

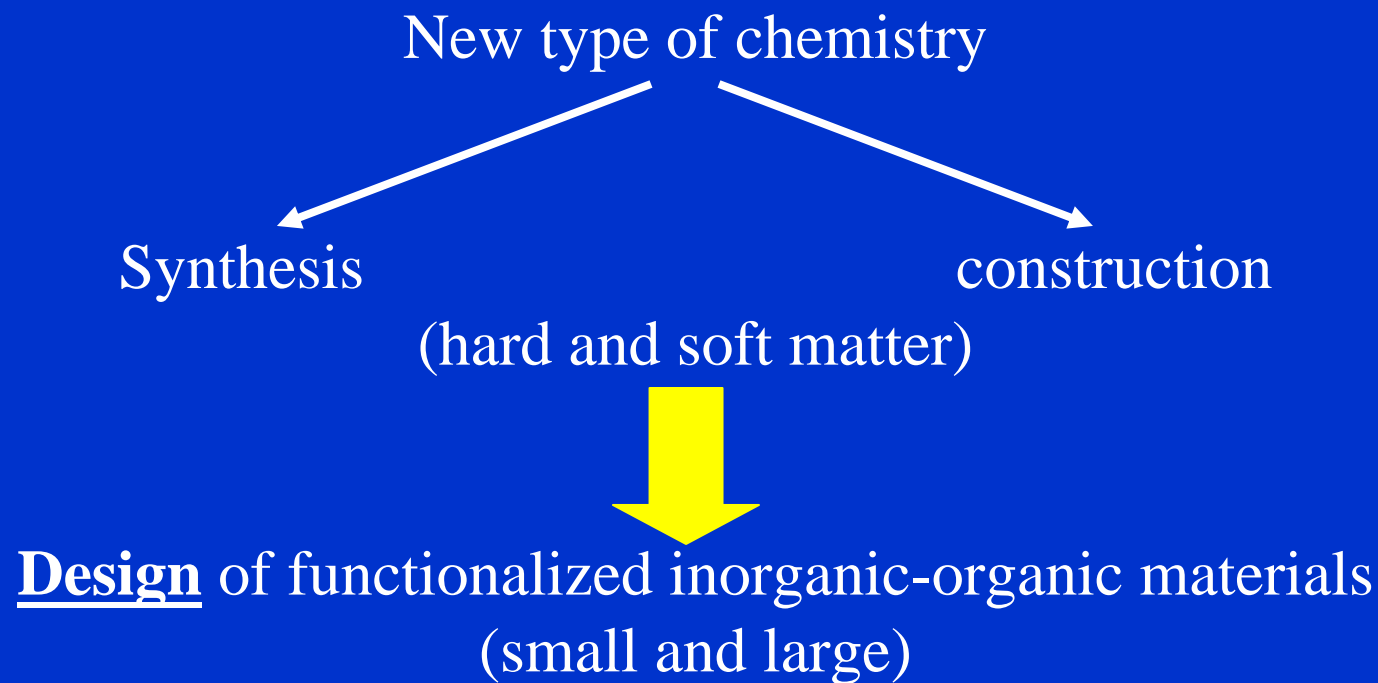
Inorganic Structures of Life



Biomaterialization: the study of the formation, structure and properties of inorganic solids deposited in biological systems

Stephen Mann “Biomaterialization: Principles and concepts in Bioinorganic materials chemistry, Oxford University Press, 2001

Biomaterialization is a new type of chemistry



Biom mineralization: the “big” picture

Selective extraction and uptake of elements from local environment
Strict biological control

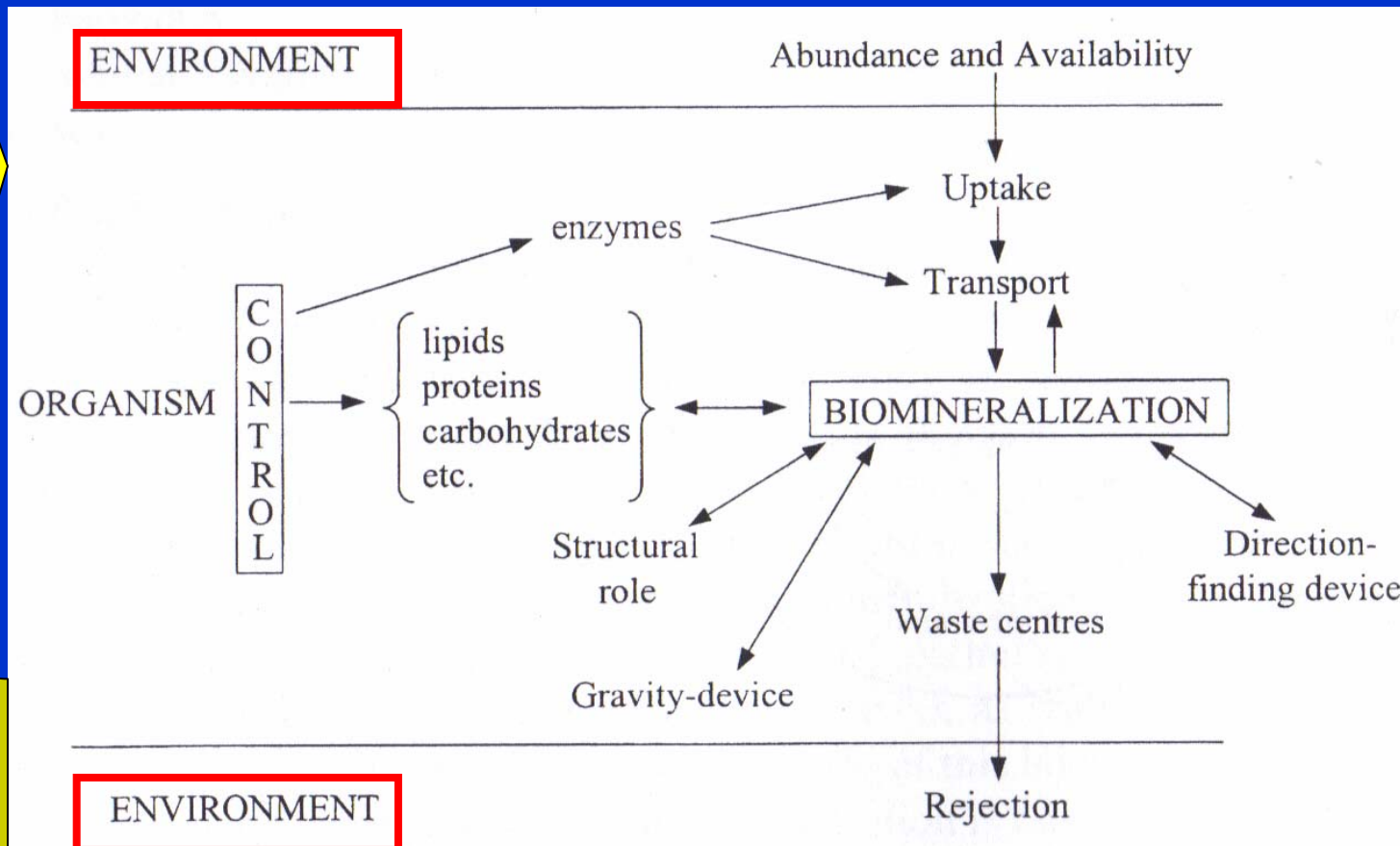
This process leaves “traces” (signatures) in contrast to other
biological transformations
(Examples: bones, shells, fossils)

Biom mineralization became abundant ~ 570 millions of years ago

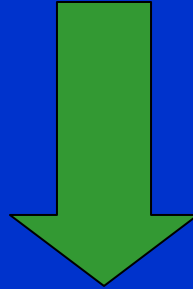
Evidence (stromatolites) for inorganic biom mineralization
3500 millions of years ago
(the Earth is ~ 4200 millions of years old)

Random processes

Biom mineralization: the "big" picture



Biom mineralization: implications at the global scale



EARTH SCIENCES

Global cycling of elements

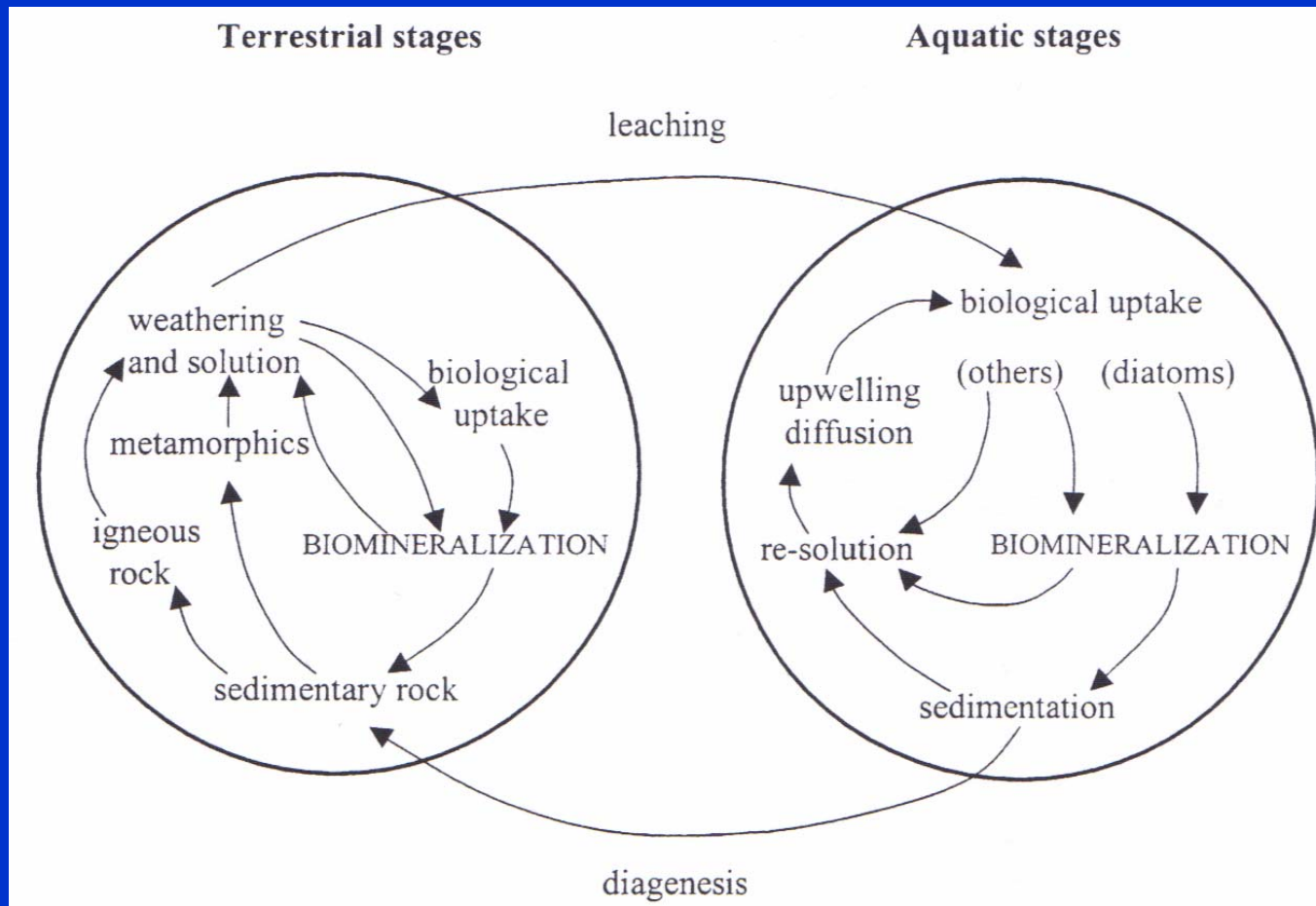
Sedimentology

Fossilization (paleontology and taxonomy)

Marine chemistry

Geochemistry

Biomining and the silicon cycle

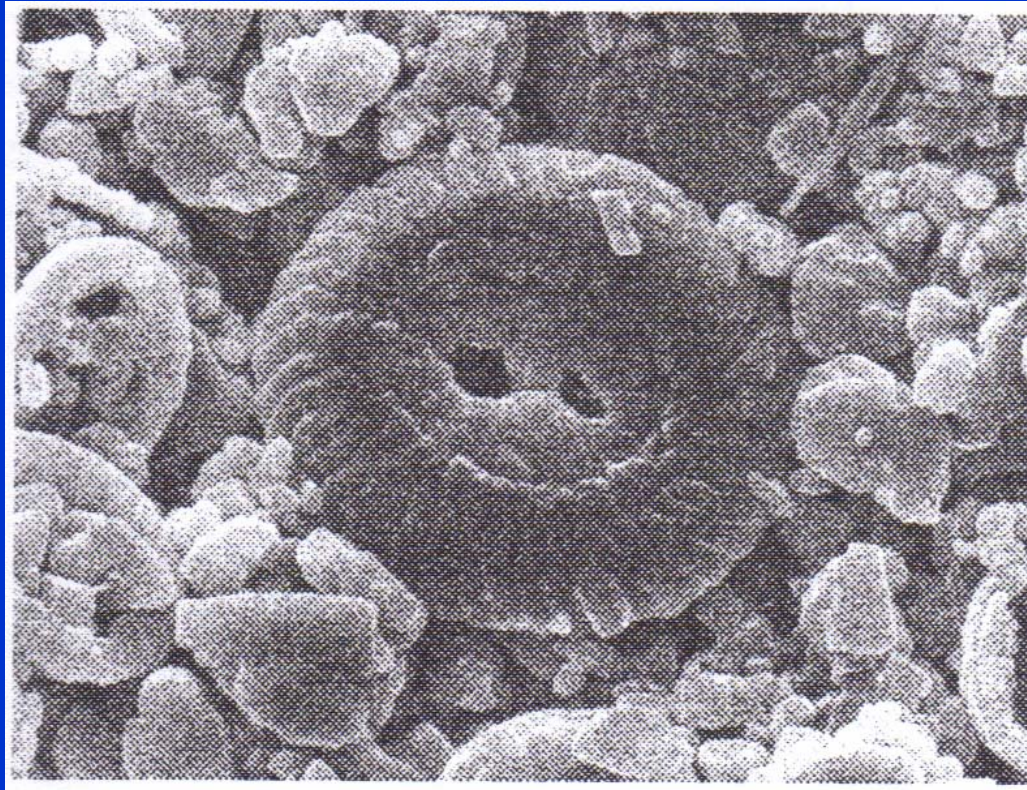


Biom mineralization is involved at some stage in element cycling

Elements such as calcium, iron, phosphorus and silicon are cycled over millions of years through complex pathways that at some stage involve biom mineralization

Huge chalk deposits (Dover, S. Britain) are a result of calcification in small single-celled organisms that lived ~ 200 millions of years ago in warm shallow sea

Biomineral structures: coccoliths (calcium sulfate dihydrate)



Biom mineralization gives a lot of information

Fossils contain a record of
The distant biology
Local climate
Chemical conditions
Marine environment

$^{18}\text{O}/^{16}\text{O}$ isotopic ratio \rightarrow paleotemperatures
Amounts of trace metals (Sr) \rightarrow salinity of ancient water

Biom mineralization is “smart” chemistry

Biom mineralization provides organisms with a tough building material

There are tough skeletons constructed by an organic polymer

(α -chitin in insect cuticle)

But the energy demand is high

Organic “armor” resists bashing or hammering....

But...

It does not work well in the arms of a predator

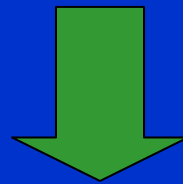
There is much to be gained when hard and stiff (but brittle) organic

Materials are combined with inorganic strength

Nature has found the solution

Building on a light-weight organic frame
(to save on metabolic energy)

Fill it with “cheap” inorganic material
(eg. calcium carbonate)



Inorganic-organic hybrid (biocomposite)
With well-defined mechanical properties

Biom mineralization provides more than just support and mechanical strength

Variety of important biological functions



Protection

Motion

Cutting and grinding

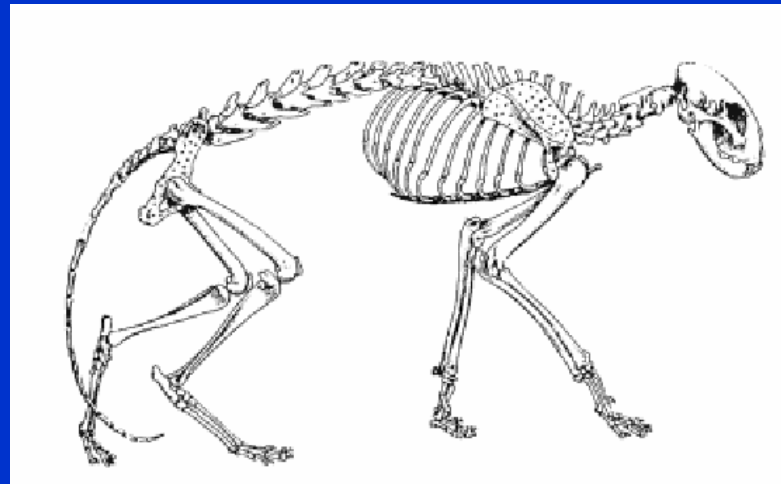
Buoyancy

Optical, magnetic and gravity sensing
storage

Tissues

The higher-order structures arise from the evolution of
Specialized tissues

These structures must be integrated into the body as a whole
And they have to function properly and efficiently



Fundamental importance of hard tissues

Pathological biomineralization

Serious medical consequences when something “goes wrong”

Kidney stones, urinary stones, dental calculus, arthritis, osteoporosis

TIME Magazine
June 9, 2003



HEALTH

The Coming Epidemic of ARTHRITIS

The Bad News: The disease starts attacking joints long before middle age >>
The Good News: The latest treatments are more effective than ever >>

MORE STORIES

- COVER STORY**
[Age of Arthritis](#)
We're headed for an epidemic of joint disease
- [Rheumatoid Arthritis](#)
The other crippling joint disease
- [What You Can Do](#)
There are many ways to find relief
- [Table of Contents](#)

GALLERY AND GRAPHICS

- [Anatomy of a Breakdown](#)
How wear and tear take their toll
- [Where it Hurts](#)
Joints all over the body are vulnerable

QUICK VOTE

What's the most effective arthritis remedy?

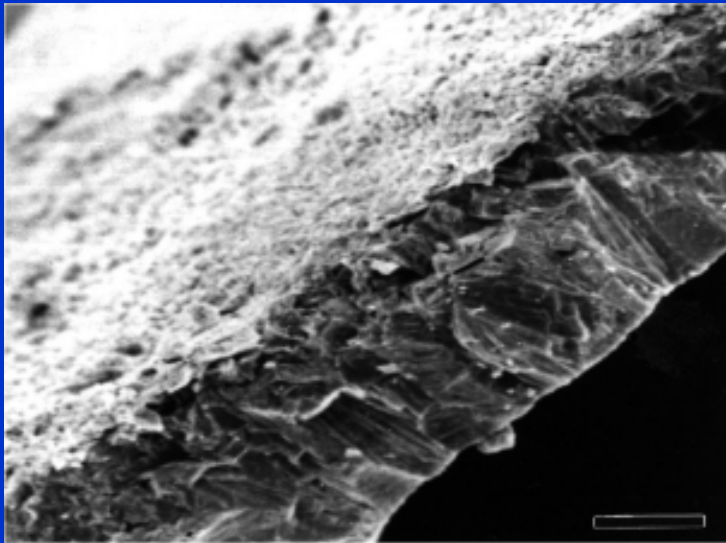
- Over-the-counter painkillers
- Cox-2 inhibitors
- Exercise
- Acupuncture

TIME ARCHIVE

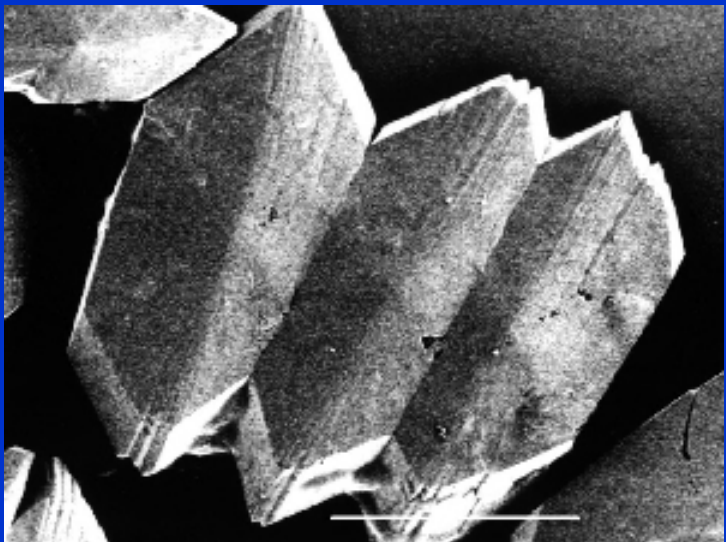
- [Preventing Headaches](#) [P]
Doctors have found better weapons to beat back migraines 10/07/2002
- [Staying Healthy](#) [P]
It's better not to get sick in the first place 01/21/2002

[P] Indicates premium content.

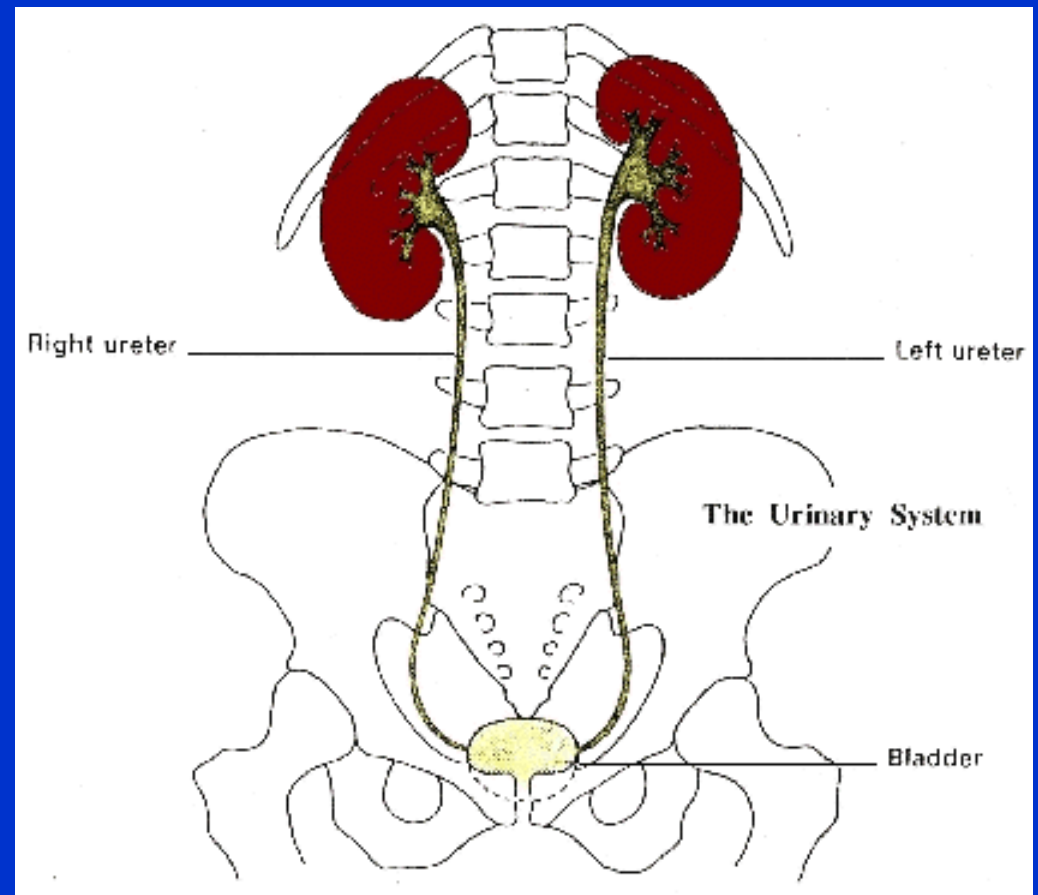
ΠΑΘΟΛΟΓΙΚΗ ΚΡΥΣΤΑΛΛΩΣΗ Ca(ox) ΣΕ ΒΙΟΪΑΤΡΙΚΑ ΟΡΓΑΝΑ



«ΦΥΣΙΚΟΙ» ΚΡΥΣΤΑΛΛΟΙ



«ΤΕΧΝΗΤΟΙ» ΚΡΥΣΤΑΛΛΟΙ



Misra, R.P. Cell. Mol. Life Sci. 57 (2000) 421

Biomineralization: a new chemistry

Biomineralization has shifted towards a chemical perspective

Bioinorganic Chemistry

Biomimetic Materials Chemistry

Structural and compositional characterization of biominerals

Understanding the functional properties of biominerals

Control by biomacromolecules

Organization and construction of biominerals

Supramolecular chemistry

Organized matter chemistry

Biomineralization: inspiration

The inorganic-based structures of life – biominerals – represent a new area of study for bioinorganic chemistry and a source of inspiration in materials chemistry. Biomineralization is an example of organized-matter chemistry, which is concerned with the chemical construction, synthesis and emergence of organized architectures and complex forms.