

Bioeconomy and Biosystems

So complicated, so simple, so smart
the lego puzzle of nature

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National and Kapodistrian University of Athens

The structure of our biosystem

The blue planet, our home



The ecosystem

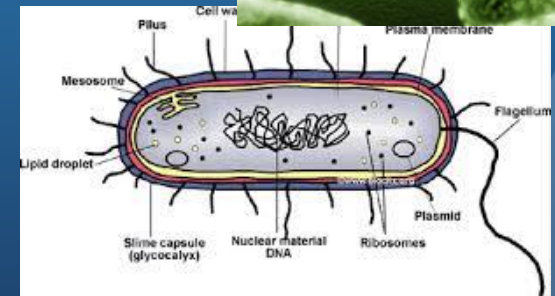
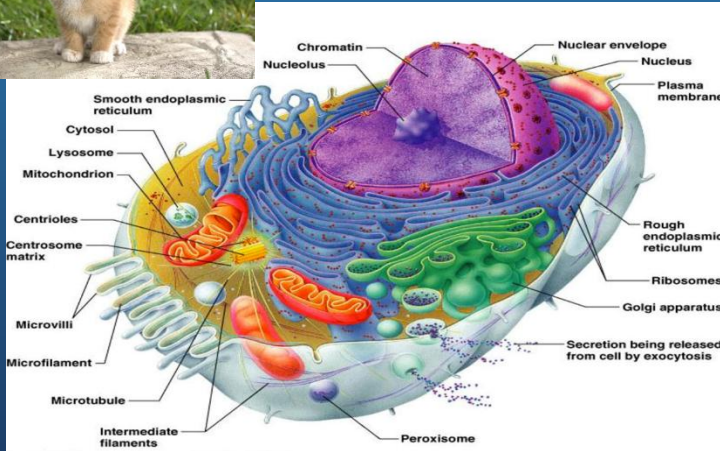
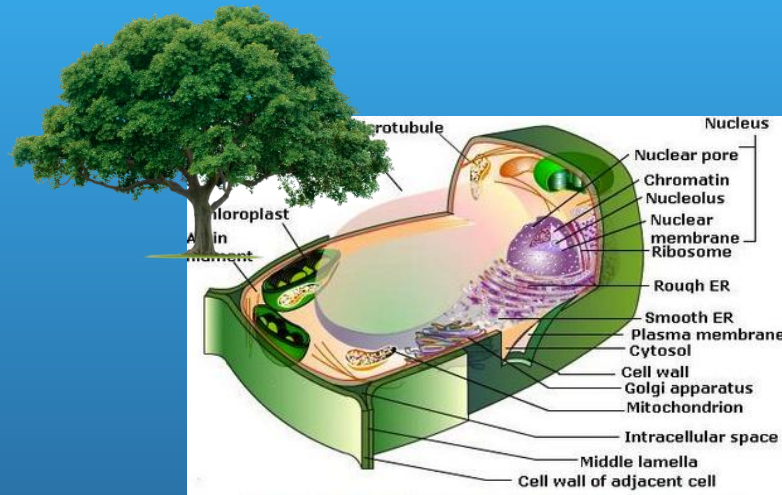


Components of our ecosystem



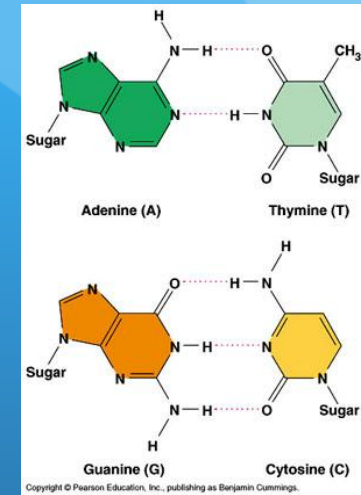
We are seeing a tiny part of what is there

Basic components of the living organisms are the cells

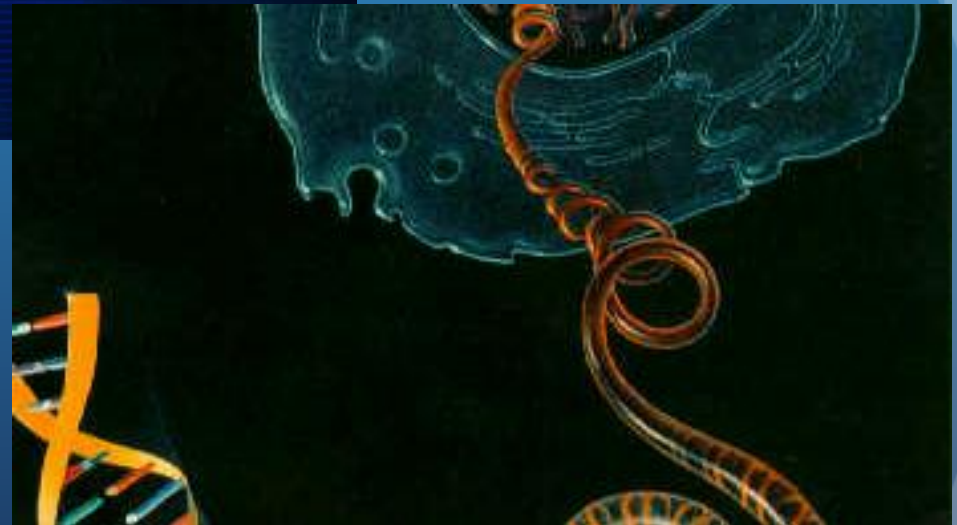


The information stockpile of our biosystem

DNA > RNA



~3 meters in humans
only 2% encodes proteins

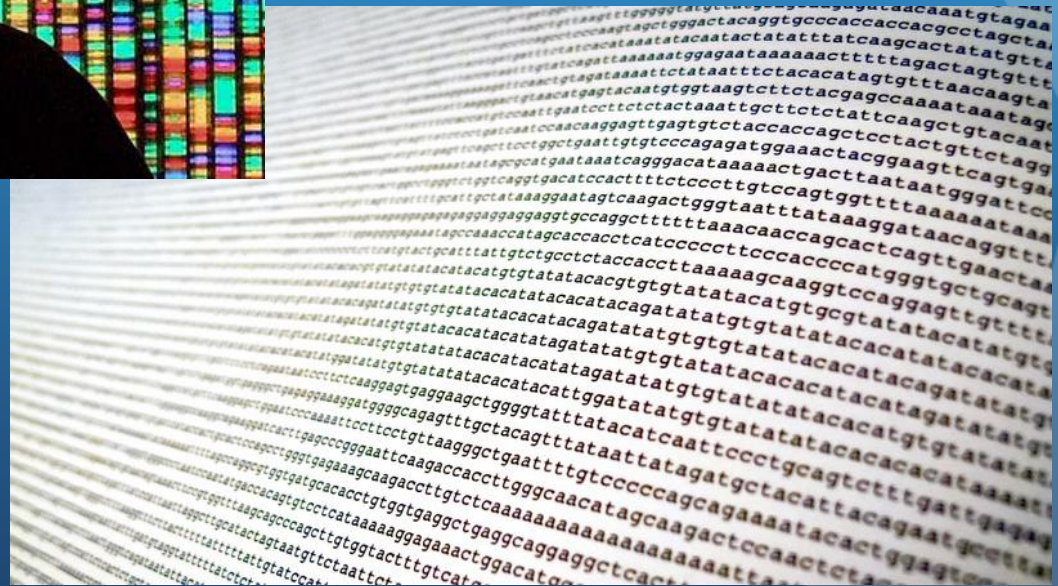


The human genome



The book is open

To understand the entire information in the book it will take a long time



DNA: an unlimited pool of information: why?

Bacterial DNA (*10⁶)

Archeobacterial DNA(*10⁶)

Viral DNA(*10⁴)

Eucaryotic DNA(*10¹⁰)

Cell free environmental DNA

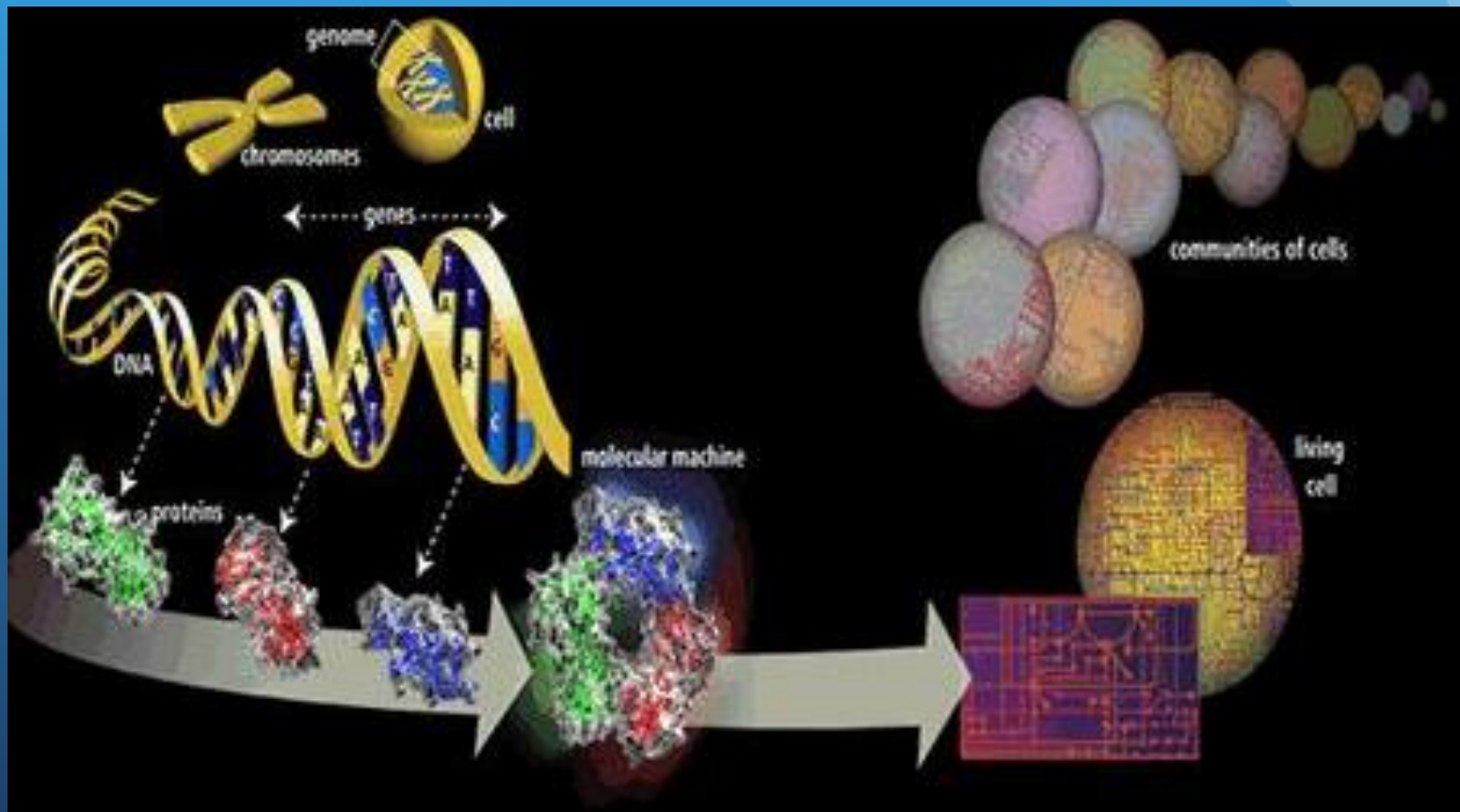
Recombinant DNA-gene technology

Shuffled DNA-directed evolution

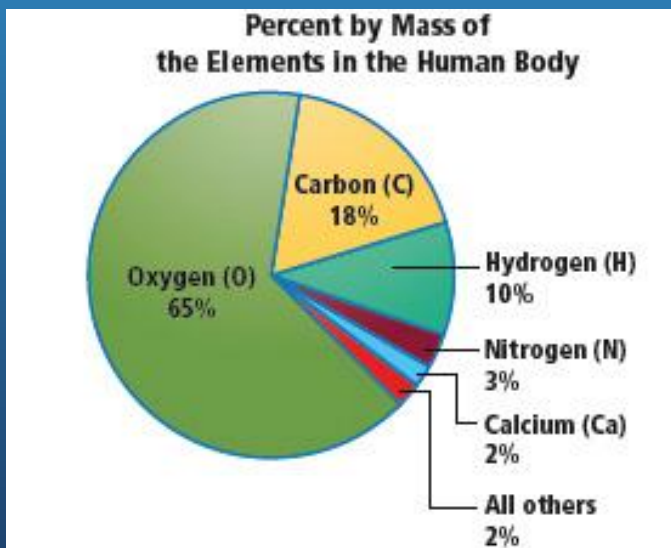
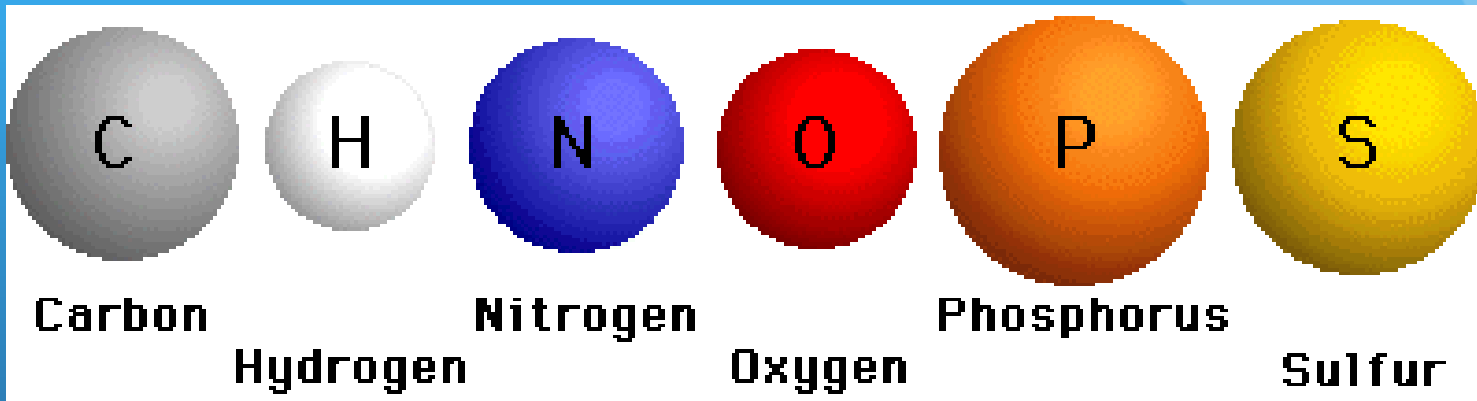
Ancestral DNA (calculated)

Synthetic DNA (artificial)

The DNA provides the essential information (genes-regulatory elements etc) to the cell machinery (protein synthesis) to build functional molecules: the proteins

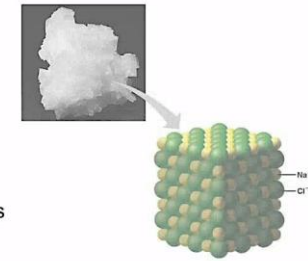


The chemical basis of life

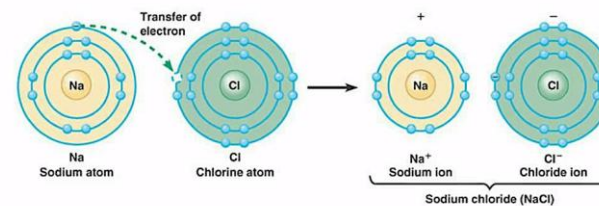


Bonds in Biology

- Strong bonds
 - covalent bonds
- Weak bonds
 - hydrogen bonds
 - hydrophobic & hydrophilic interactions
 - Ionic – transfer of electron



Ionic bonding



The physical basis of life

The Laws of Thermodynamics

0. Two bodies in thermal equilibrium are at same T
1. **Energy can never be created or destroyed.**

$$\Delta E = q + w$$

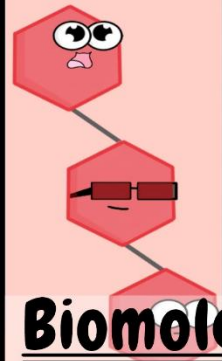
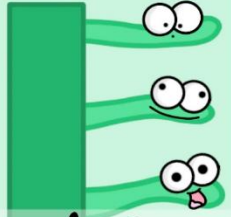
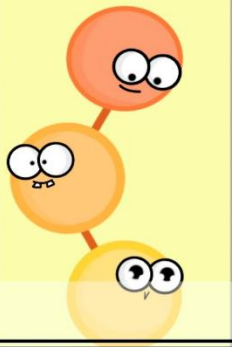
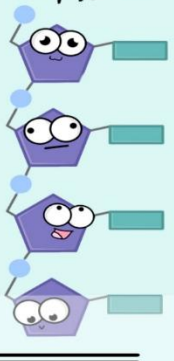
2. **The total entropy of the UNIVERSE (= system plus surroundings) MUST INCREASE in every spontaneous process.**

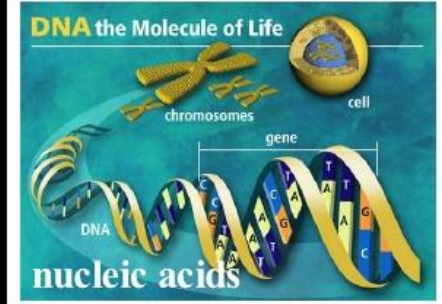
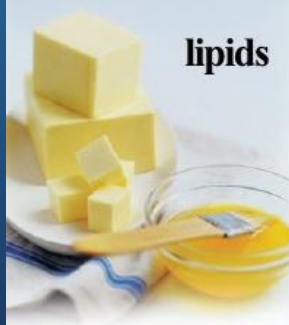
$$\Delta S_{\text{TOTAL}} = \Delta S_{\text{system}} + \Delta S_{\text{surroundings}} > 0$$

3. The entropy (S) of a pure, perfectly crystalline compound at T = 0 K is ZERO. (no disorder)

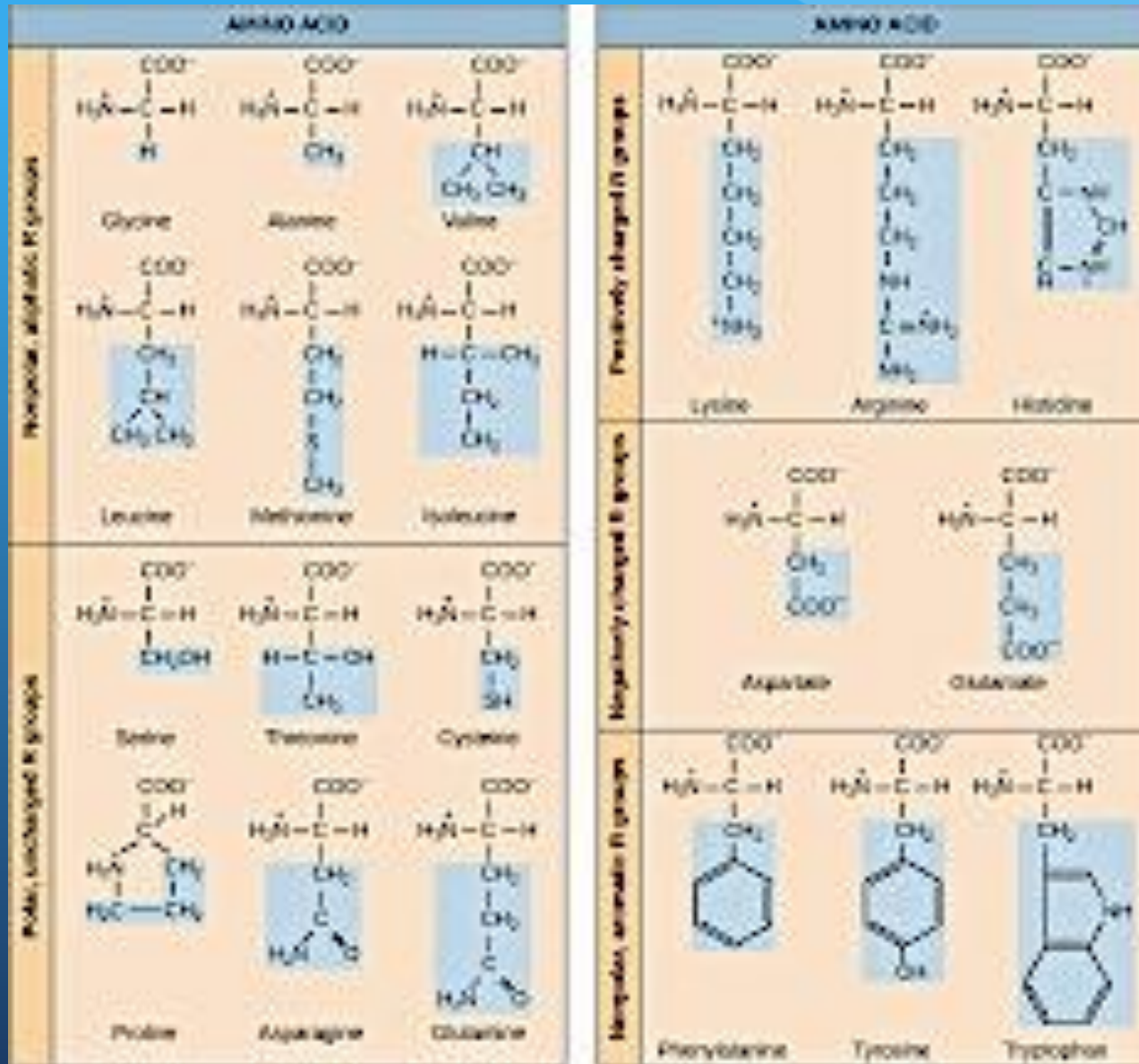
$$S_{T=0} = 0 \text{ (perfect xll)}$$

The major biomolecules

<p>Carbohydrate</p>  <p>Biomolecules with the Amoeba Sisters</p>	<p>Lipid</p> 	<p>Protein</p> 	<p>Nucleic Acid</p> 
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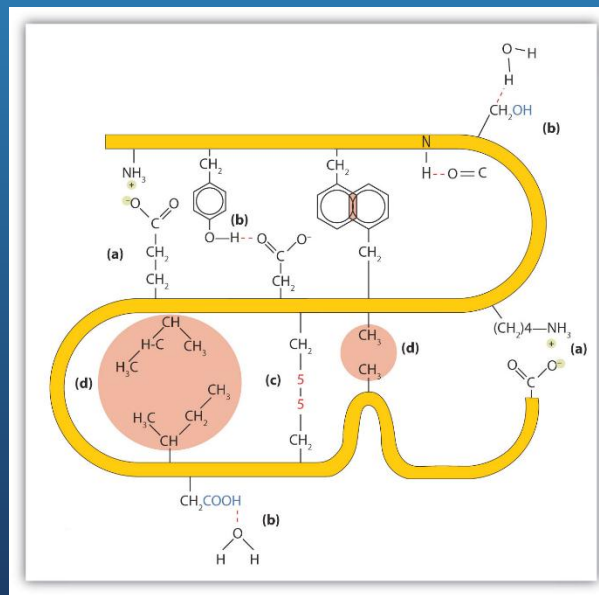
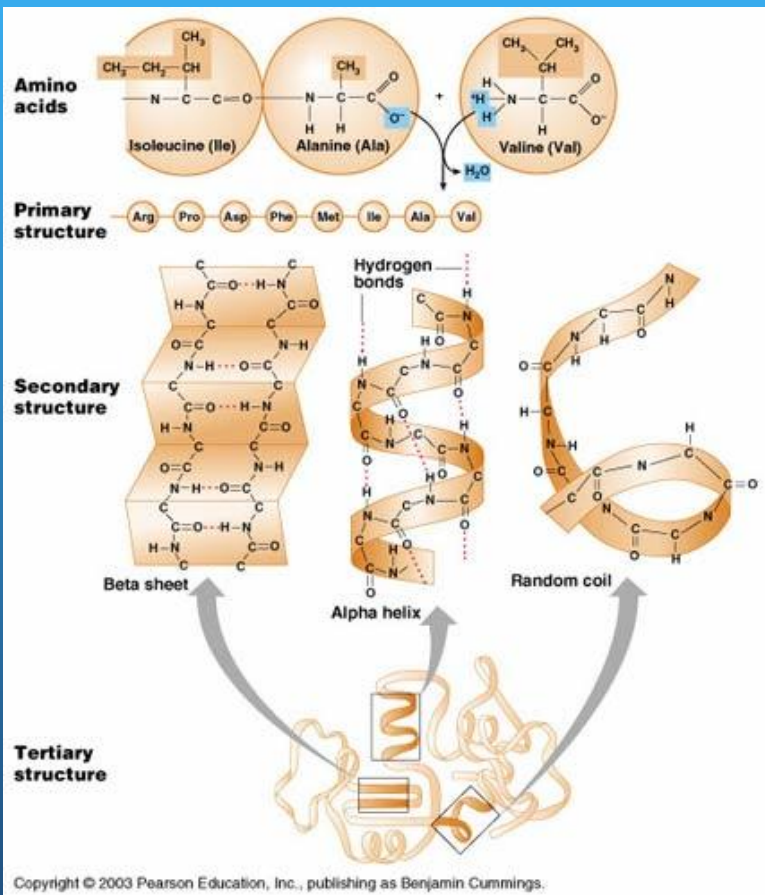


Proteins=linear chains of amino acids

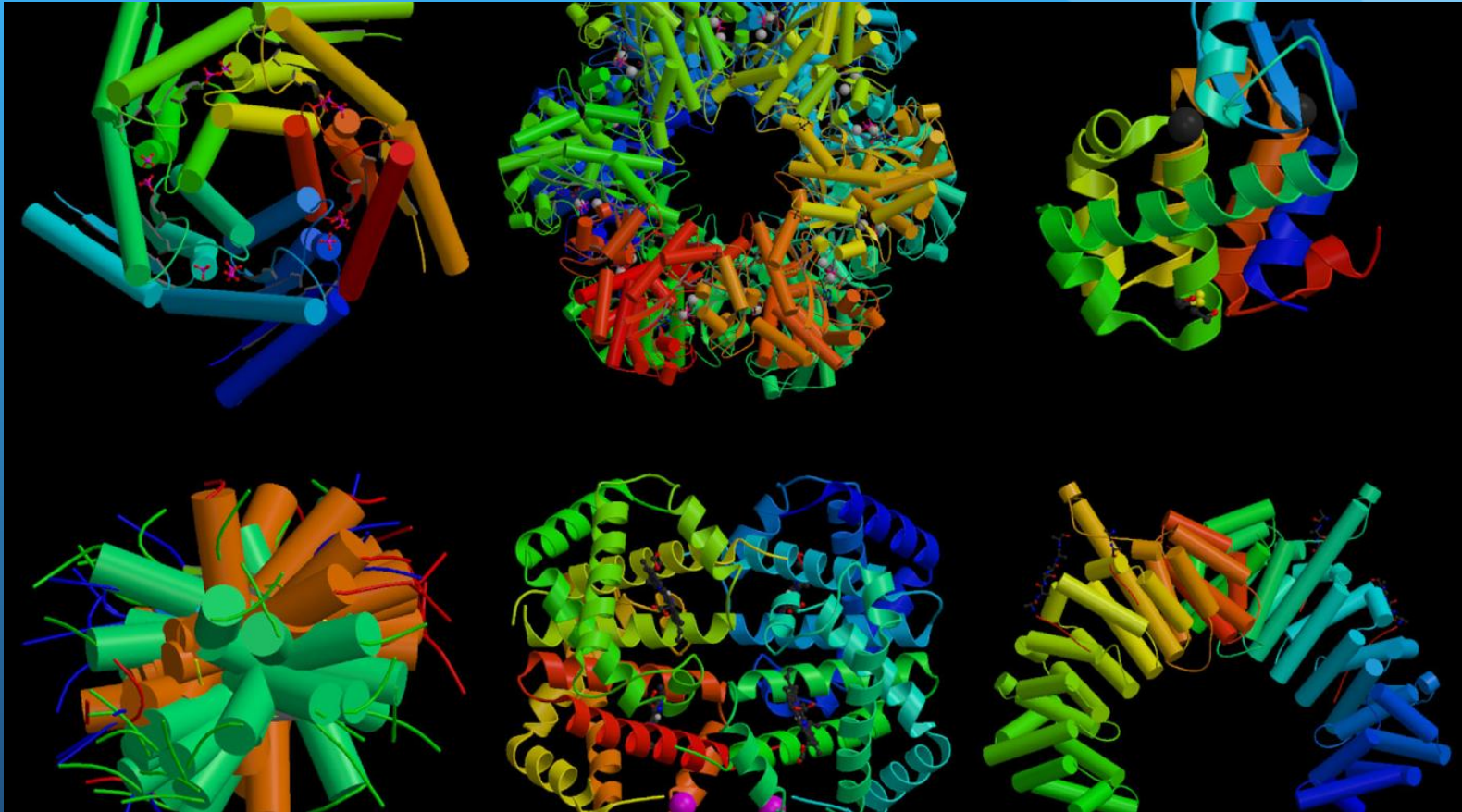


The structure of proteins

Amazing numbers:
 random synthesis of
 proteins of 300 aa length,
 using the 20 amino acids
 can create 20^{300} (~50000)

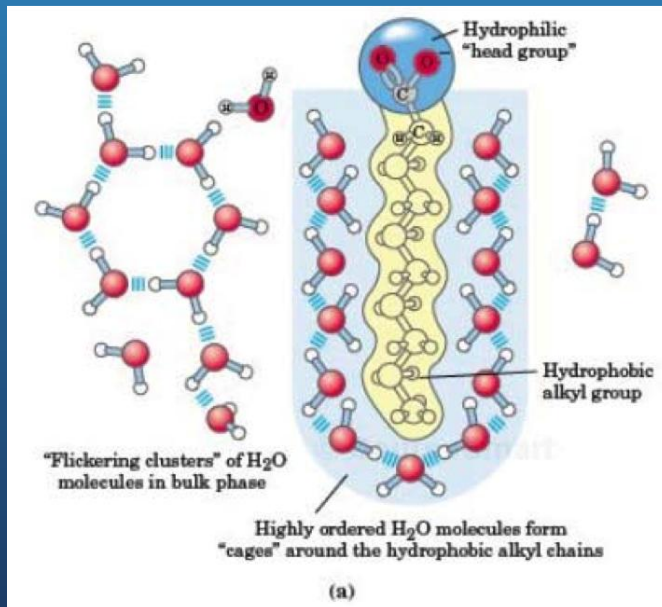
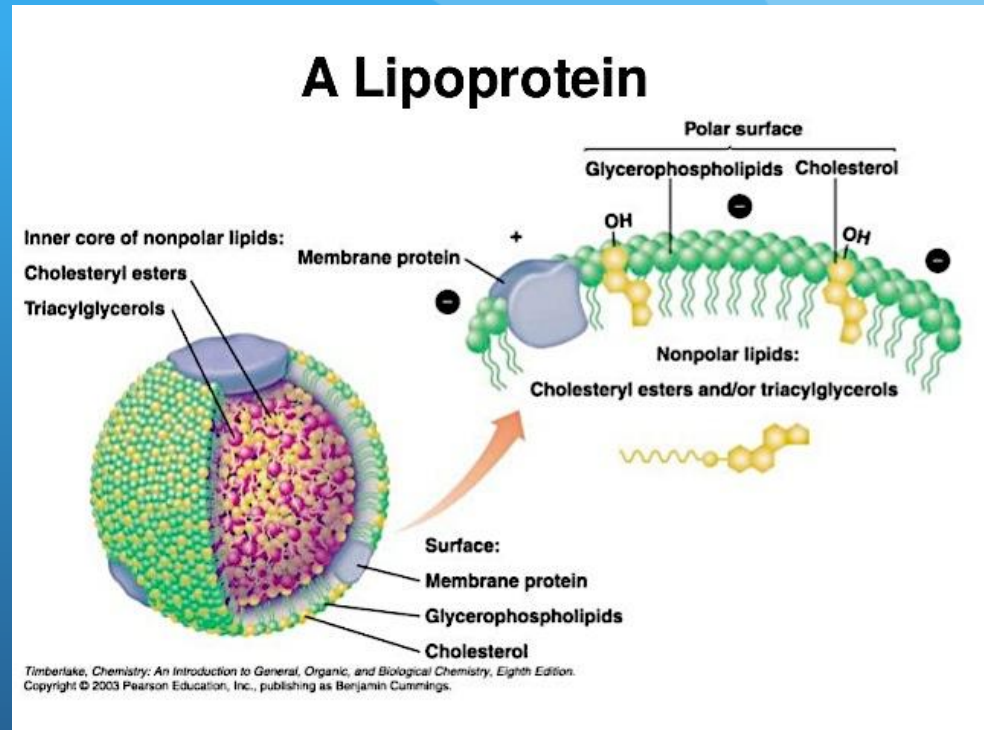
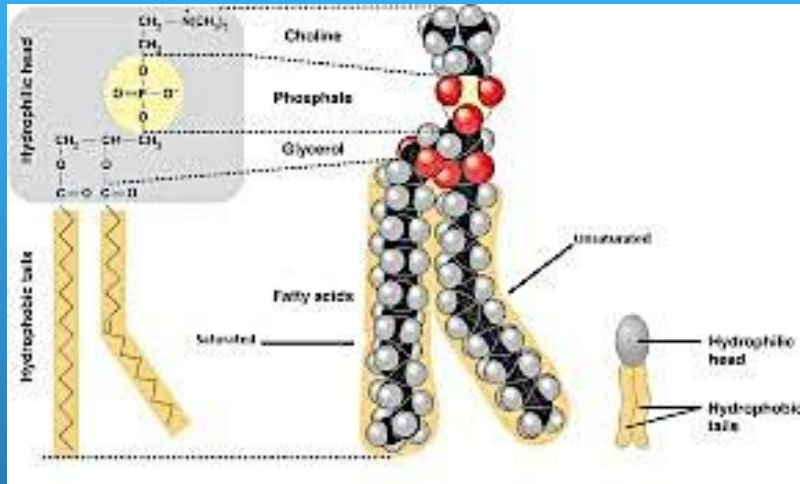


The structure of proteins



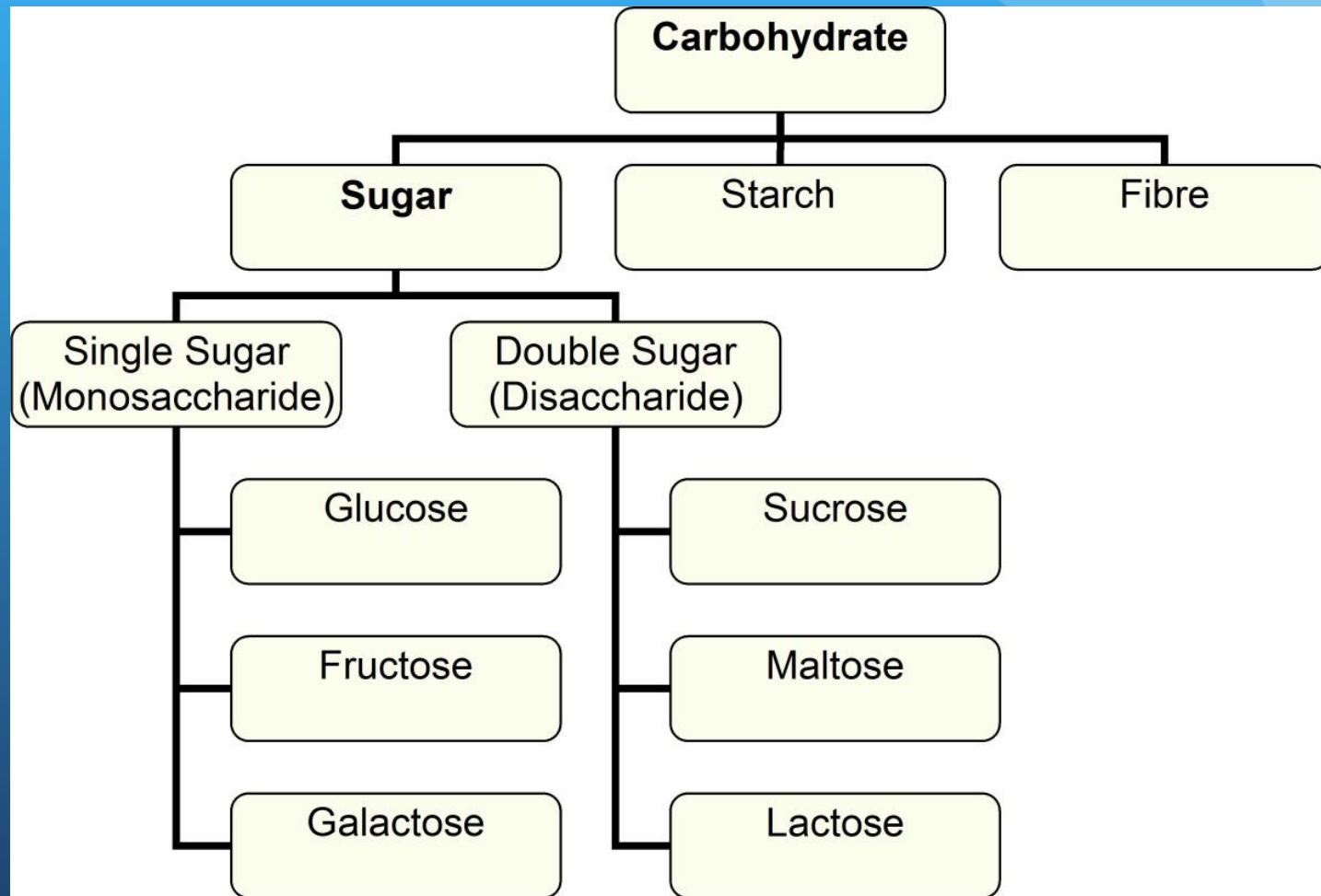
The existing proteins is a tiny fraction of the existing possibilities

The structure of lipids

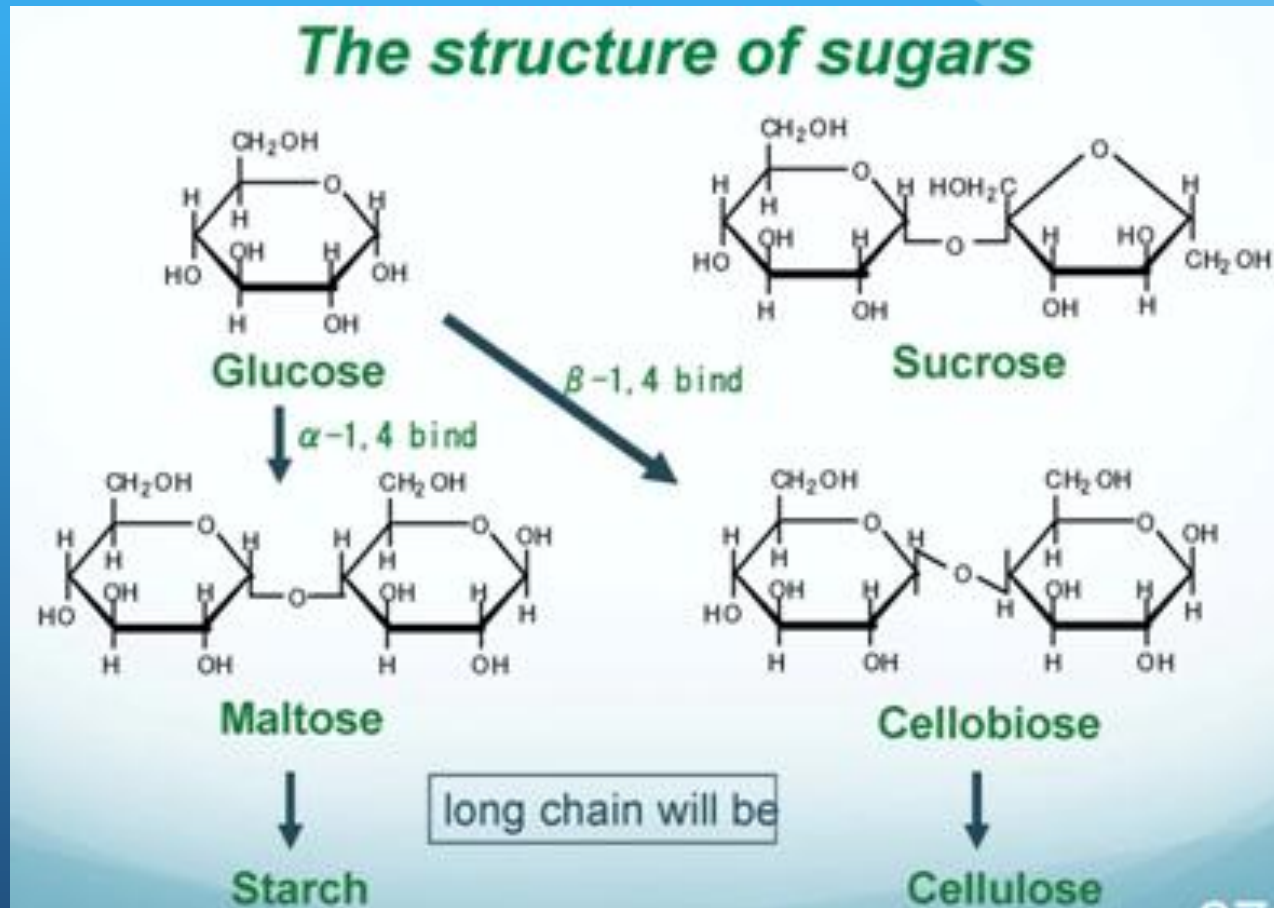


An amazing feature of lipids is their hydrophobicity, the driving force for self assembly

The structure of carbohydrates



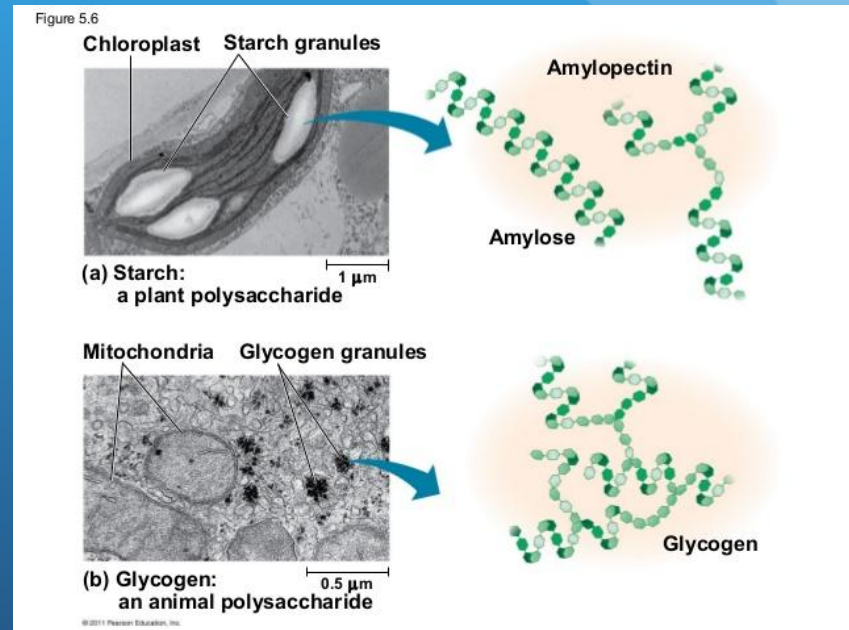
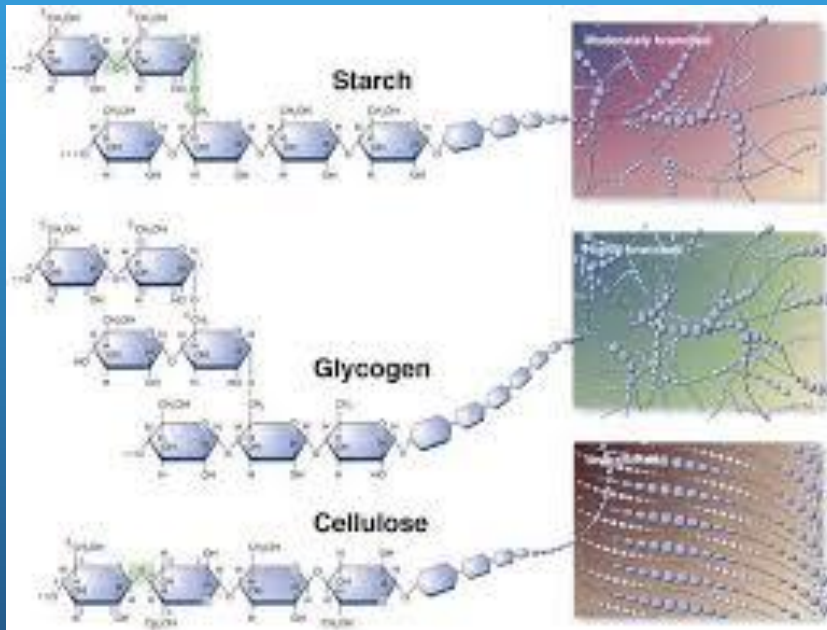
The structure of carbohydrates



A single bond defines the structure of polysaccharides

The structure of carbohydrates

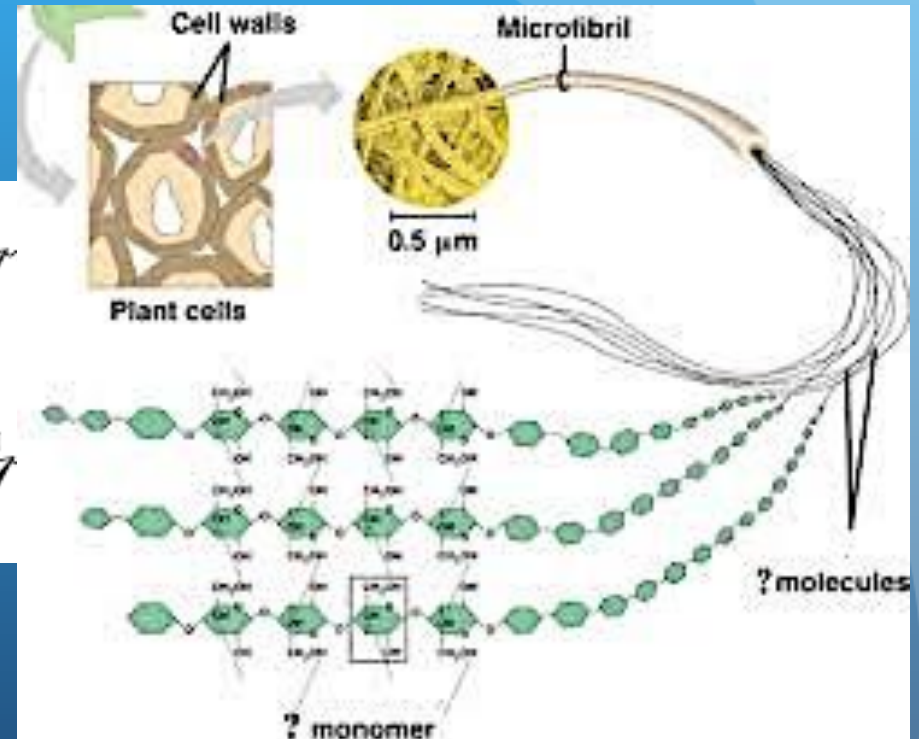
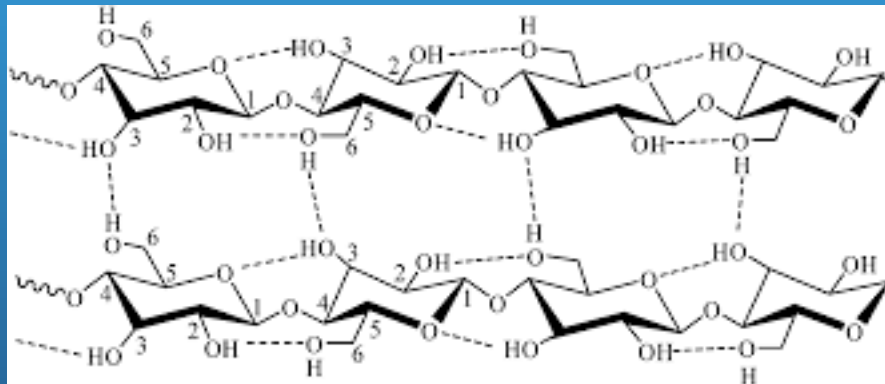
The polysaccharides are linear and branched



α -1,4 construct helical polysaccharides=storage

The structure of cellulose

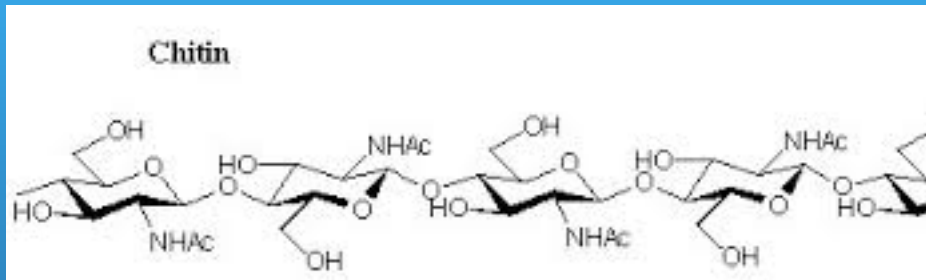
The structural polysaccharides are linear



β -1,4 construct linear polysaccharides=structure

The structure of chitin

The structural polysaccharides are linear



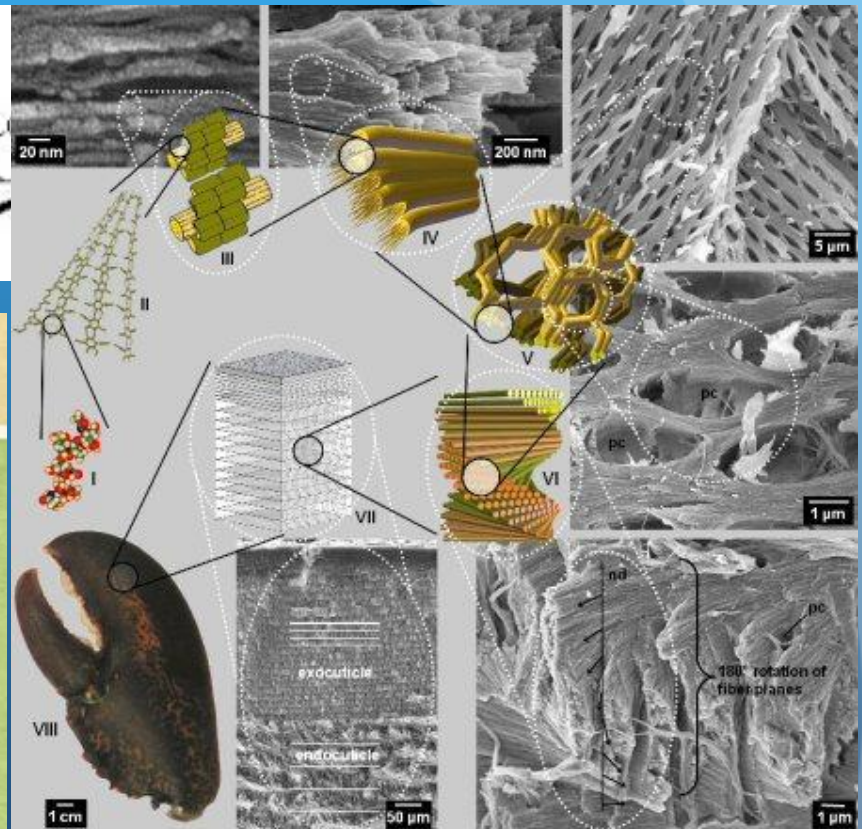
Does mushrooms cells have cell wall?

My cell walls are made of **chitin**. Chitin is made of glucose and chitin is primarily used as a structural component, strengthening exoskeletons, shells, and cell walls of fungus.

My hard shells are made of **chitin** too

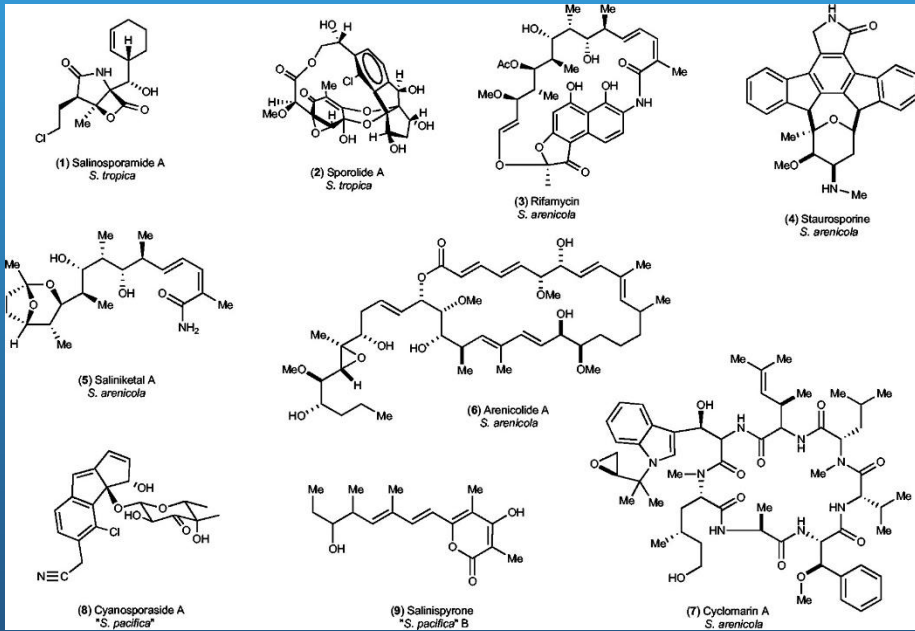
Mine too

mokumoku.my



β -1,4 construct linear polysaccharides=structure

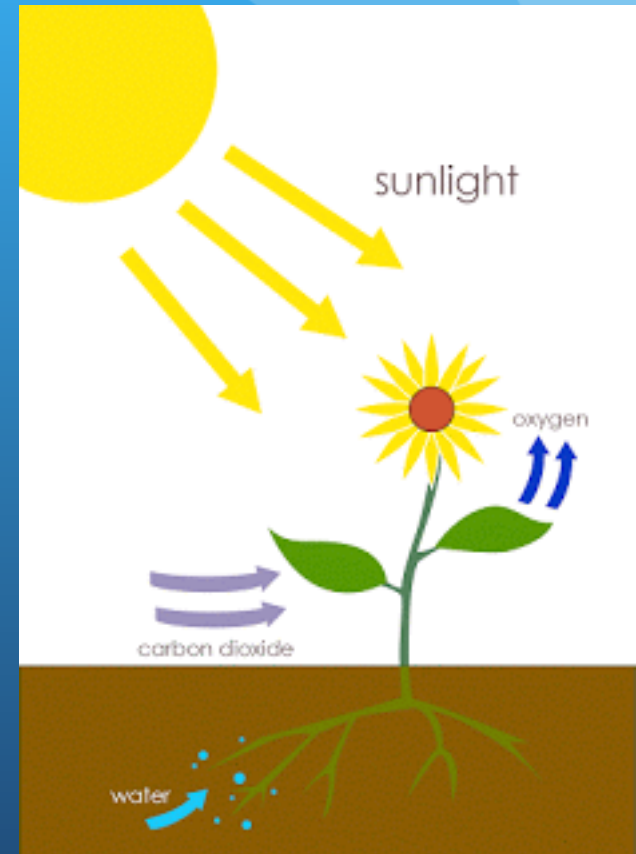
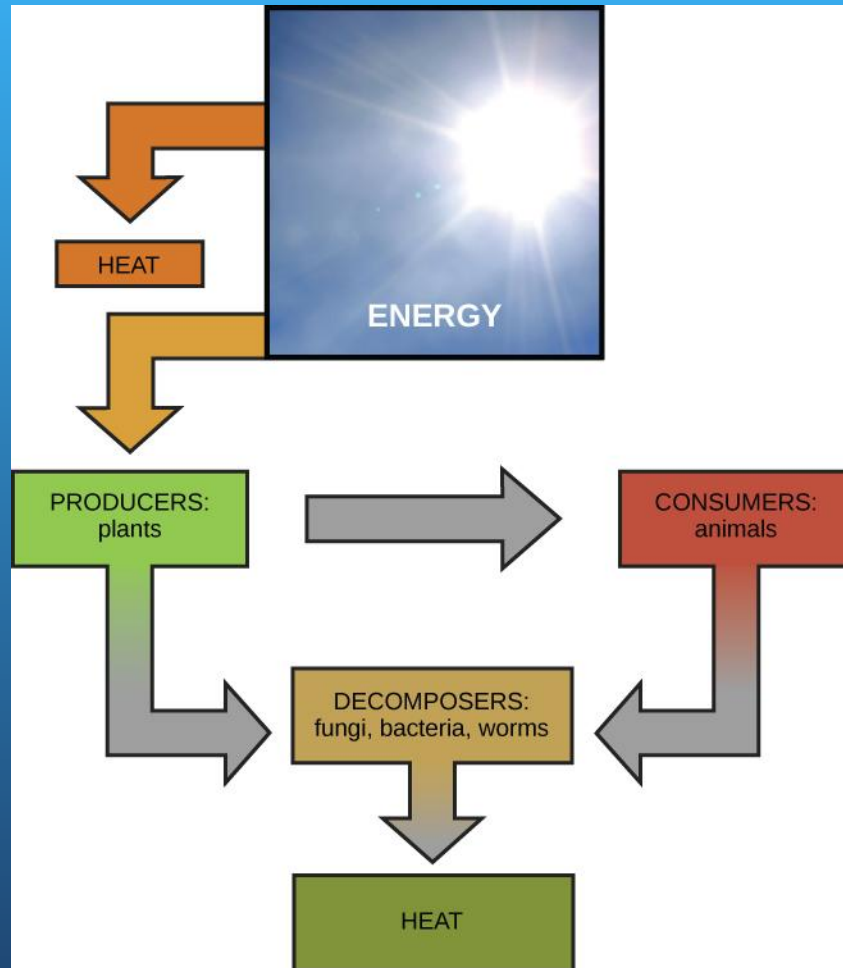
The rest: small metabolites and trace elements



MINERALS

Ca Calcium
Mg Magnesium
Fe Iron
Na Sodium
Zn Zinc
P Phosphorus

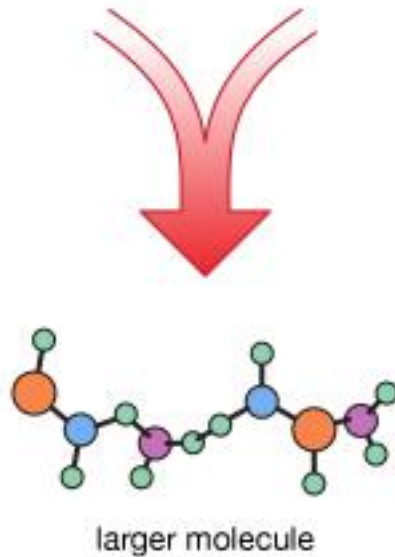
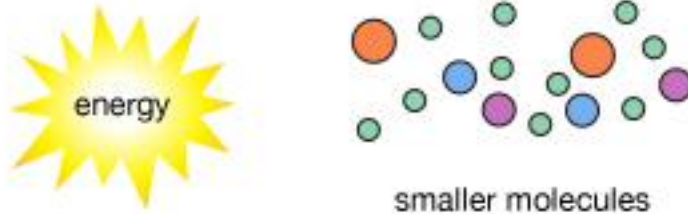
Energy in biosystems



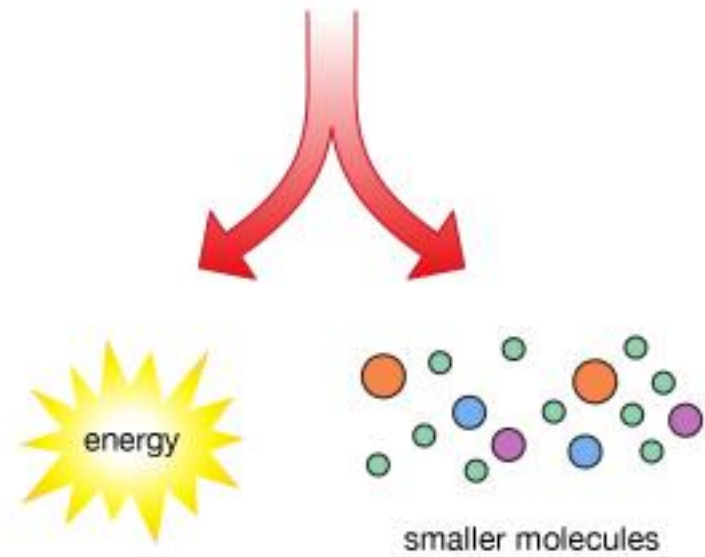
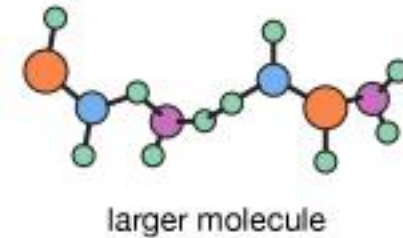
The cellular metabolism

Metabolism

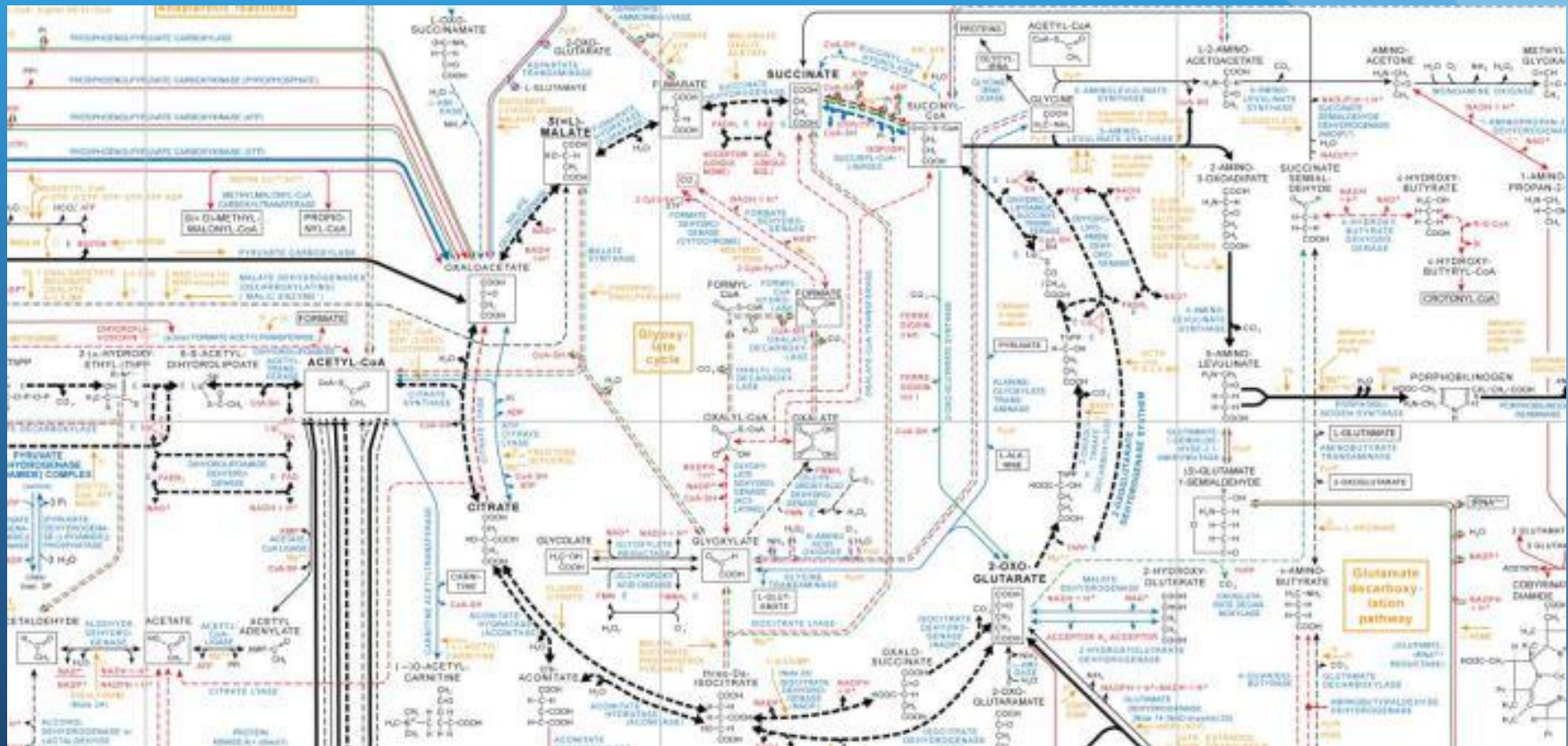
anabolic reaction



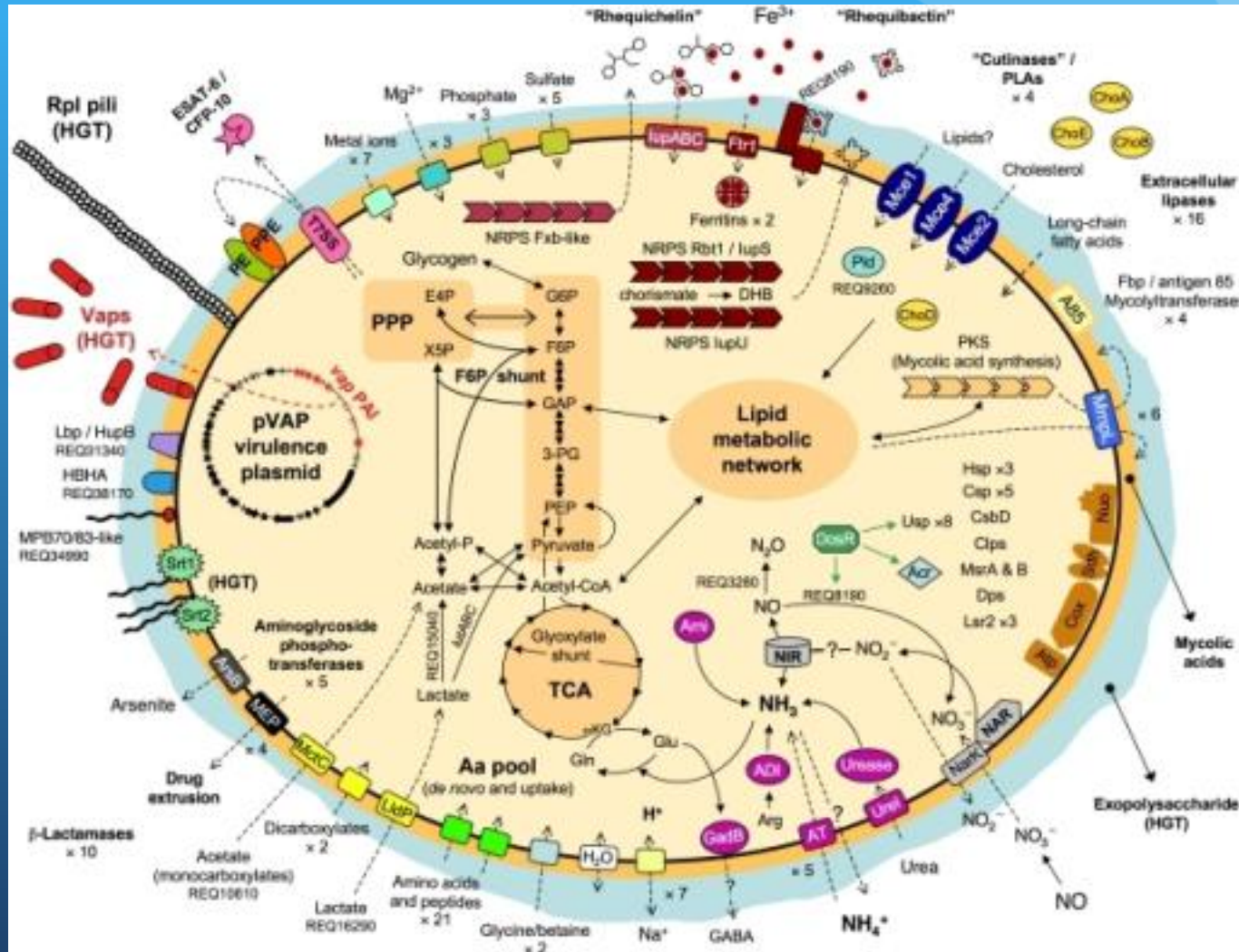
catabolic reaction



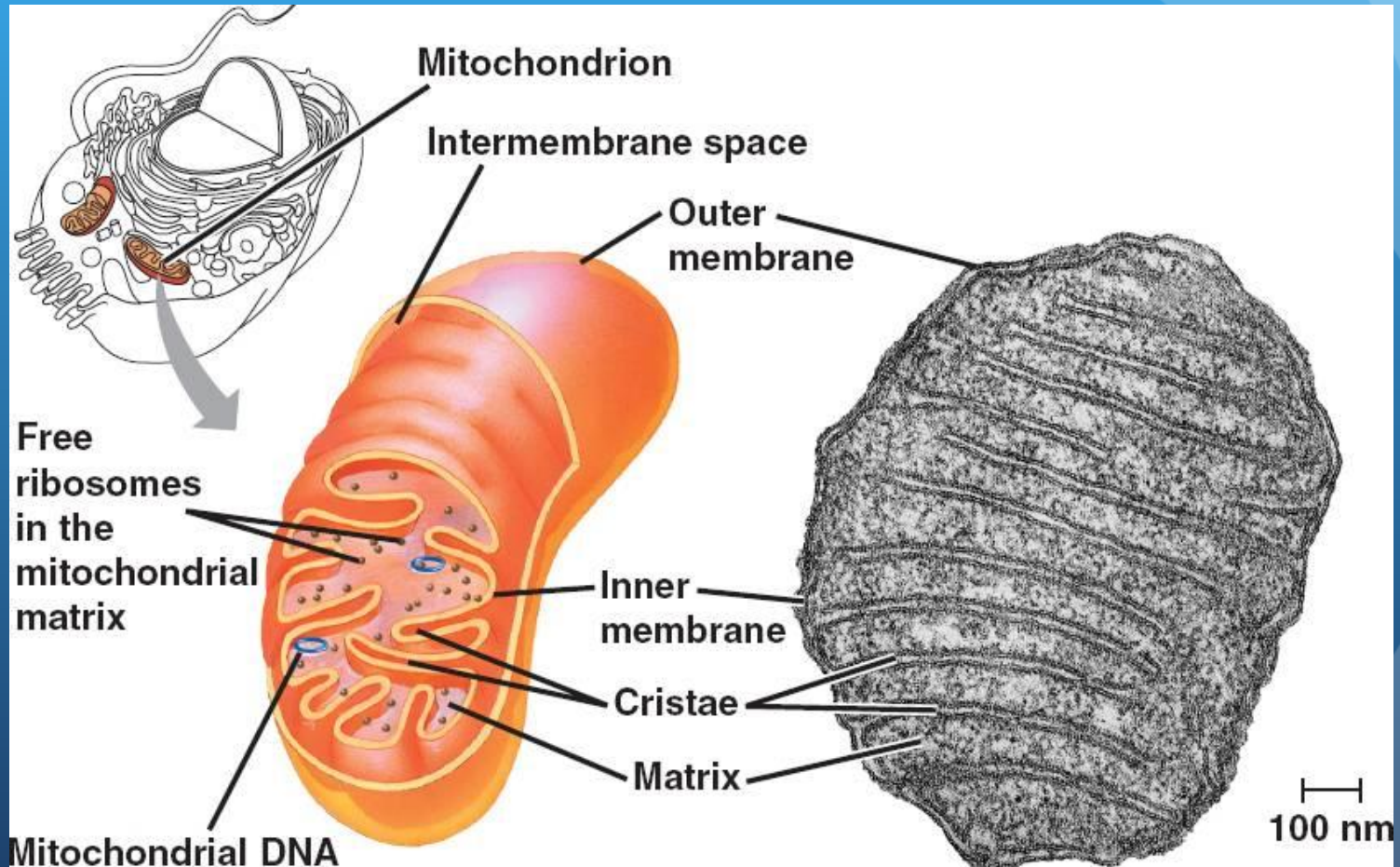
The cellular metabolism is a very complicated network of simple organic chemistry reactions, the metabolic pathways



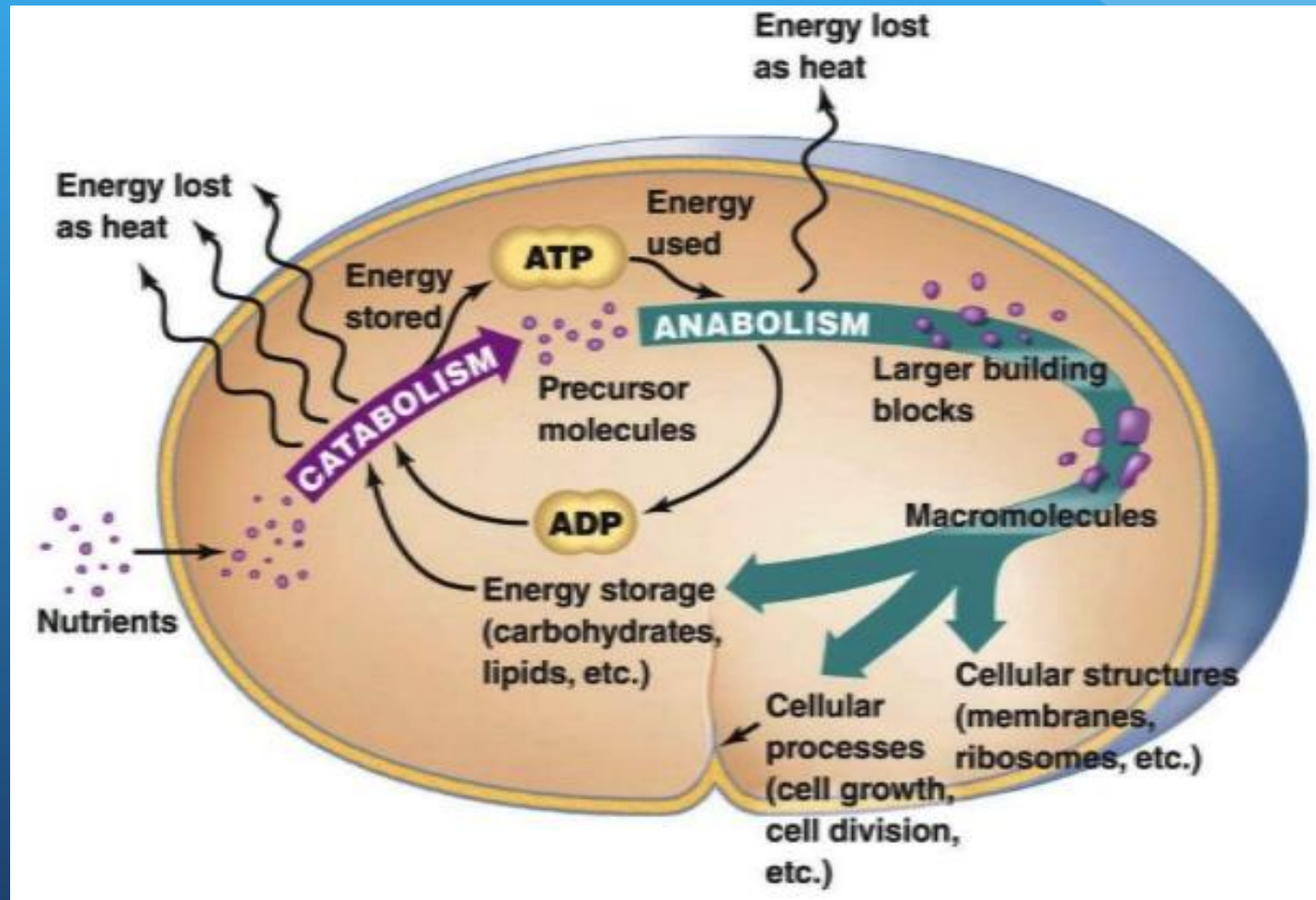
The cellular metabolism is controlled in various ways



The energy is captured either in high energy bonds (**ATP**) or in reduced molecules (**NADPH, NADPH, FADH₂**)



The cell factory mostly recycle the biomolecules very efficiently



Biotechnology: so young and so old

NSF
Award
#0501953



How Old Is Biotechnology ?

10,000 BC
Domesticating
Crops



6,000 BC
Brewing Beer



Domesticating Animals
8,000-9,000 BC



4,000 BC
Leavening Bread

1880's
Production of Vaccines



1940's
Production of Antibiotics

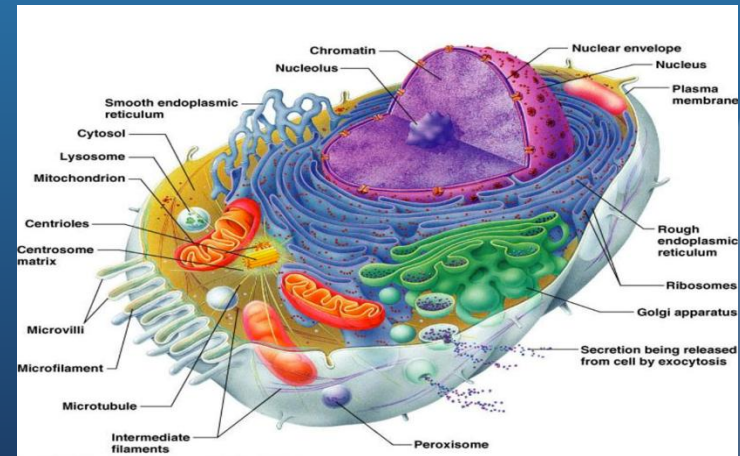
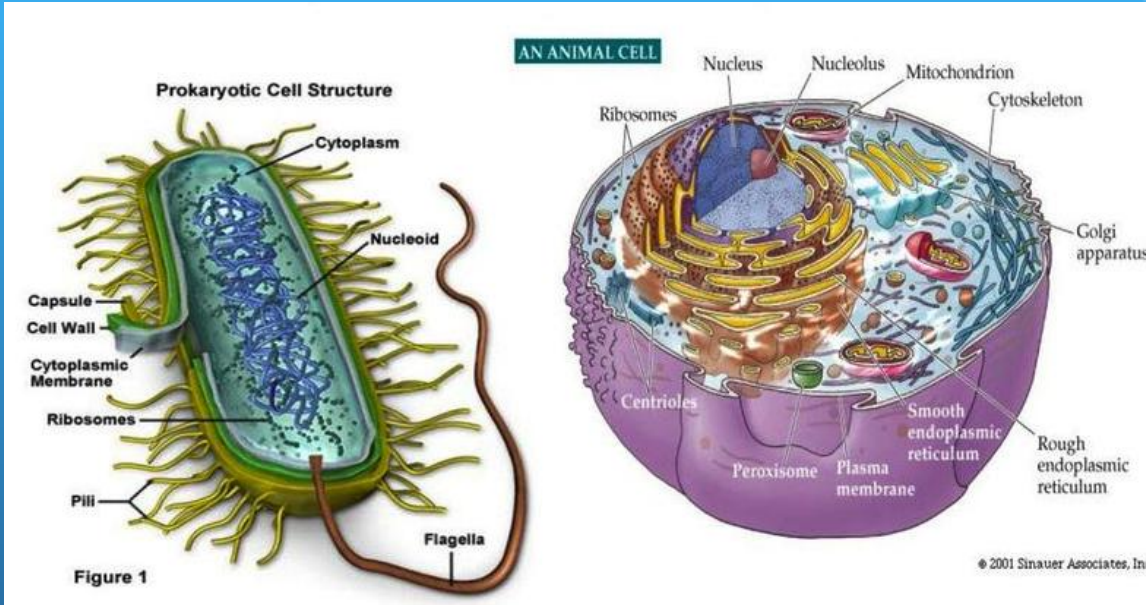
1980's Use of genetically modified organisms



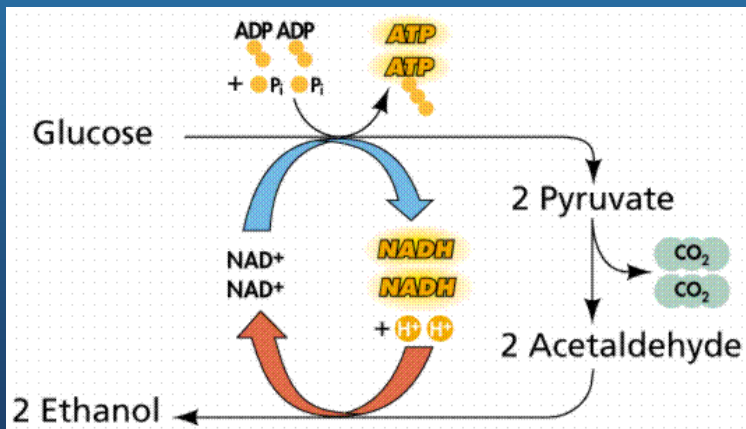
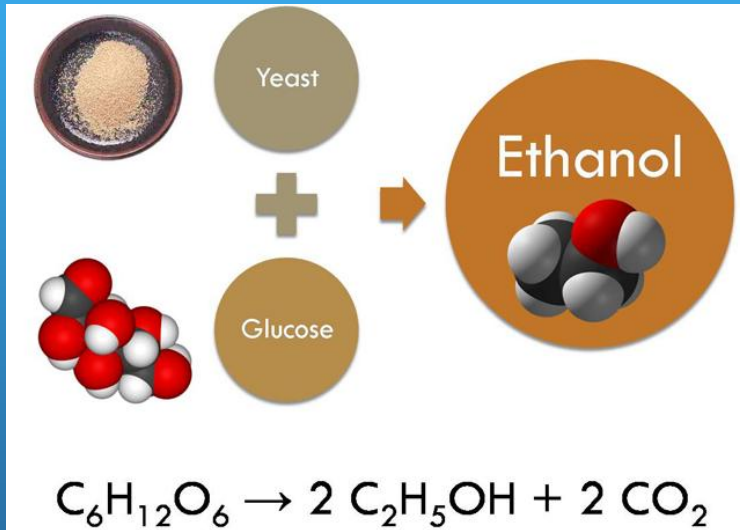
Northeast Biomanufacturing Center and Collaborative

www.Biomanufacturing.org

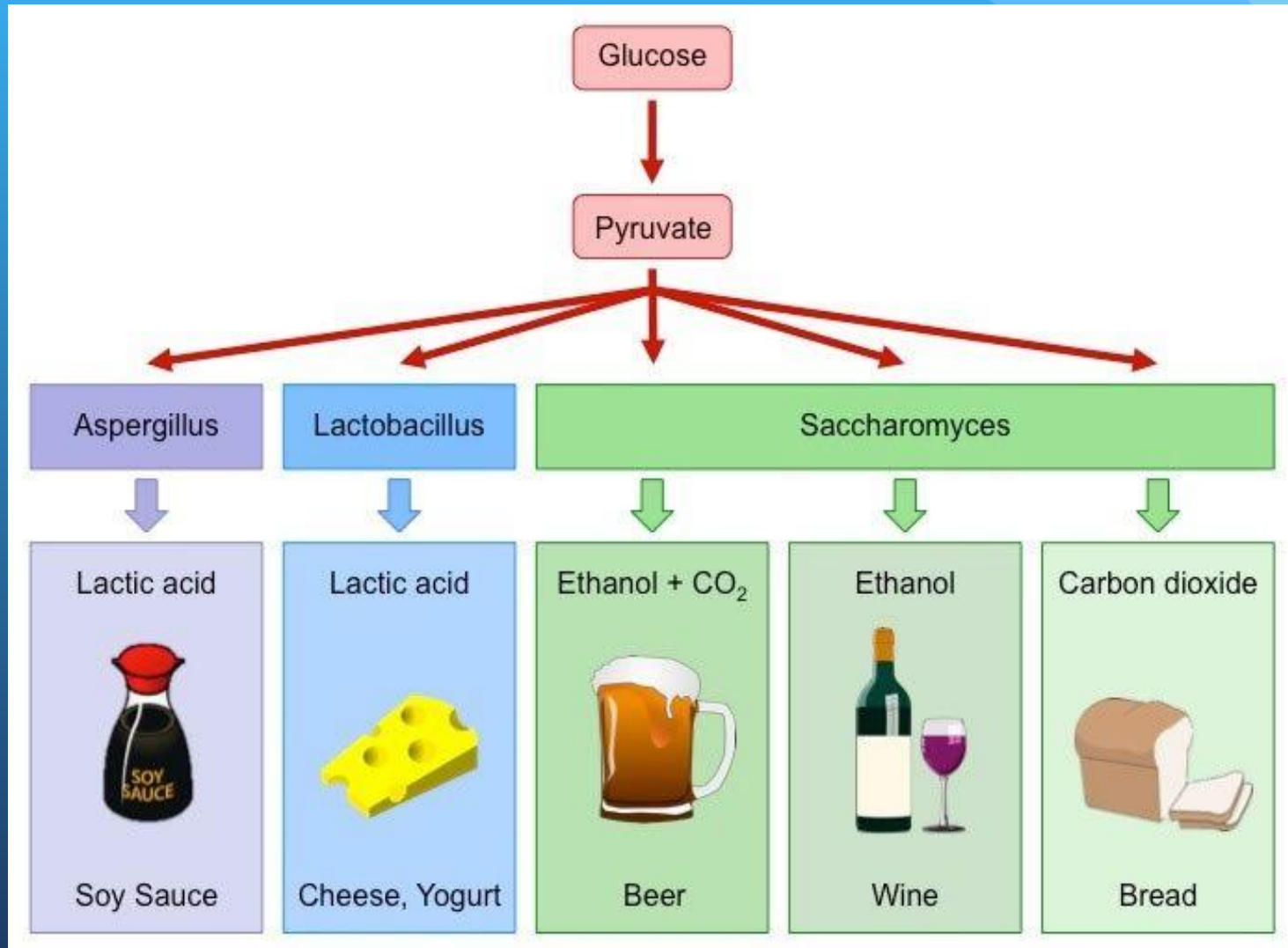
The cell factory the major tool of modern biotechnology 32



The most important biotechnological application



The most usual biotechnological applications



Traditional vs Modern Biotechnology

Pharmaceutical biotechnology

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graph TD; A[Pharmaceutical biotechnology] --> B[Traditional biotechnology]; A --> C[Modern biotechnology]
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Traditional biotechnology

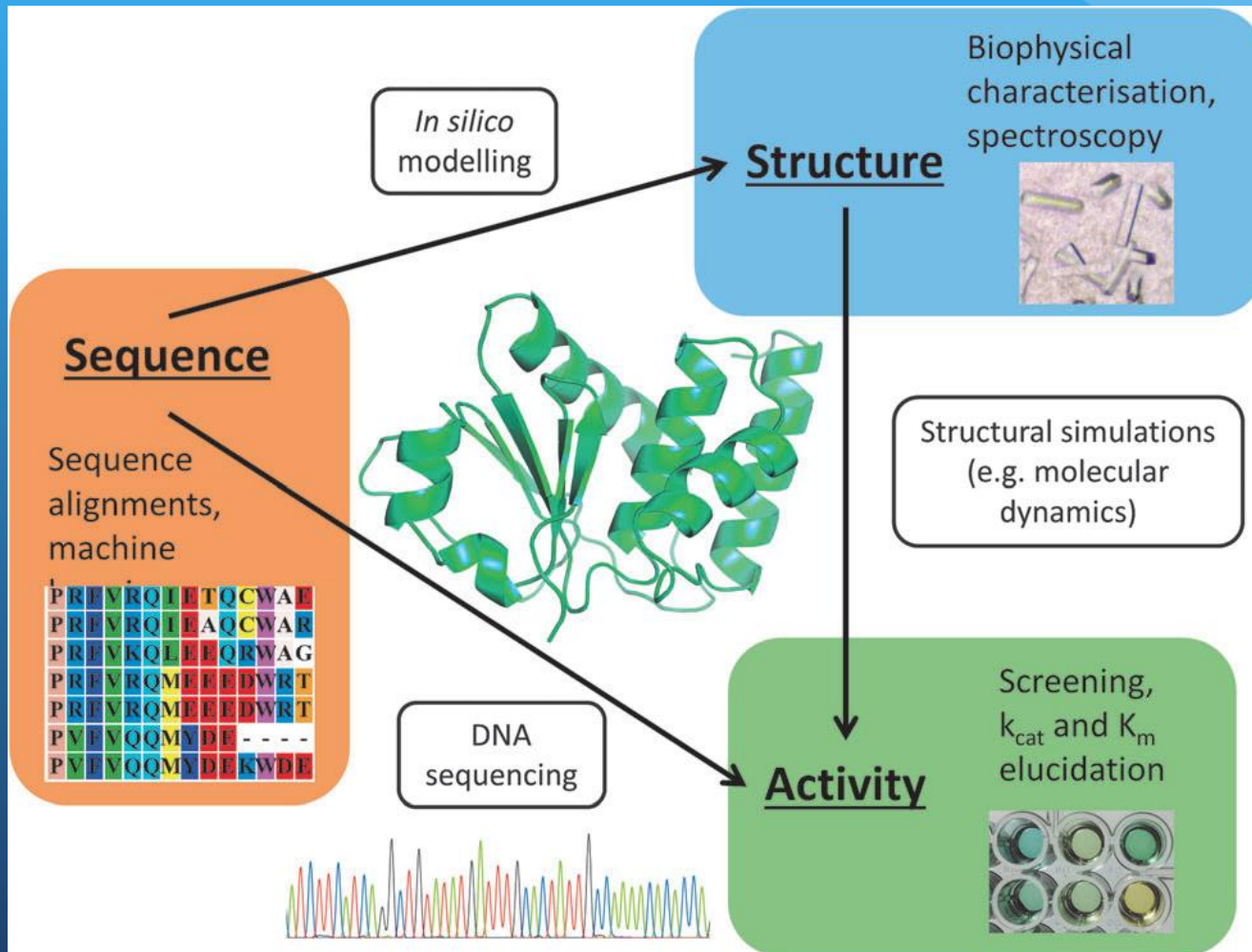
- secondary metabolites
- antibiotics
- steroids
- vitamins, etc

Modern biotechnology

- recombinant proteins
- monoclonal antibodies
- gene therapy
- transgenic organisms

Synthetic biology-directed evolution

New biocatalysts



Synthetic biology-directed evolution New biocatalysts of universal interest

J | A | C | S
JOURNAL OF THE AMERICAN CHEMICAL SOCIETY

Article

pubs.acs.org/JACS

Toward Efficient Enzymes for the Generation of Universal Blood through Structure-Guided Directed Evolution

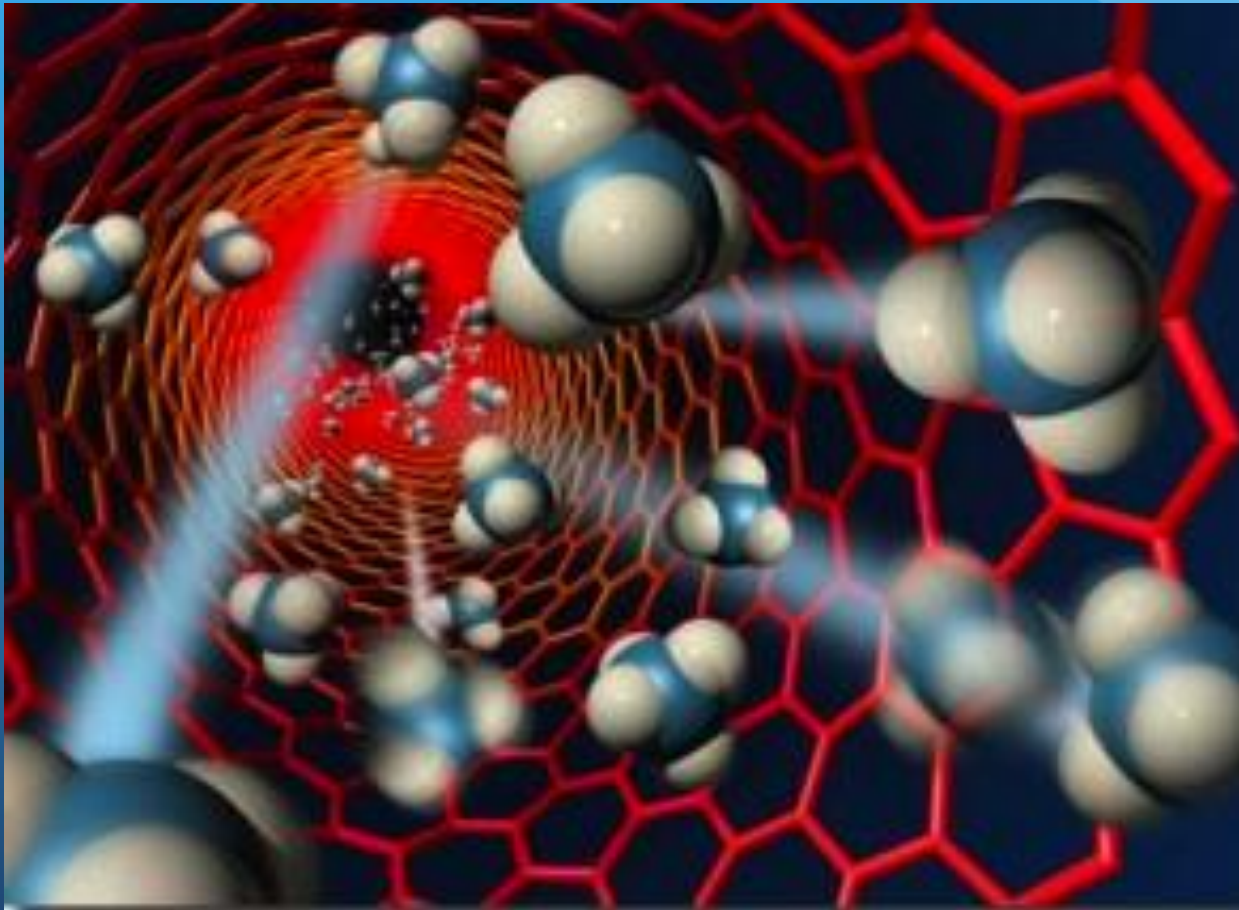
David H. Kwan,^{†,‡} Iren Constantinescu,^{§,||} Rafi Chapanian,^{§,||} Melanie A. Higgins,[⊥] Miriam P Kötler,^{†,‡} Eric Samain,[#] Alisdair B. Boraston,[⊥] Jayachandran N. Kizhakkedathu,^{‡,§,||} and Stephen G. Withers^{*,†,‡}

[†]Centre for High-Throughput Biology, [‡]Department of Chemistry, [§]Centre for Blood Research, ^{||}Department of Pathology and Laboratory Medicine, University of British Columbia, Vancouver, British Columbia, Canada V6T 1Z3

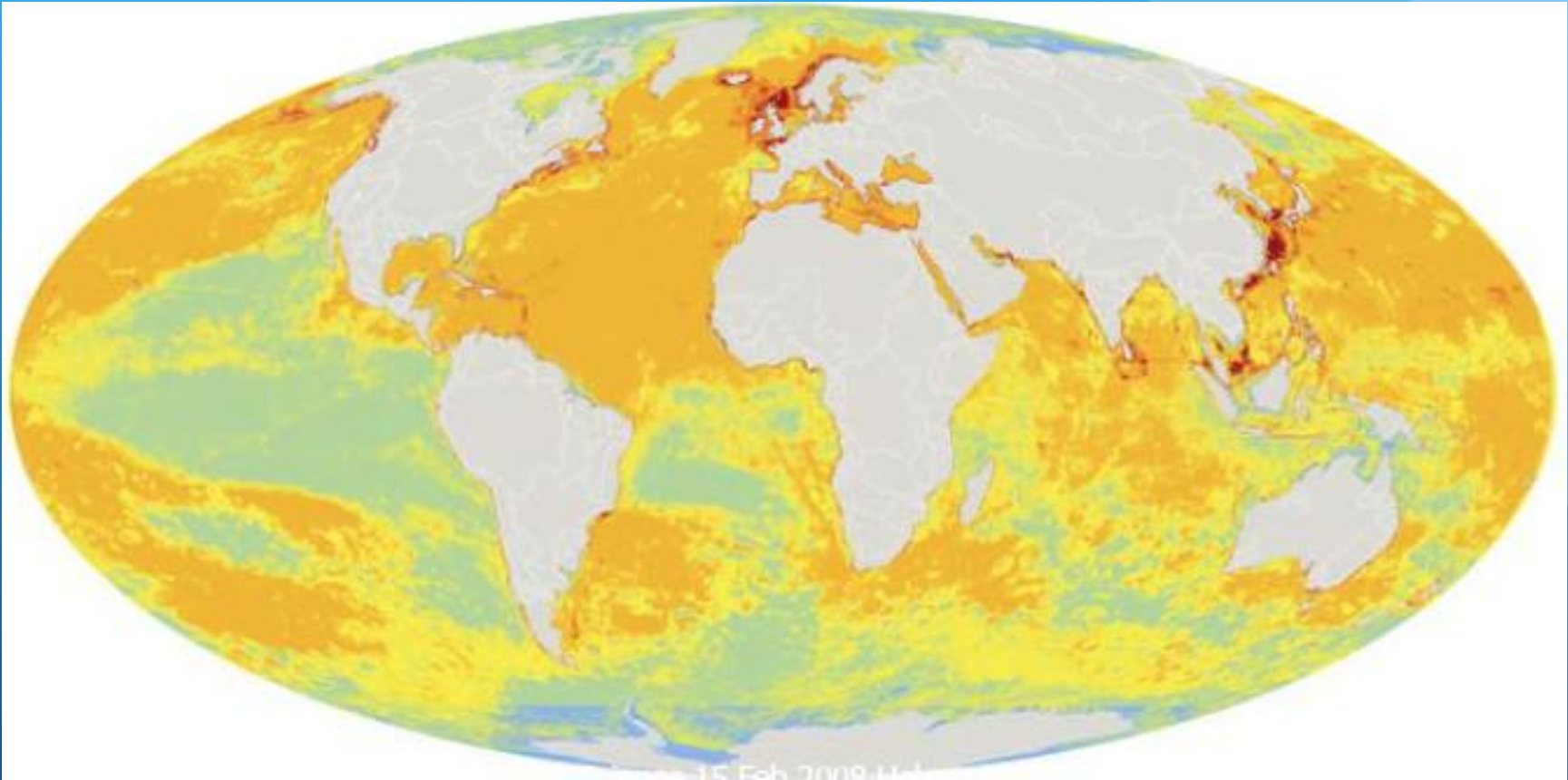
[⊥]Department of Biochemistry and Microbiology, University of Victoria, Victoria, British Columbia, Canada V8W 3P6

[#]Centre de Recherches sur les Macromolécules Végétales, Centre National de la Recherche Scientifique, Grenoble Cedex 9, France BP 53, 38041

Biotechnology and Nanotechnology



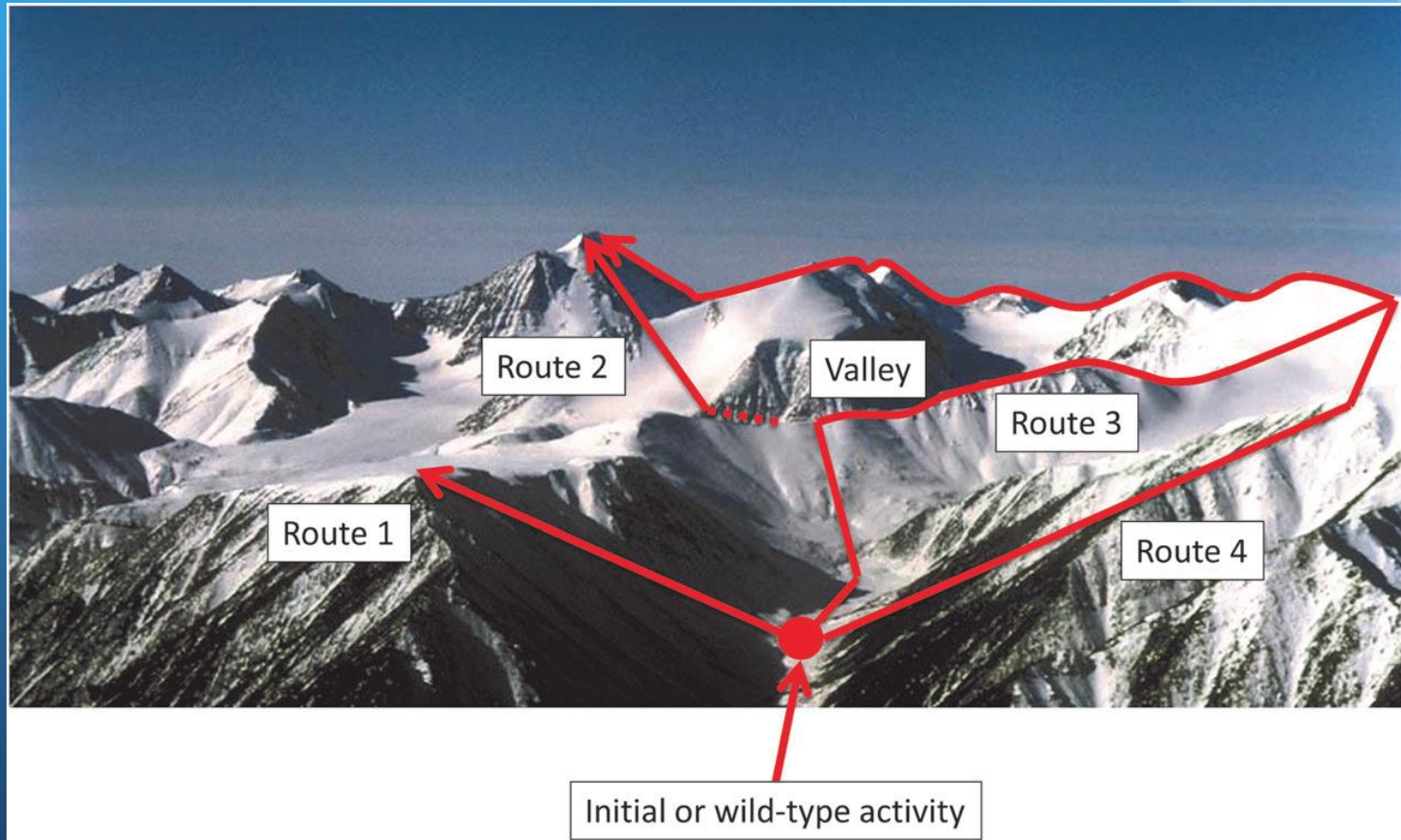
Marine environment is “the bioresource” for the future



Very Low Impact (<1.4) Medium Impact (4.95–8.47) High Impact (12–15.52)
Low Impact (1.4–4.95) Medium High Impact (8.47–12) Very High Impact (>15.52)

Research presented by Halpern et al in Science in Feb 2008

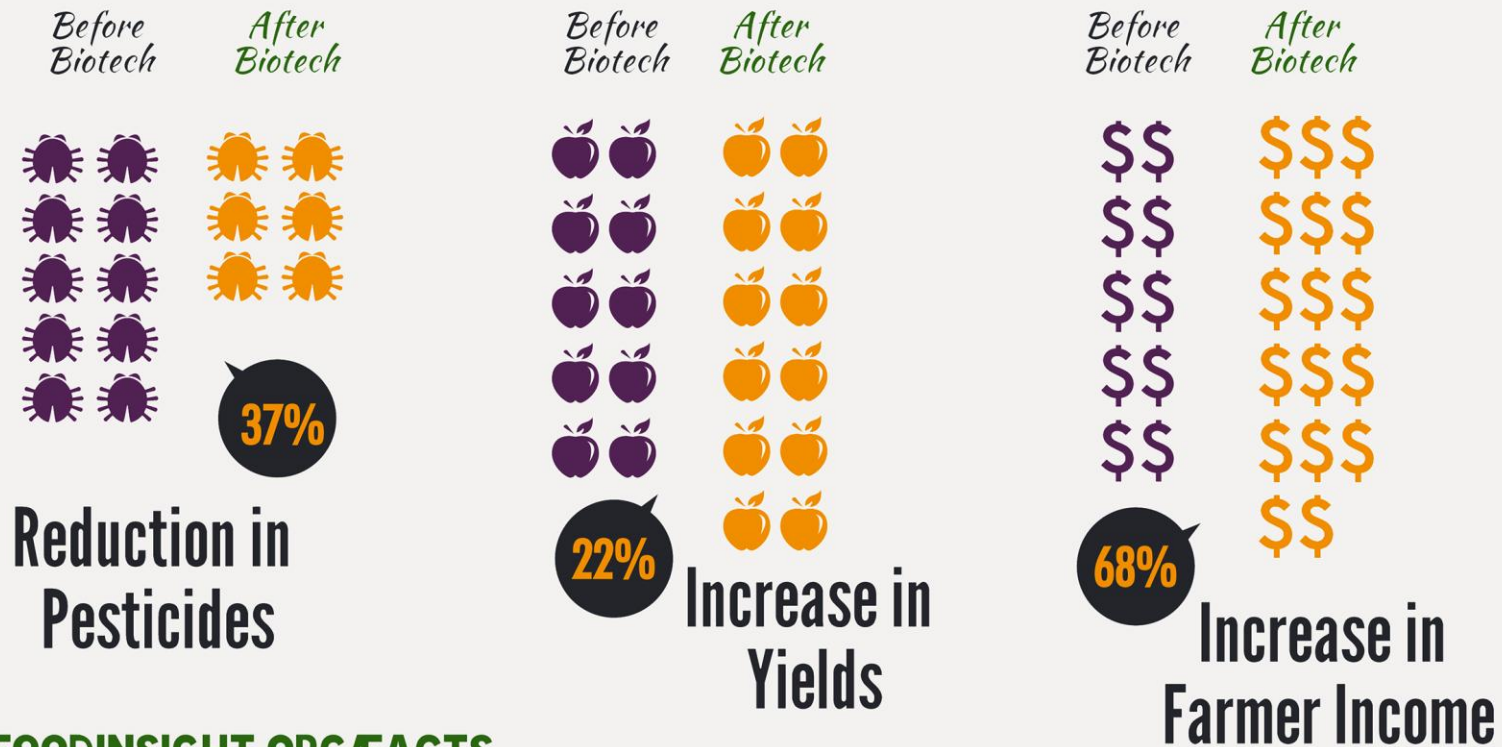
Synthetic biology: a “sport” similar to climbing



Biotech and Bioeconomy

IMPACTS OF BIOTECH

The latest PLOS ONE metastudy looked at the impacts of biotechnology. We dove in.



FOODINSIGHT.ORG/FACTS

The take home message

We have to think simple to solve complicated problems

Nature has the time to play its own “Lego” and find wise and sustainable solutions

We do not have the time to do so, therefore we have to learn from nature and copy

Thank you