Complexity – Yesterday, Today, Tomorrow

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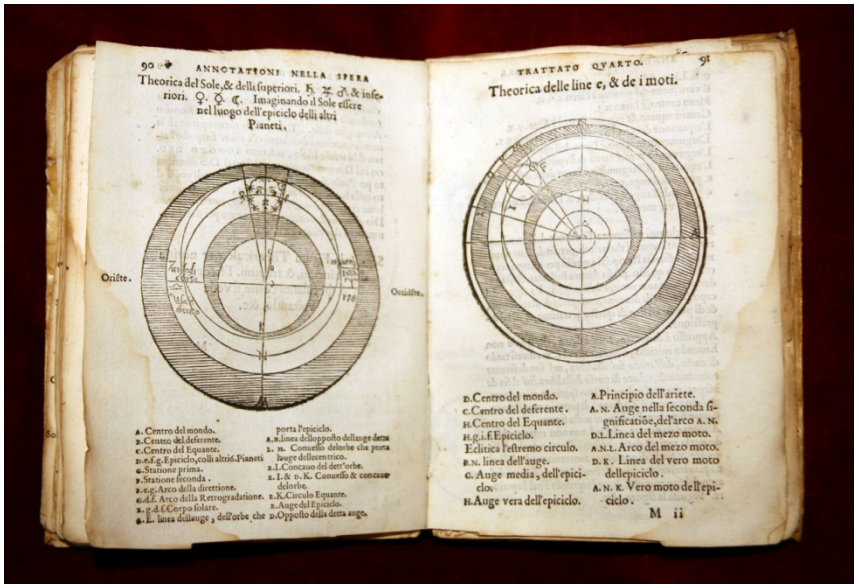
Complexity Science Hub Vienna

Visions for Complexity

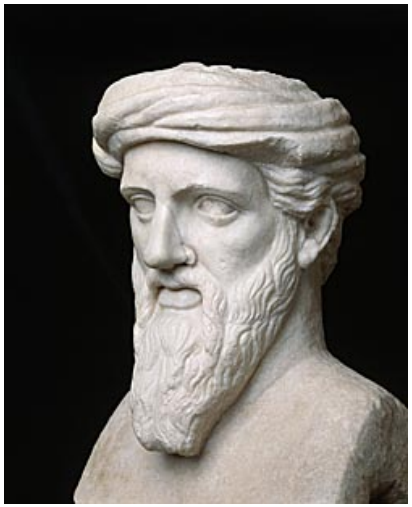
Wien, 23.05.2016

Complexity may result from lack of insight

celestial spheres
and
epicycles



Sacrobosco‘s Tractatus de Sphaere, 1230



Pythagoras, 575 – 495 BC

Isaac Newton, 1643 - 1727

$$F_1 = F_2 = g\frac{m_1 \times m_2}{r^2}; \quad F = m \times b$$

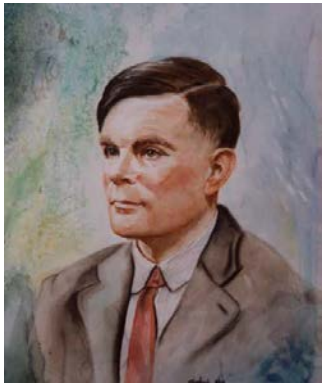
law of gravity

Complexity may result from lack of methods

Henri Poincaré,
1854 -1912

spatiotemporal pattern in
chemical reactioons

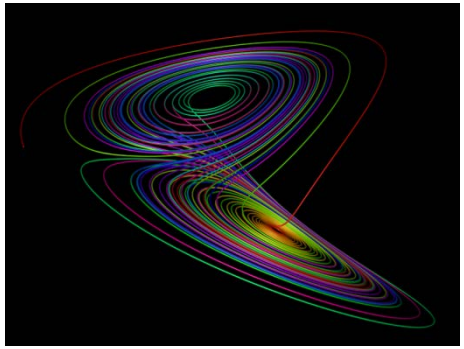
deterministisches chaos



mathematics of chemical
pattern formation

Alan Turing,
1912 - 1954

Wilhelm Ostwald,
1853-1932

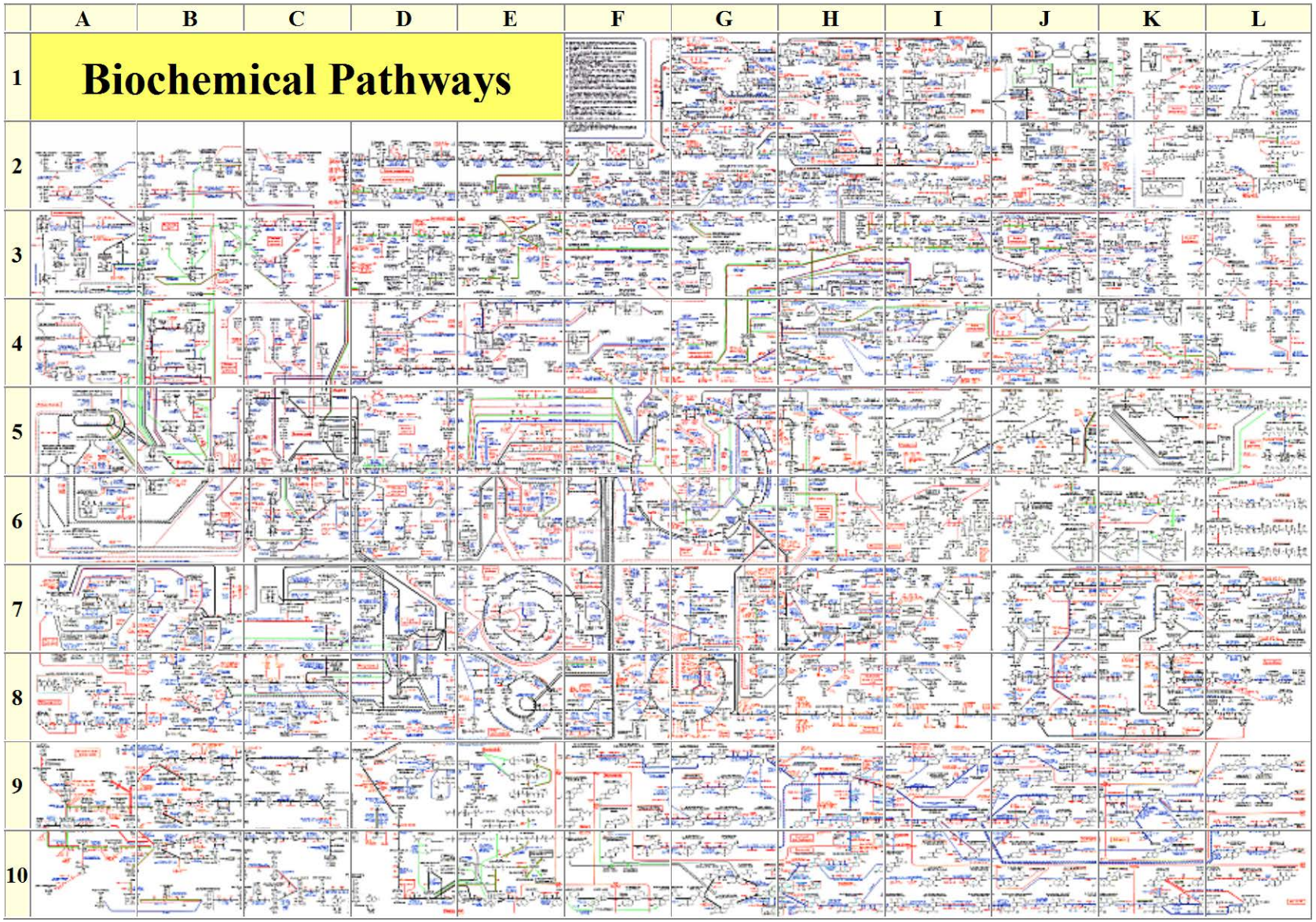


Edward N. Lorenz,
1917-2008

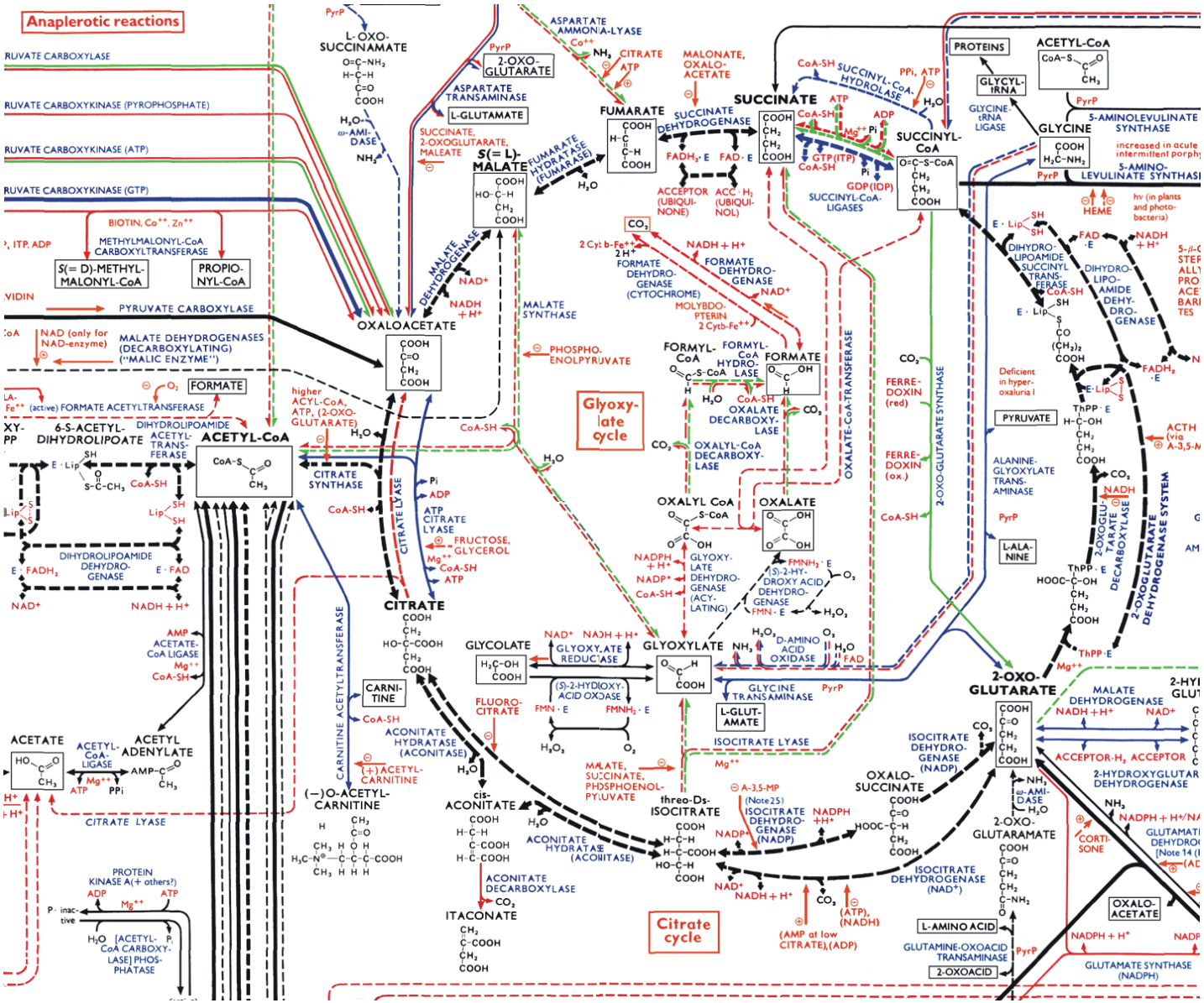
combined analytical and numerical
approaches in the analysis of
complex systems

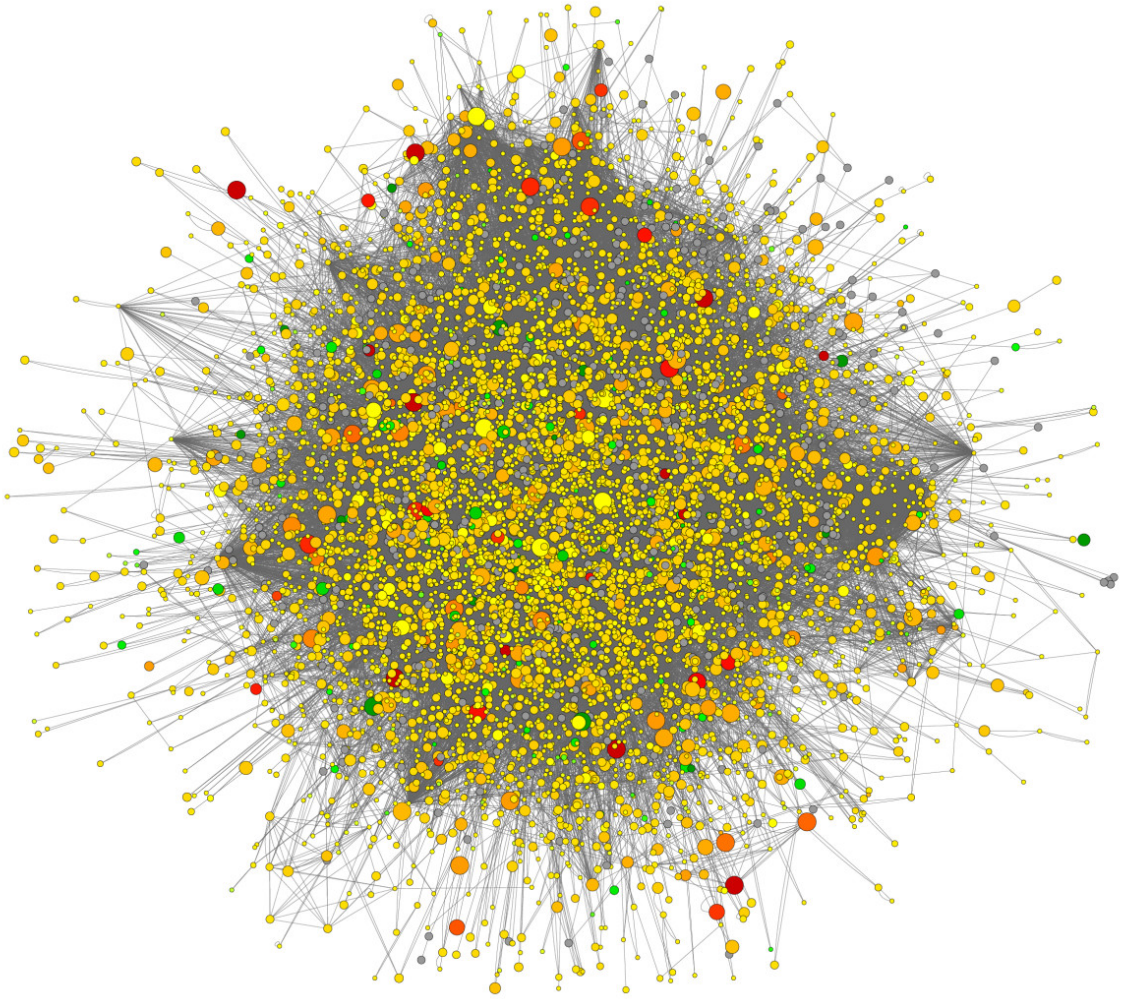
and many others.

Complexity may be inherent in the system

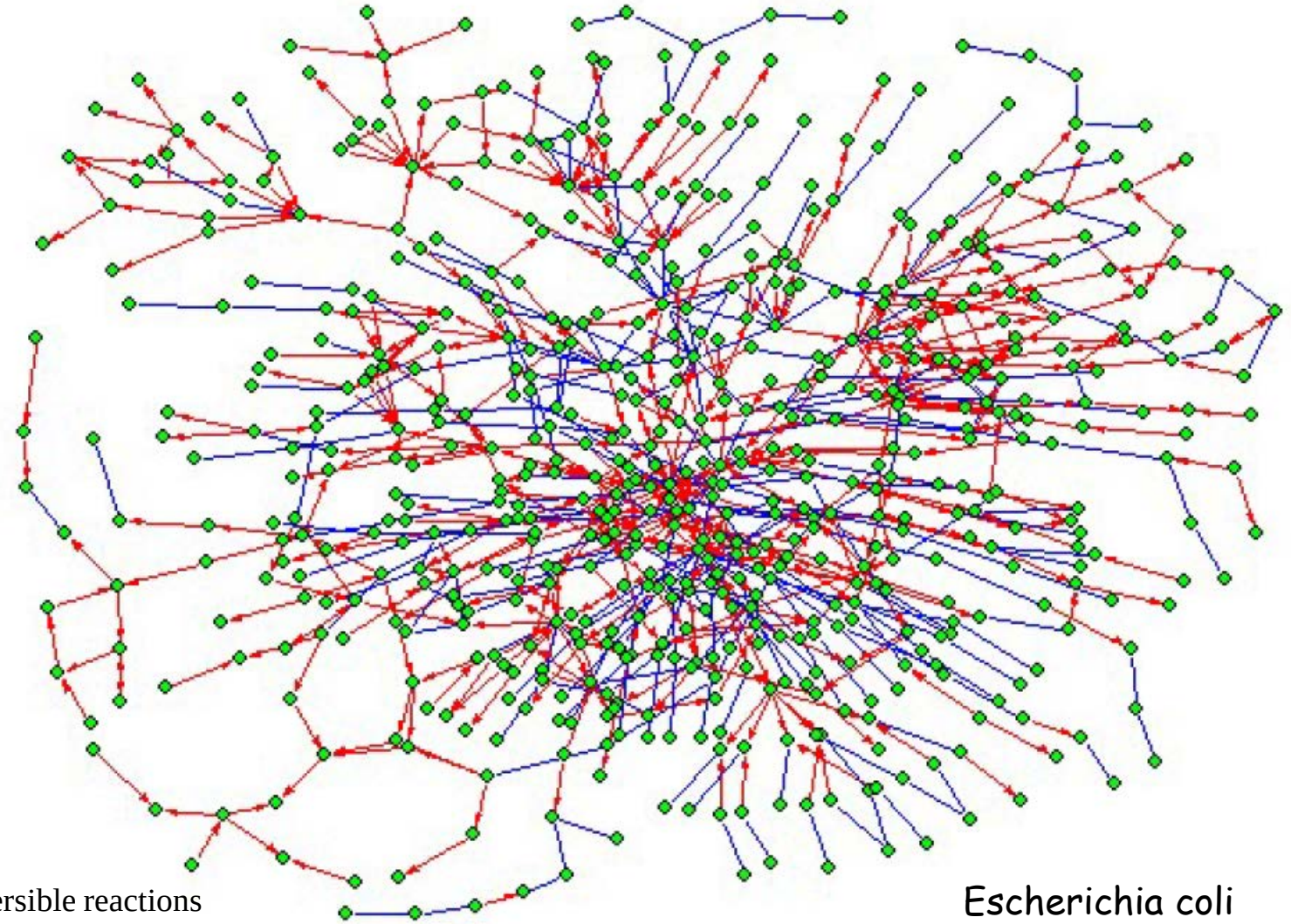


The reaction network of cellular metabolism published by Boehringer-Mannheim.


Anaplerotic reactions
RUVATE CARBOXYLASE
RUVATE CARBOXYKINASE (PYROPHOSPHATE)
RUVATE CARBOXYKINASE (ATP)
RUVATE CARBOXYKINASE (GTP)
BIOTIN, Co++, Zn++
METHYLMALONYL-CoA CARBOXYLTRANSFERASE
S(= D)-METHYL-MALONYL-CoA
PROPIO-NYL-CoA
VIDIN
PYRUVATE CARBOXYLASE
NAD (only for NAD-enzyme)
MALATE DEHYDROGENASES (DECARBOXYLATING) ("MALIC ENZYME")
FORMATE
(active) FORMATE ACETYLTRANSFERASE
6-S-ACETYL-DIHYDROLIPOATE
ACETYL-TRANS-FERASE
ACETYL-CoA
DIHYDROLIPOAMIDE DEHYDRO-GENASE
L-OXO-SUCCINAMATE
ω-AMI-DASE
2-OXO-GLUTARATE
ASPARTATE TRANSAMINASE
L-GLUTAMATE
ASPARTATE AMMONIA-LYASE
SUCCINATE, 2-OXOGLUTARATE, MALEATE
S(= L)-MALATE
FUMARATE HYDRATASE (FUMARASE)
FUMARATE
MALONATE, OXALO-ACETATE
SUCCINATE DEHYDROGENASE
SUCCINATE
ACCEPTOR (UBIQUI-NONE)
ACC · H2 (UBIQUI-NOL)
SUCCINYL-CoA-HYDROLASE
SUCCINYL-CoA
SUCCINYL-CoA-LIGASES
GDP(IDP)
GTP(ITP)
PROTEINS
GLYCYL-tRNA
GLYCINE-tRNA LIGASE
GLYCINE
ACETYL-CoA
5-AMINOLEVULINATE SYNTHASE
increased in acute intermittent porphy
5-AMINO-LEVULINATE SYNTHASE
HEME
hν (in plants and photo-bacteria)
MALATE DEHYDROGENASE
NAD+
NADH + H+
MALATE SYNTHASE
OXALOACETATE
CO2
2 Cyt b-Fe++ 2 H+
FORMATE DEHYDRO-GENASE (CYTOCHROME)
MOLYBDO-PTERIN 2 Cytb-Fe++
FORMATE DEHYDRO-GENASE
PHOSPHO-ENOLPYRUVATE
FORMYL-CoA
FORMYL-CoA HYDRO-LASE
FORMATE
Glyoxy-late cycle
OXALATE DECARBOXY-LASE
OXALYL-CoA DECARBOXY-LASE
OXALYL CoA
OXALATE
OXALATE-CoA-TRANSFERASE
2-OXOGLUTARATE SYNTHASE
FERRE-DOXIN (red)
FERRE-DOXIN (ox.)
DIHYDRO-LIPOAMIDE SUCCINYL TRANS-FERASE
DIHYDRO-LIPO-AMIDE DEHY-DRO-GENASE
Deficient in hyper-oxaluria I
PYRUVATE
ALANINE-GLYOXYLATE TRANS-AMINASE
L-ALA-NINE
ACTH (via A-3,5-N
2-OXOGLU-TARATE DECARBOXYLASE
2-OXOGLUTARATE DEHYDROGENASE SYSTEM
higher ACYL-CoA, ATP, (2-OXO-GLUTARATE)
CITRATE SYNTHASE
CITRATE LYASE
ATP CITRATE LYASE
FRUCTOSE, GLYCEROL
CITRATE
GLYOXY-LATE REDUCTASE
GLYOXYLATE
GLYCOLATE
D-AMINO ACID OXIDASE
GLYCINE TRANSAMINASE
L-GLUT-AMATE
2-OXO-GLUTARATE
MALATE DEHYDROGENASE
2-HYDROXYGLUTAR DEHYDROGENASE
ISOCITRATE LYASE
ISOCITRATE DEHYDRO-GENASE (NADP)
ISOCITRATE DEHYDROGENASE (NAD+)
OXALO-SUCCINATE
threo-Ds-ISOCITRATE
2-OXO-GLUTARAMATE
CARNI-TINE
CARNITINE ACETYLTRANSFERASE
(+)ACETYL-CARNITINE
(−)O-ACETYL-CARNITINE
FLUORO-CITRATE
ACONITATE HYDRATASE (ACONITASE)
cis-ACONITATE
ACONITATE DECARBOXYLASE
ITACONATE
MALATE, SUCCINATE, PHOSPHOENOL-PYUVATE
A-3,5-MP
(Note 25)
(AMP at low CITRATE), (ADP)
(ATP), (NADH)
Citrate cycle
L-AMINO ACID
GLUTAMINE-OXOACID TRANSAMINASE
2-OXOACID
OXALO-ACETATE
GLUTAMATE SYNTHASE (NADPH)
CORTI-SONE
ACETATE
ACETYL-CoA-LIGASE
ACETYL ADENYLATE
AMP
PPi
ATP
CITRATE LYASE
PROTEIN KINASE A(+ others?)
P · inac-tive
[ACETYL-CoA CARBOXY-LASE] PHOS-PHATASE



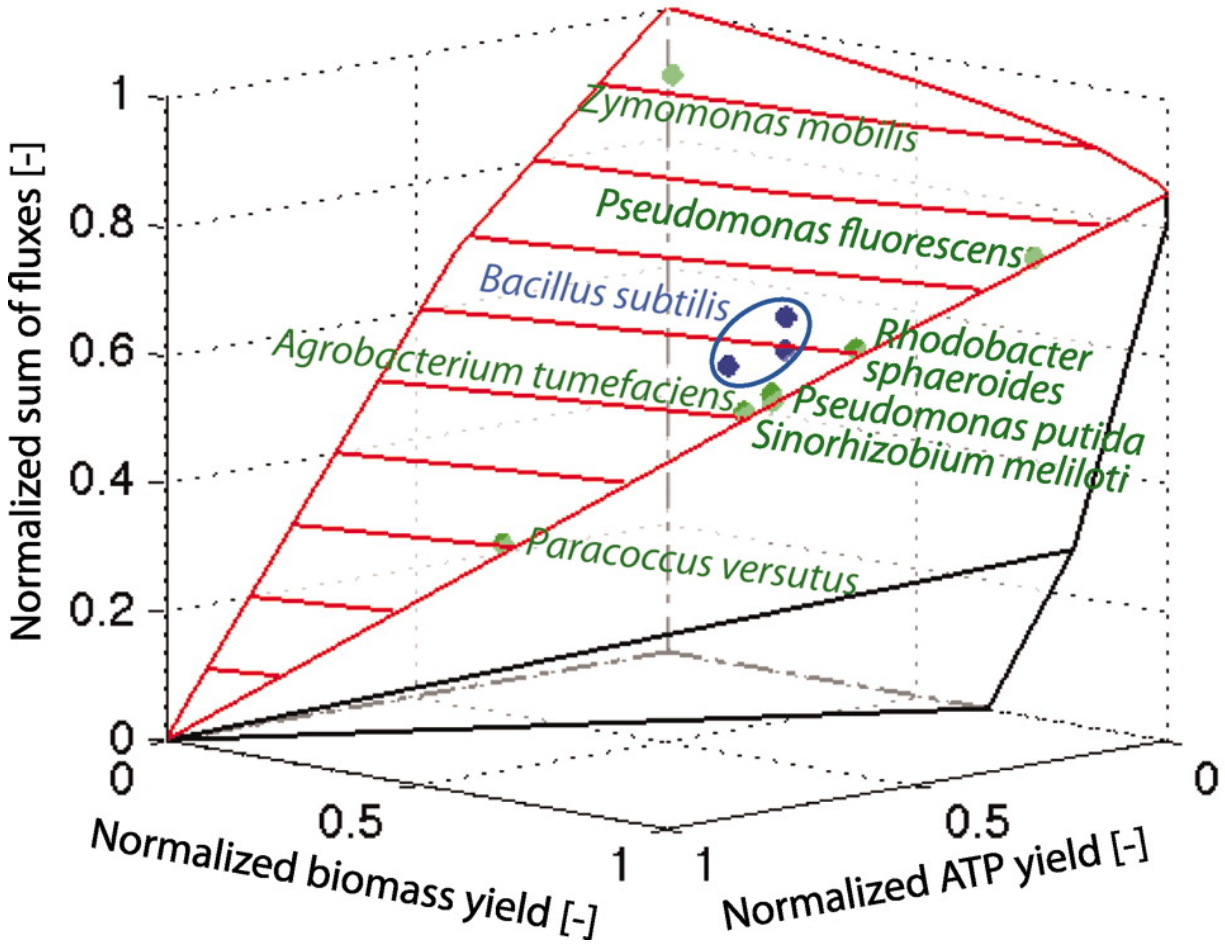
Christopher R. Bauer, Andrew M. Epstein, Sarah J. Sweeney, Daniela C. Zarnescu, and Giovanni Bosco. Genetic and Systems level analysis of *Drosophila sticky/citron kinase* and *dFmrl* mutants reveal common regulation of genetic networks. *BMC Systems Biology* **2**:e101 (2008).



reversible reactions
irreversible reactions

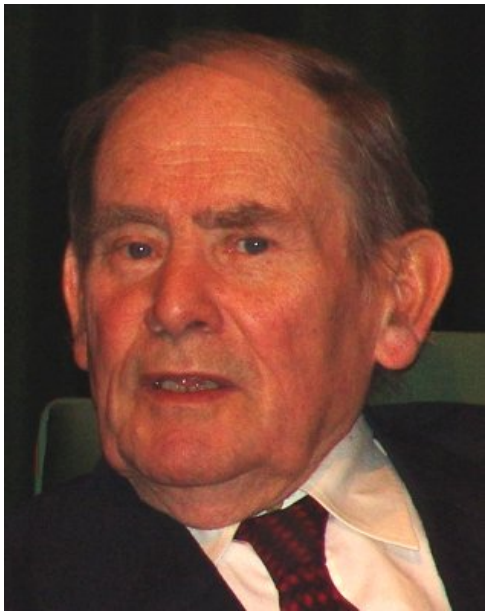
Escherichia coli

Hongwu Ma, An-Ping Zeng. Reconstruction of metabolic networks from genome data and analysis of their global structure for various organisms. *Bioinformatics* **18**:270-277 (2003).



Robert Schuetz, Nicola Zamboni, Mattia Zampieri, Matthias Heinemann, Uwe Sauer. Multidimensional optimality of microbial metabolism. *Science* **336**:601-604 (2012)

…… the prime intellectual task of the future lies in constructing an appropriate theoretical framework for biology …… theoretical biology has a bad name because of its past …… I have decided to forget and forgive the past and call it – *the badly required new discipline* – theoretical biology.



Sydney Brenner, 1927 -

Sydney Brenner. Theoretical biology in the third millenium. *Phil.Trans.Roy.Soc.London* B **354**:1963-1965, 1999

Complexity will be manageable in the future only
by the right combination of **rigorous mathematical analysis**,
big data and **computer simulation**

Thank you for your attention!

Web-Page for further information:

http://www.tbi.univie.ac.at/~pks

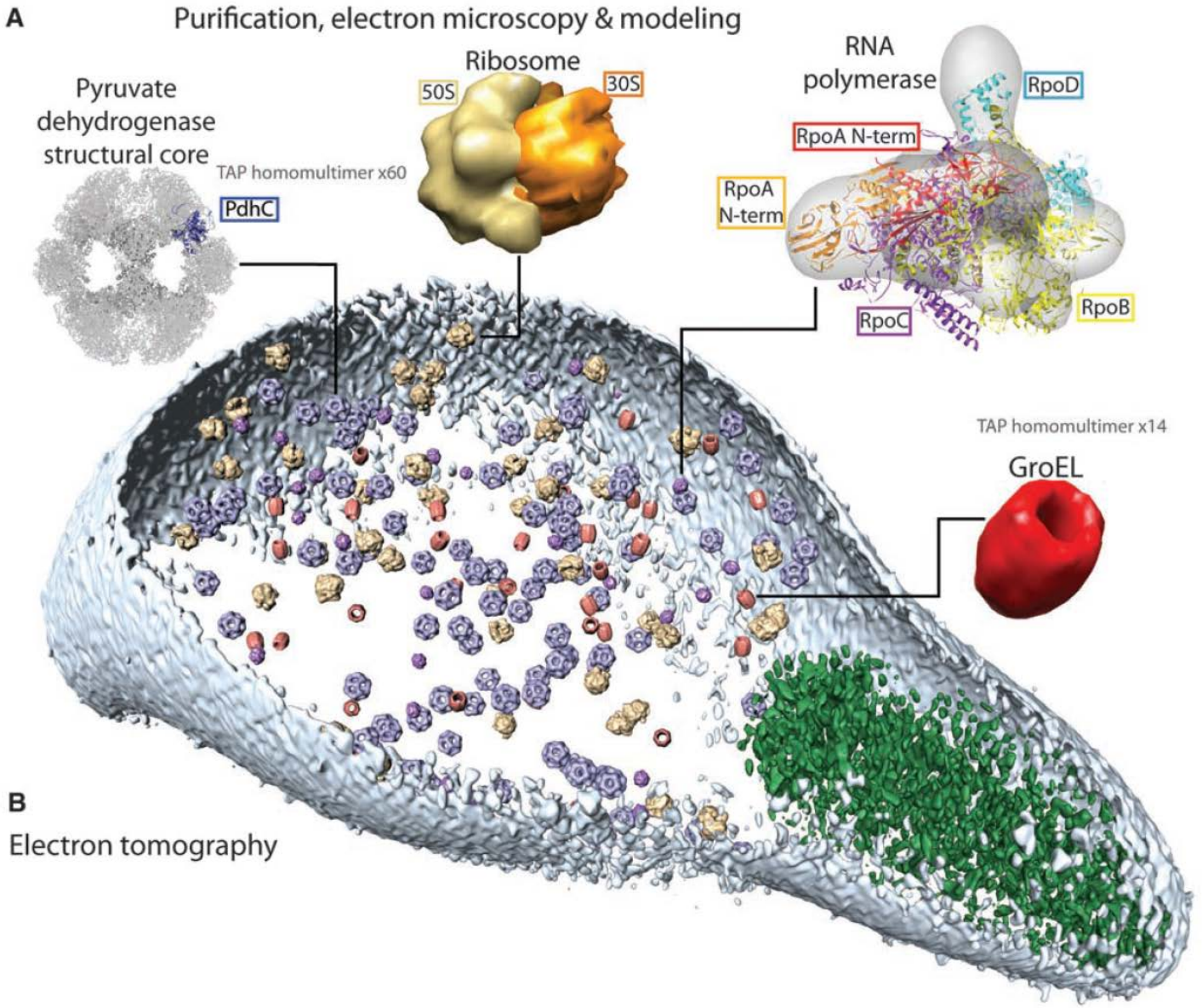


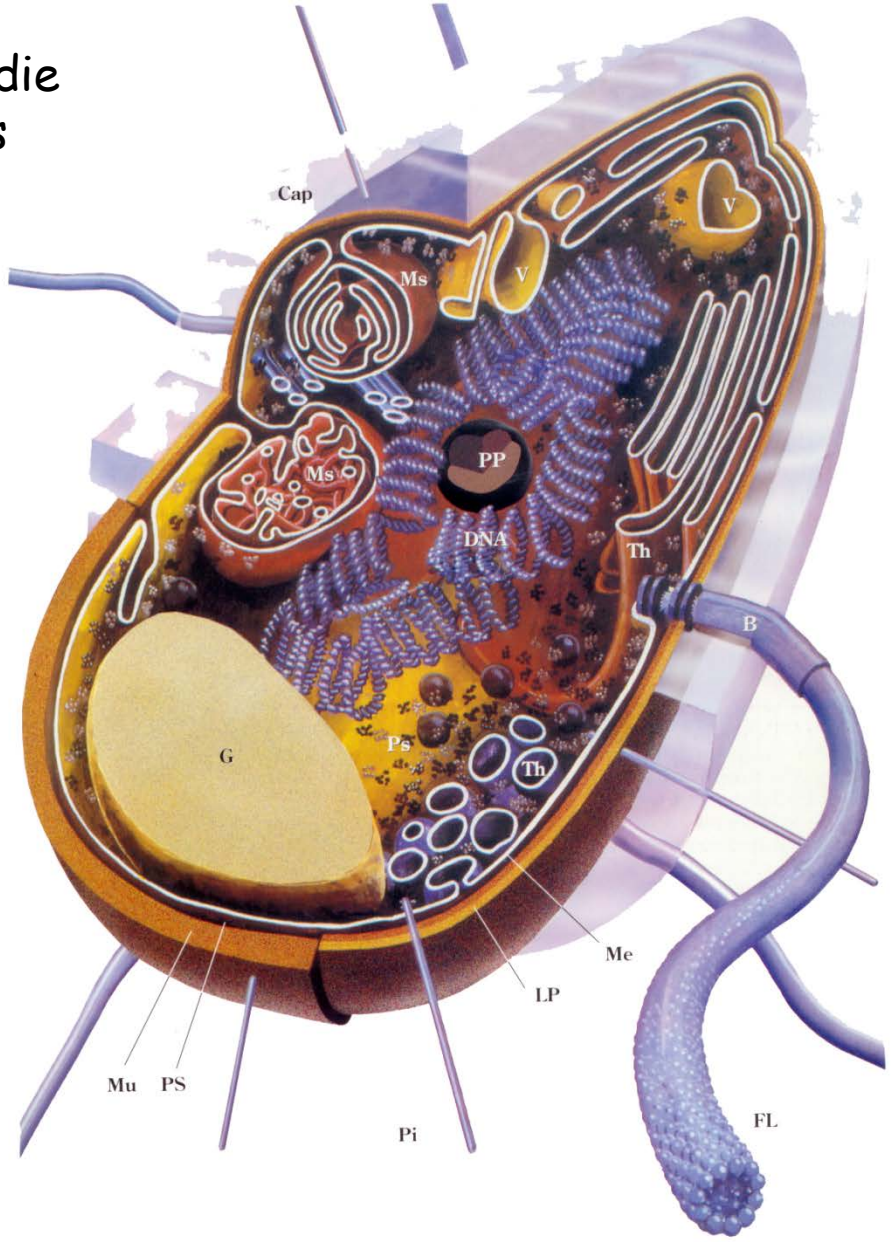
Fig. 4. From proteomics to the cell. By a combination of pattern recognition and classification algorithms, the following TAP-identified complexes from *M. pneumoniae*, matching to existing electron microscopy and x-ray and tomogram structures (**A**), were placed in a whole-cell tomogram (**B**): the structural core of pyruvate dehydrogenase in blue (~23 nm), the ribosome in yellow (~26 nm), RNA polymerase in purple (~17 nm), and GroEL homomultimer in red (~20 nm). Cell dimensions are ~300 nm by 700 nm. The cell membrane is shown in light blue. The rod, a prominent structure filling the space of the tip region, is depicted in green. Its major structural elements are HMW2 (Mpn310) in the core and HMW3 (Mpn452) in the periphery, stabilizing the rod (*42*).The individual complexes (A) are not to scale, but they are shown to scale within the bacterial cell (B).

Die Bakterienzelle als Beispiel für die einfachste Form autonomen Lebens

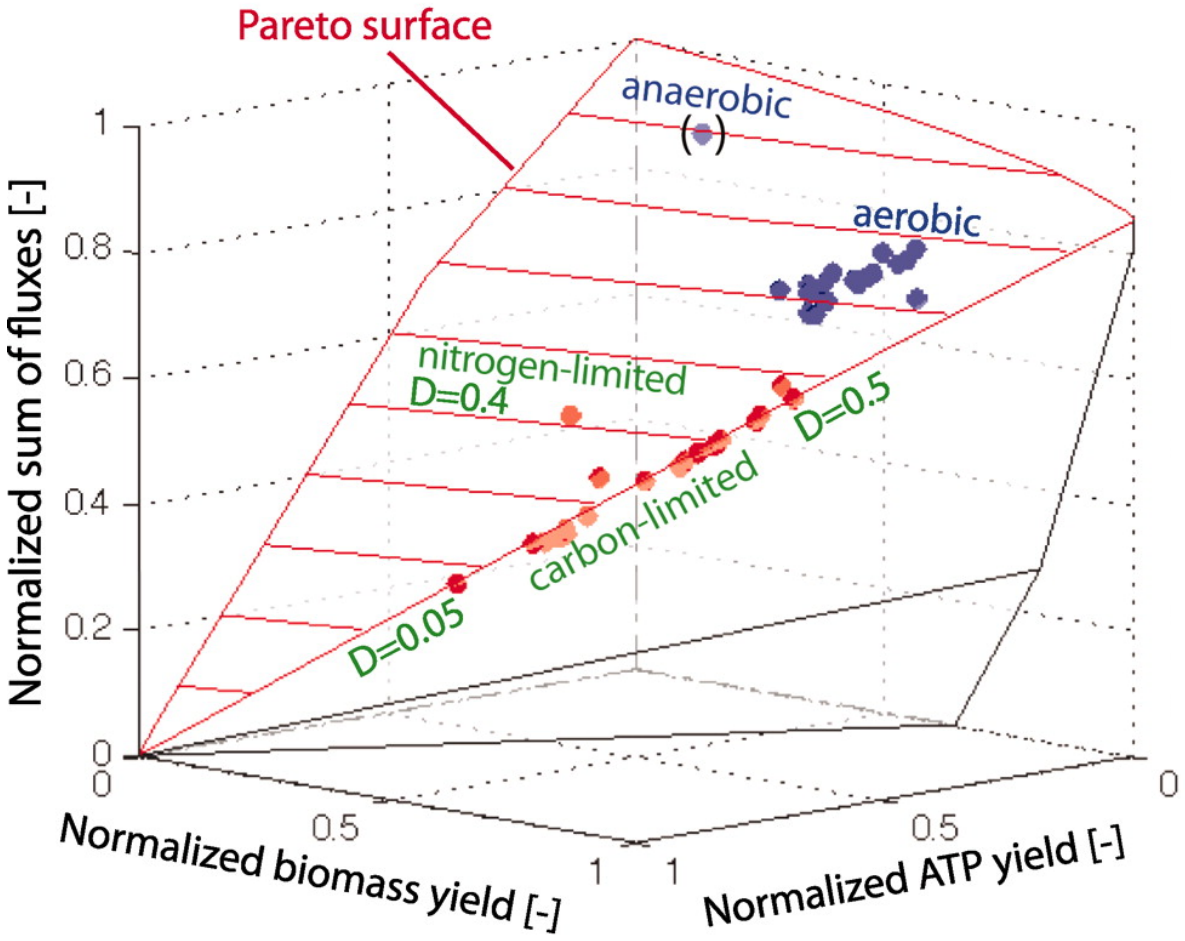
Das Escherichia coli Genom:

4 Millionen Nukleotide

4460 Gene



Die räumliche Struktur des Bakteriums *Escherichia coli*



Robert Schuetz, Nicola Zamboni, Mattia Zampieri, Matthias Heinemann, Uwe Sauer. Multidimensional optimality of microbial metabolism. *Science* **336**:601-604 (2012)

Sir Peter Brian Medawar,
1915 - 1987

…… no new principle will declare itself from below a heap of facts. ……

Torbjörn Fagerström, Peter Jagers, Peter Schuster, and Eörs Szathmáry. Biologists put on mathematical glasses. *Science* **271**:2039-240, 1996.

Nothing makes sense in biology

except in the light of evolution, …

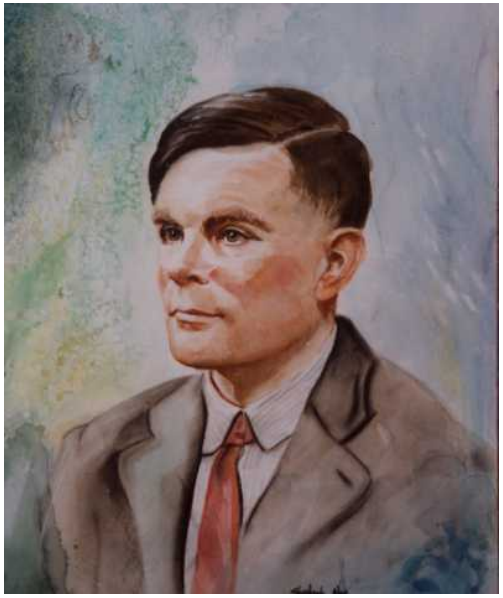
Theodosius Dobzhansky,
1900 - 1975

Theodosius Dobzhansky. Biology, molecular and organismic.
American Zoologist **4**:443-452, 1974.

Philip Maini, 1959 -

Turing patterns in embryological morphogenesis:

„..... although reaction-diffusion theory provides a very elegant mechanism for segmentation, nature seems to have chosen a much less elegant way of doing it."



Alan M.Turing, 1912 - 1954

Philip K. Maini, Kevin J. Painter, and Helene Nguyen Phong Chau.
Spatial pattern formation in chemical and biological systems.
J.Chem.Soc., Fraday Trans. **93**:3602-3610, 1997.