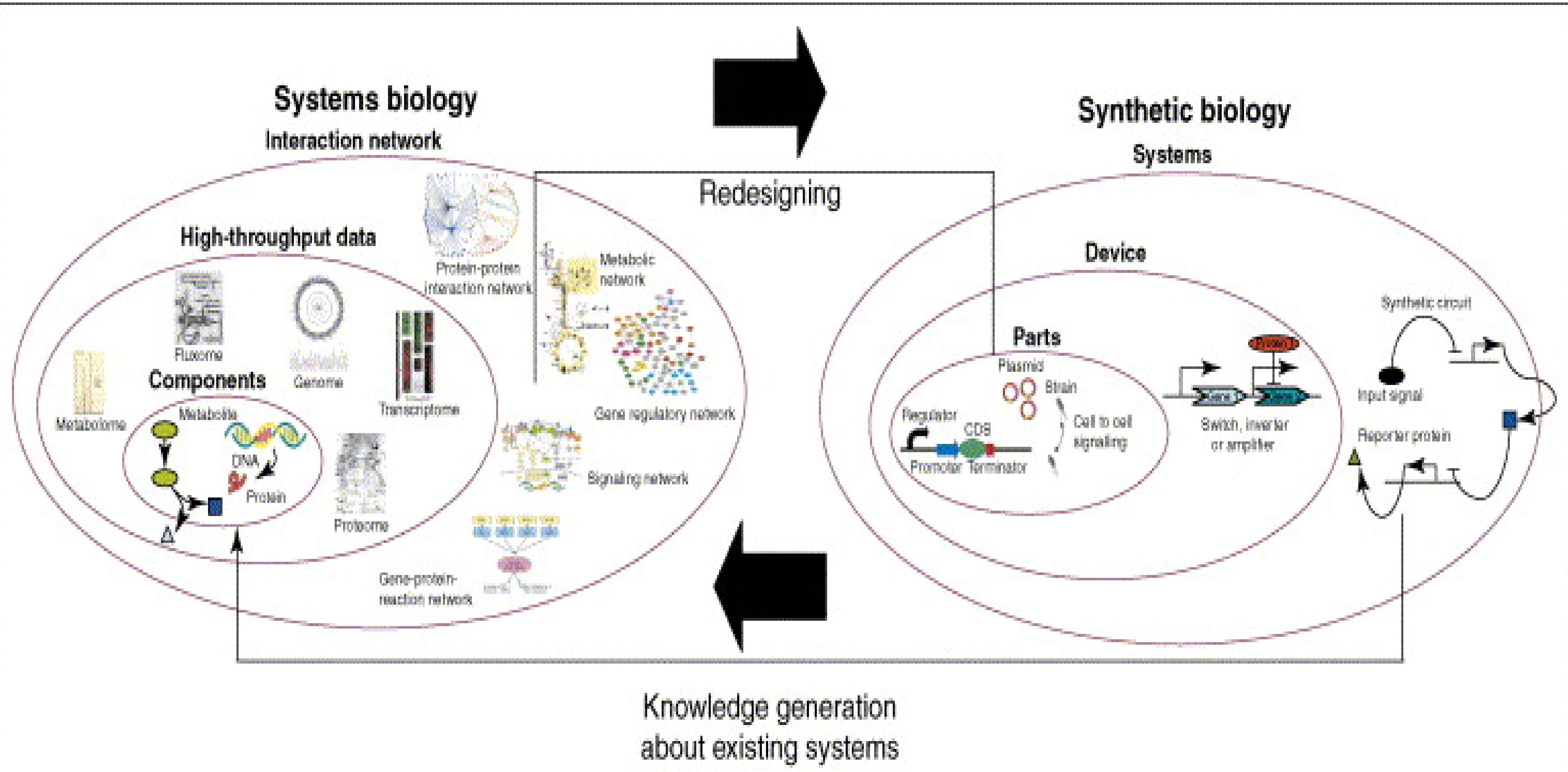
$$Z2 + P_Y \xrightarrow{y2} Z2' + P_Y$$
$$Z2' \xrightarrow{\eta 2} Z2 + P_{Z2}$$

$$P_X \xrightarrow{\delta} \varnothing$$
$$P_Y \xrightarrow{\delta} \varnothing$$
$$P_{Z1} \xrightarrow{\delta} \varnothing$$
$$P_{Z2} \xrightarrow{\delta} \varnothing$$



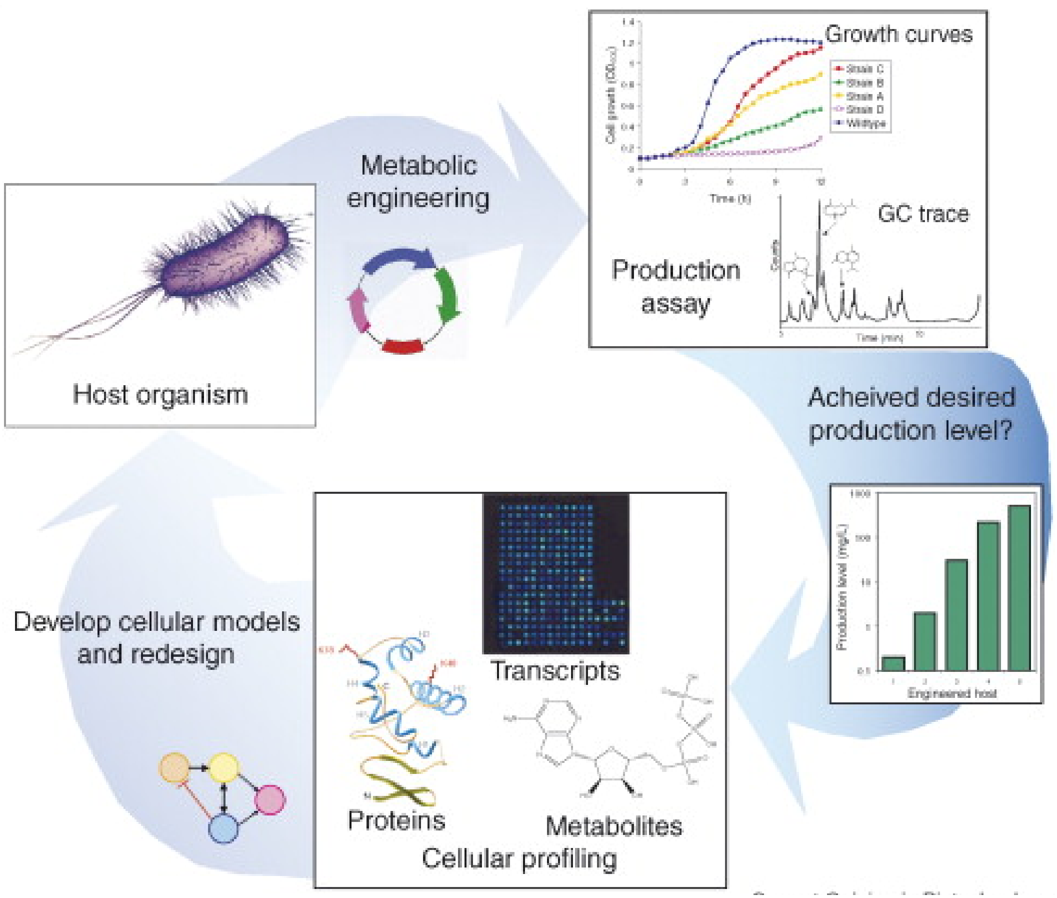






Current Opinion in Biotechnology

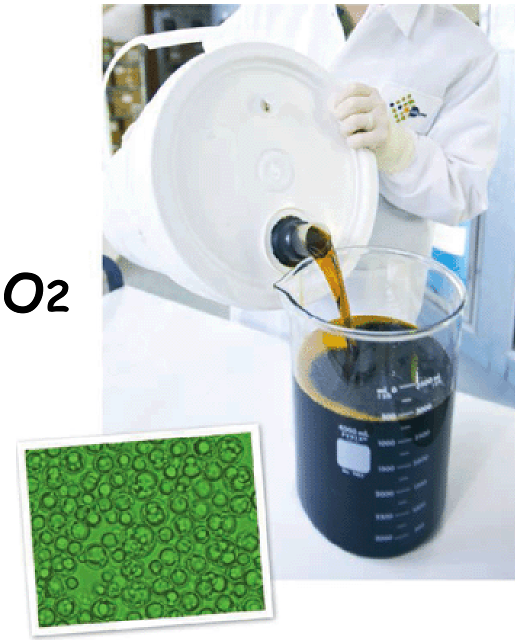
From systems analysis to engineering to systems analysis



A second example (towards Safe Energy)

Fuel from microalgae

Sun+CO_2+H_2O=product+O_2

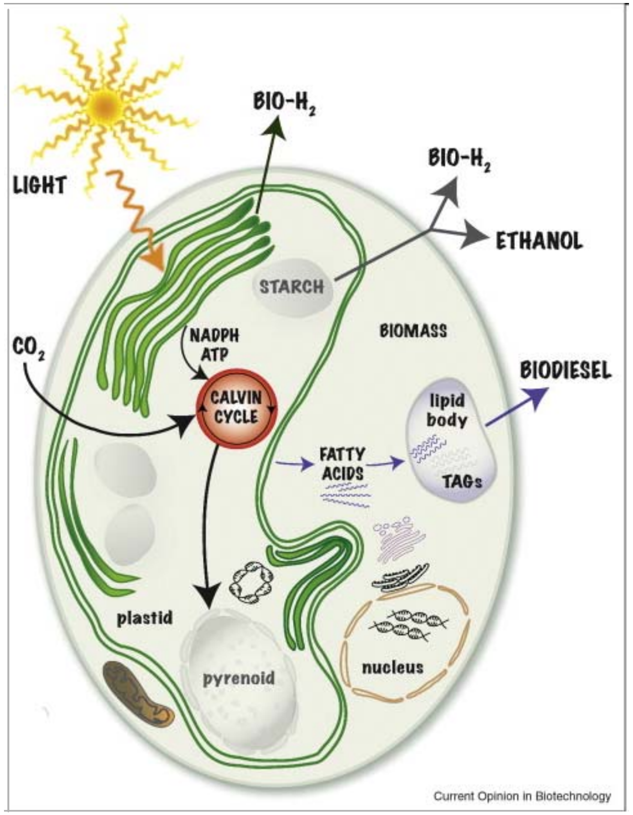


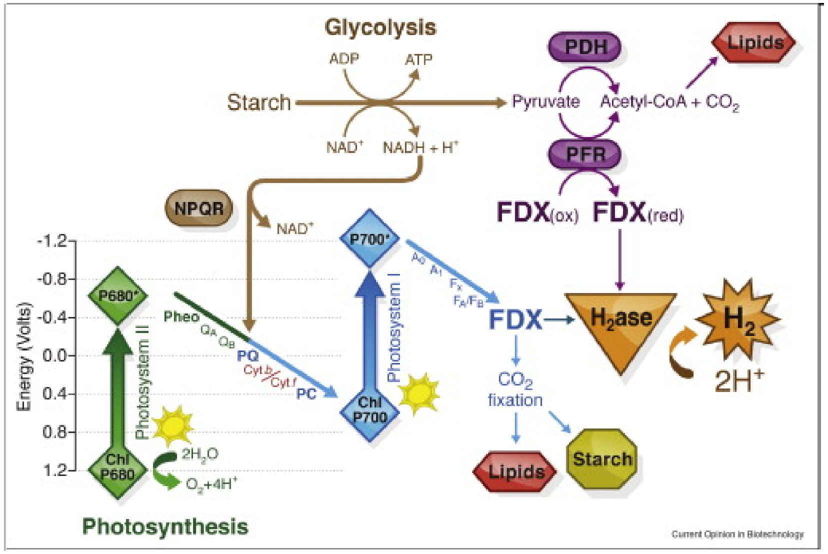
Transforn the Sunlight to:

Biomass **Biodiesel** **Bioethanol** H_2

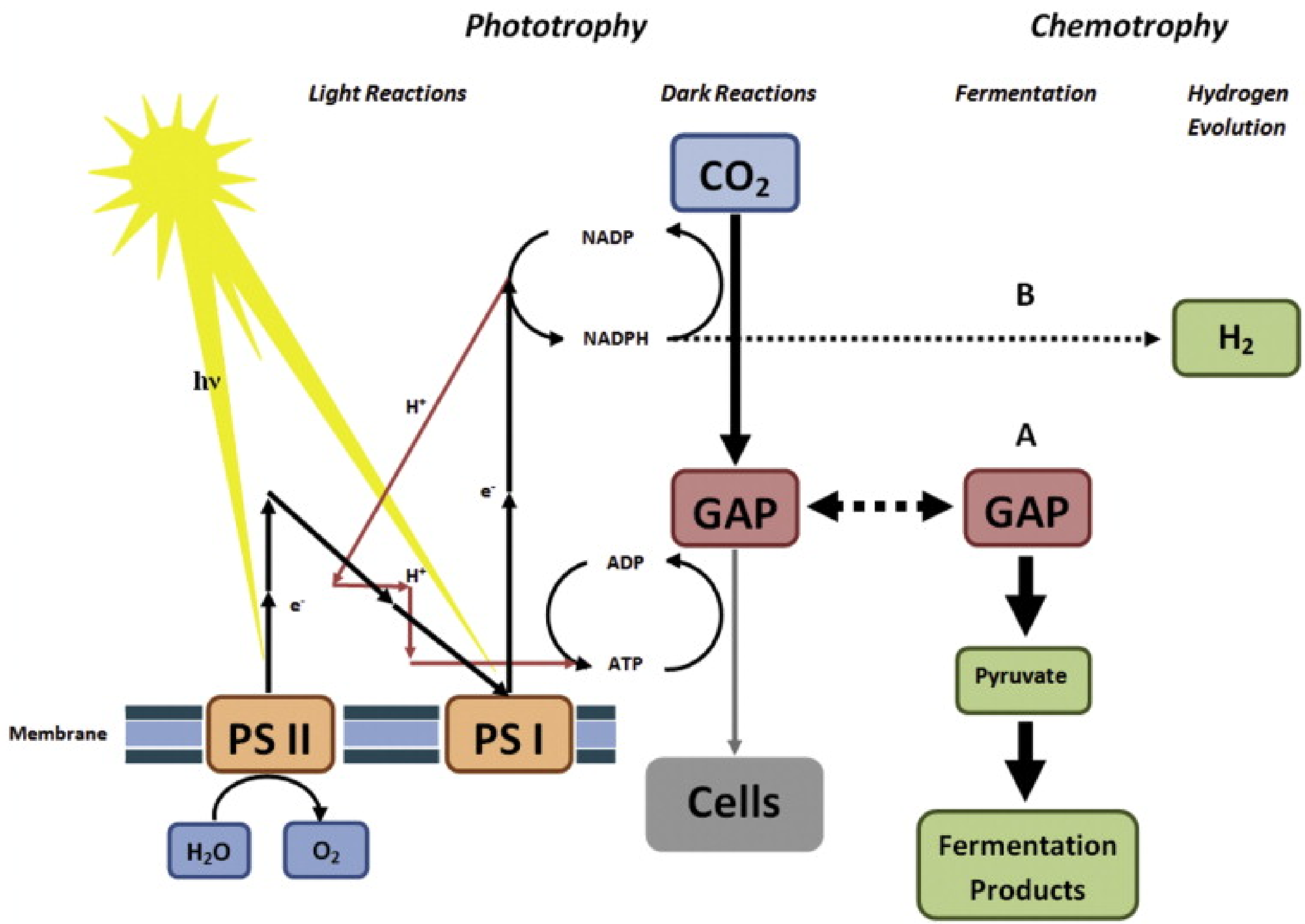
Zero CO_2 balance

The process

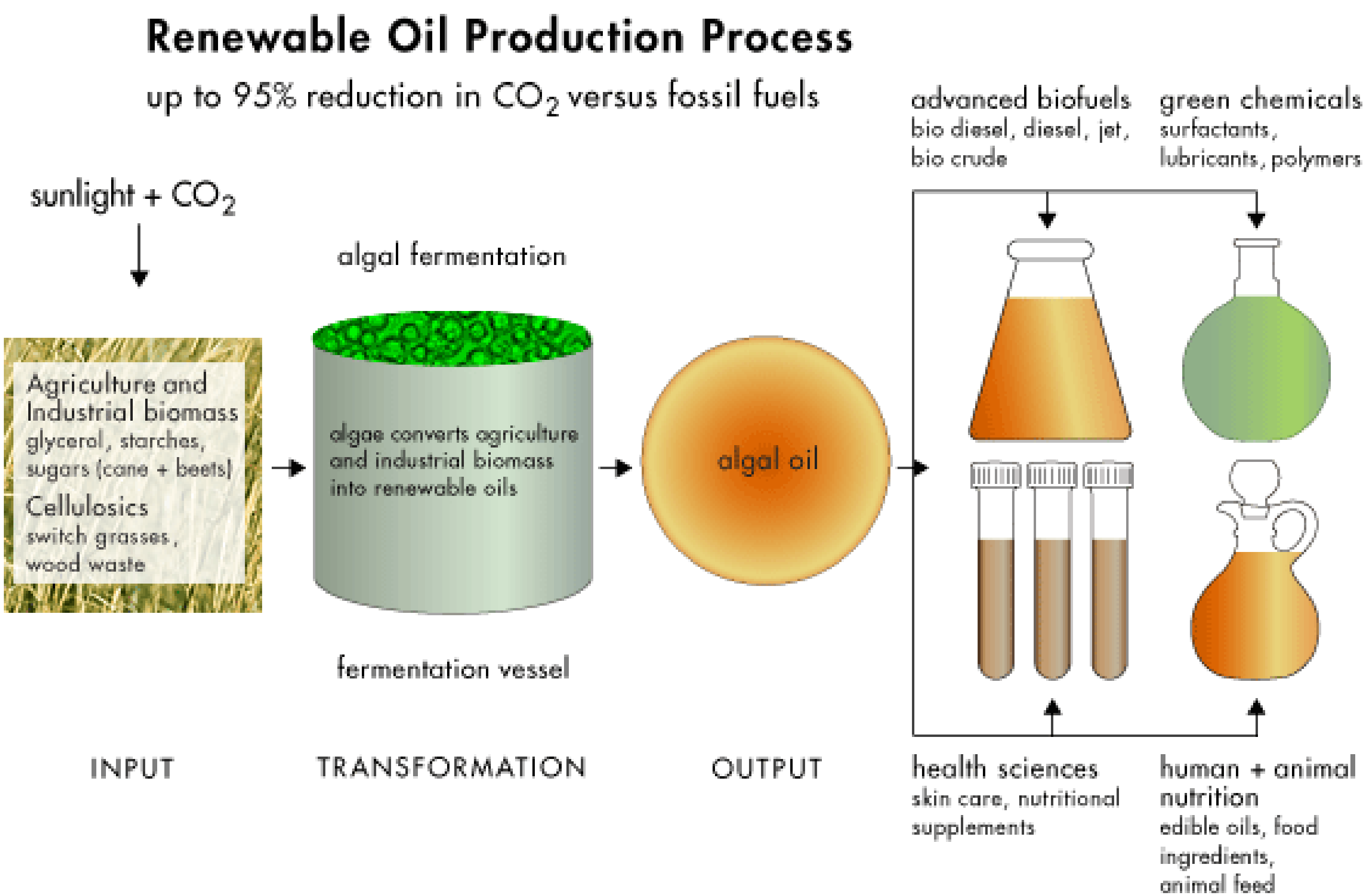

LIGHT
BIO-H_2
BIO-H_2
ETHANOL
STARCH
BIOMASS
CO_2
NADPH
ATP
CALVIN CYCLE
BIODIESEL
lipid body
FATTY ACIDS
TAGs
plastid
pyrenoid
nucleus
Current Opinion in Biotechnology


Glycolysis
ADP
ATP
Starch
NAD$^+$
NADH + H$^+$
Pyruvate
PDH
Acetyl-CoA + CO_2
PFR
Lipids
FDX(ox)
FDX(red)
NPQR
NAD$^+$
P700*
P680*
Pheo
PQ
PC
Photosystem II
Photosystem I
Chl P680
Chl P700
$2H_2O$
O_2+4H^+
Energy (Volts)
-1.2
-0.8
-0.4
0.0
0.4
0.8
1.2
FDX
H_2ase
H_2
$2H^+$
CO_2 fixation
Lipids
Starch
Photosynthesis
Current Opinion in Biotechnology

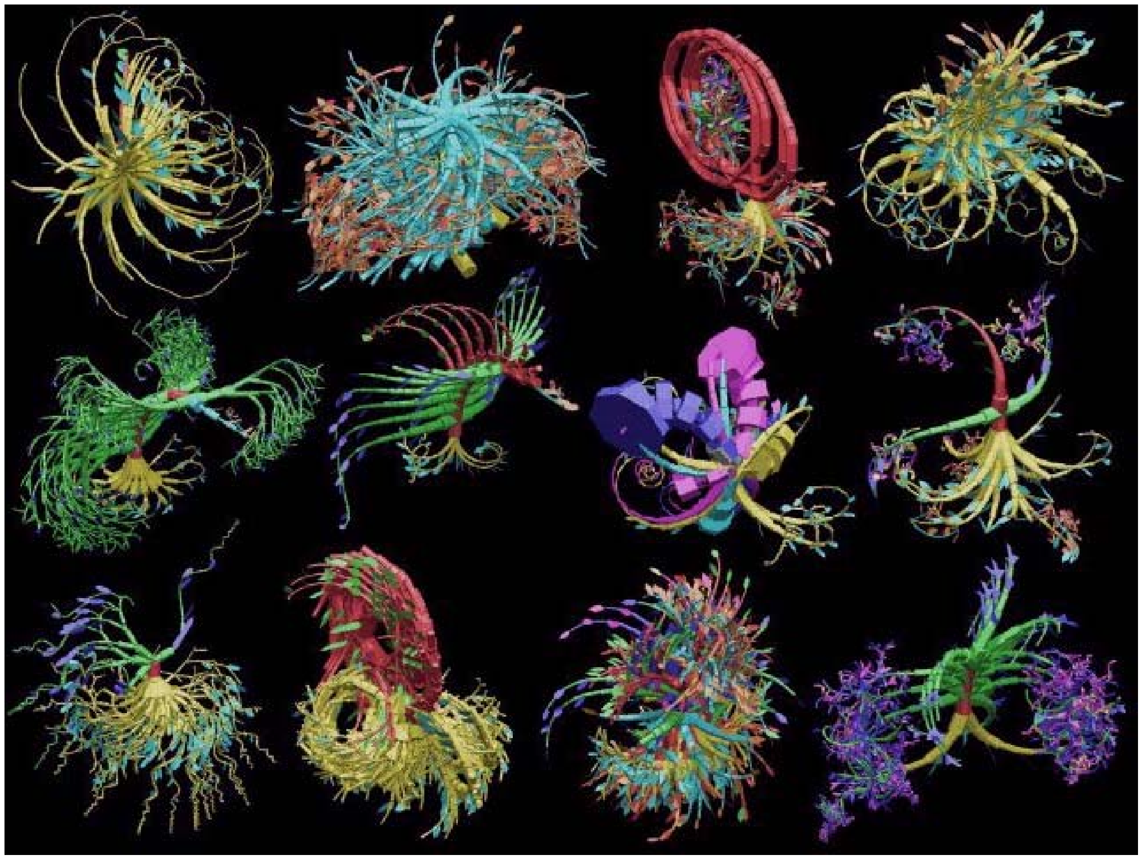
Introducing chemotrophy to phototrophy

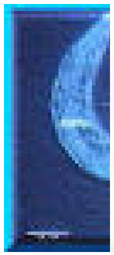
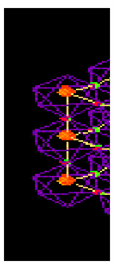


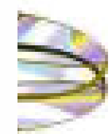
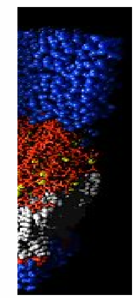
Introducing a dark phase



Before taking the next step




It only matters on how we look at ourselves