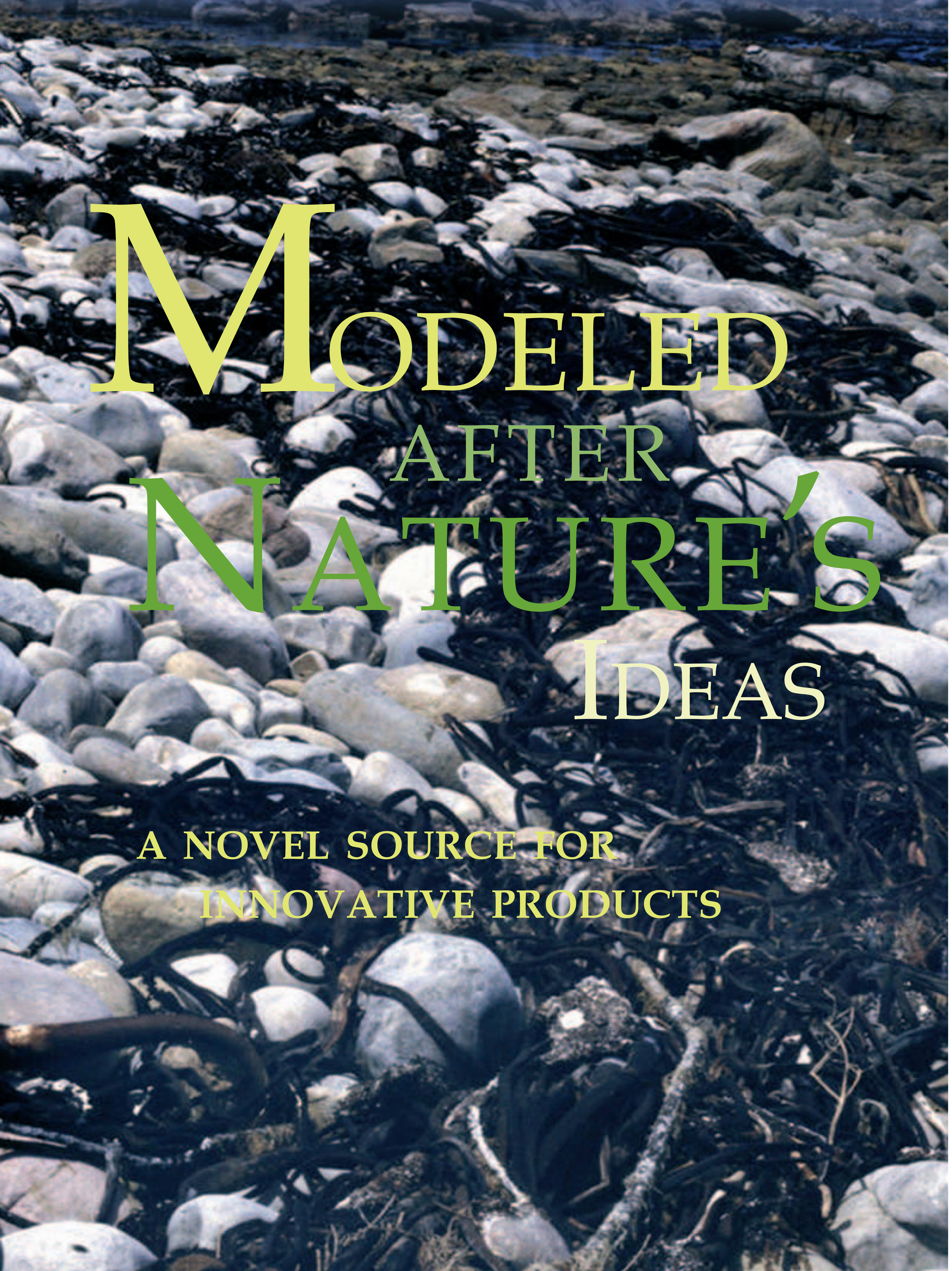


Modeled after Nature's Ideas

A novel source for innovative products

Natural product research is a discipline that is often associated with the search for novel pharmaceutically active compounds. Extracts of plants, fungi, animals, or cultures of microorganisms are indeed fruitful sources for novel drugs but it becomes more and more obvious that natural products have also an enormous potential as tools for the solution of other problems in our modern society. Careful observation of living beings in nature can lead to hitherto undiscovered and unexpected novel functions of natural products. The connection of ecological and potential technical functions of natural products pushes the successful young discipline "chemical ecology" that deals with the function of natural products in the interactions of living beings.

New functions of natural products can be discovered, if the processes that lead to their production or delivery in nature are considered. Most of the classical work in natural product chemistry focused only on the structure elucidation of natural compounds and on the evaluation of their activity in laboratory experiments. Now we begin to develop methods to also investigate the function of the compounds in nature. This allows understanding how evolution leads to the production of elaborate chemical tools that help the organisms to survive in their environment. If we understand these processes we can also adopt the discovered new principles for the development of novel materials and metabolic tools for technical applications.

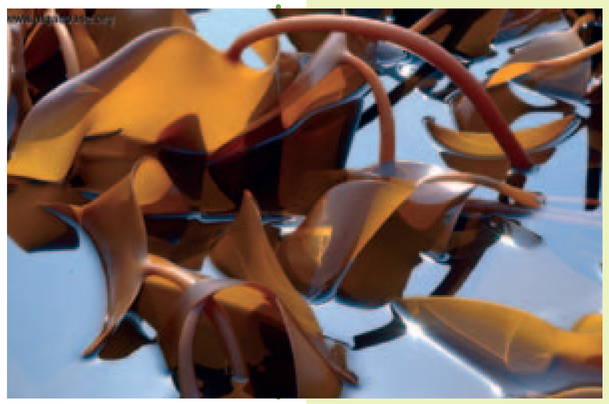
Some selected examples

If we monitor plants in their natural environment we realize that they do by no means always produce an arsenal of chemical weapons for their defense. Some of the active compounds are rather only produced in times of threat. This chemical armament can be stimulated by e.g. feeding insects or pathogens and researchers aimed to understand how the plant's response is orchestrated. It is now clear that plants can recognize signals from the attackers and respond with the production of defensive chemistry. Even minute amounts of these triggering signals – so called elicitors – can stimulate the plant to protect itself. This principle is already exploited in modern crop protection. It was found that extracts from brown algae contain active elicitors that can be applied to fields with economic plants. Spraying with these natural elicitors is an ecological way to stimulate plant protection and allows reducing amounts of pesticides or herbicides applied to the fields. The concept to produce active principles only in times of danger is widely found in nature. If rapid responses to external stress are required nature selects often a strategy, which is based on the storage of precursors of aggressive chemicals that can be quickly activated. This rapid activated response is not only limited to the production of toxins but also employed in wound reactions. An example is the wound healing mechanism of certain green algae that respond to disruption of their cells with the immediate formation of a protecting polymer. This polymer formation is based on the transformation of a non-reactive compound that is stored in the tissue of the algae. The transformation rapidly leads to a type of biological super glue. For polymerization a simple principle is employed that connects proteins of the algae and reactive aldehyde groups from the activated glue leading to an insoluble polymer. A similar mechanism is found in the defensive secretion of certain termites, which is used to stick together the feeding organs of attackers and prevent them from further feeding. Independent from the principles employed in nature the general concept of gluing proteins together using reactive aldehydes is employed in modern medicine. The surgical adhesive bioglue® is employing the same mechanism as found in algae and termites to successfully connect tissue during operations. Using the principles of nature we might soon be able to imitate the regulation mechanisms that control polymerization

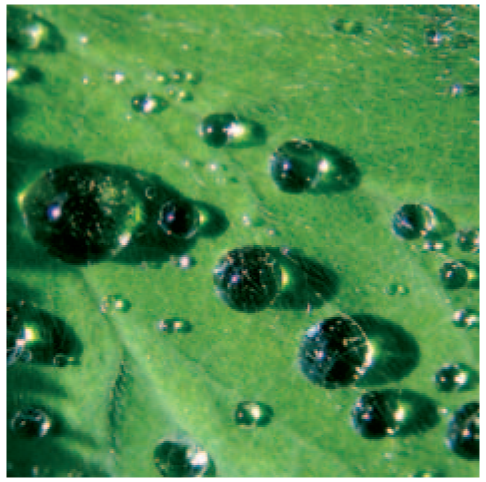
Aldehyde groups
H-C=O groups.
Typical functional groups of organic compounds. This structure element allows other substances to react with aldehydes.

Brown algae
So called macroalgae that can grow in forms from small filaments of a couple of millimeters to length of up to several meters. Brown algae are distributed worldwide along the coastlines.

Cultures of microorganisms
Unicellular organisms, such as bacteria or microalgae can often be isolated from their natural environment and transferred into culture. These cultures can be kept in the lab in artificial media or on plates with nutrients.



Extracts from the brown alga *Laminaria hyperborea* can be used trigger the resistance of crops against pathogens and herbivores.



Even in muddy waters leaves of the lotus are always pristine. Dirt simply rolls of due to the self purifying property of the leave surface. The underlying principle could be imitated by material scientists who generated self cleaning surfaces that have numerous applications in households and industry.

Biomineralization
Formation of inorganic solids within or on the surface of organisms. The materials can contain e.g. calcium or silica and can be considered as minerals produced by living beings.

Diatoms
Unicellular algae that are the most important photosynthetic active organisms in the oceans.

in algal cells or termite glands and develop more elaborate medicinal agents.

The lotus leaves emerging with pristine green surfaces from muddy waters gave the impulse for another innovative product line. Material science has adopted the principle of microstructured surfaces where water and dirt containing droplets cannot adhere. As on the lotus leaves small bumps on the surface decrease the contact surface to water drops enabling a readily rolling off of liquid droplets. Products with the "lotus effect" including car varnish, toilet seats, and eyeglass lenses are now found in everyday live.

The red alga *Plocamium rigidum*

There are many more ideas from nature that found their way into material sciences. Scientists were fascinated since the early days of light microscopy by unicellular algae with a silica shell. The so called diatoms are masters in the nano pattering of their cell wall. This is achieved by a directed precipitation of silica that gives a perfectly designed biomaterial. Dead algal cells that sediment on the bottom of the sea are a source of silica, that can, for example, be used for chromatography. The biological processes leading to the microscopic structures involve the attachment of soluble silicates to a template matrix formed of biomolecules such as proteins. This results in the formation of an organic / mineral composite material that is found in many biopolymers. Only few month after this principle was discovered in the unicellular algae material scientists already started to use this process for the generation of microscopically small silicate patterned holographic surfaces.

All these examples should motivate us to observe nature's solutions not only for toxic or pharmacologically active chemicals, but also for creative ways that were optimized during evolutionary time scales to solve problems relevant for technological processes.

Georg Pohnert

Additional Literature

Pohnert G: Wundverschluss durch Biopolymerisation (2005), Nachrichten aus der Chemie 53(6), 638-640

Baeuerlein E: Biomineralization. From biology to biotechnology and medical application (2000), (Gebundene Ausgabe), Wiley-VCH, Aufl. 1

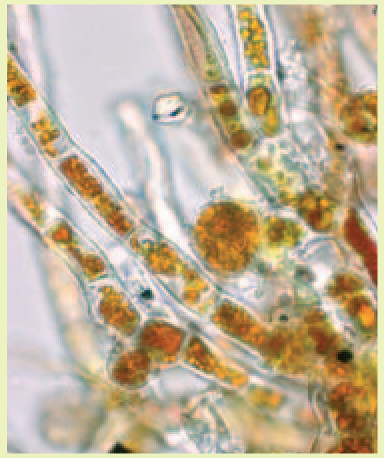
Sumper M, Brunner E: Learning from diatoms: Nature´s tools for the production of nanostructured silica (2006), Advanced Functional Materials 16(1), 17-26

Links on the Web

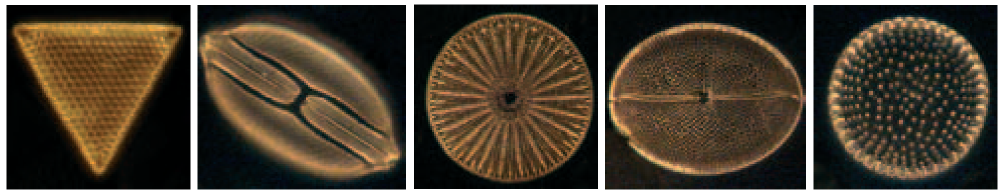
AlgaeBASE
Informationen über Algen und ihren Lebensraum sowie deren technische Anwendungen
www.algaebase.org

Forschungsgemeinschaft Knochen und Biomineralisation e.V.
www.biomineralisation.de

Lotus-Effekt
Projektgruppe Bionik am Nees-Institut der Rheinischen Friedrich-Wilhelms-Universität Bonn
www.nees.uni-bonn.de/bionik.htm



The brown alga *Trentepohlia abietina*: The picture shows mature gametangia in the basal part of the alga.



The fascinating ornamentation of diatom cell walls is generated through directed biomineralisation. The processes involved in the natural polymerization are prototypic for further developments in material sciences.