

Cosmimetic group

biomim'expo
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NEXT GENERATION BIO-INSPIRED COSMETIC INGREDIENTS : THE GUIDE

RETHINKING COSMETIC INGREDIENTS THROUGH BIOMIMICRY

This methodological guide, designed for the cosmetic formulation professions, offers a new framework for integrating biomimicry at the ingredient level. Organized around ten fundamental principles, it shows how to explore the mechanisms of living organisms and translate them into each stage of design: from the identification of biological models to the transformation of materials, through the functional expression of properties and the assessment of environmental and health impacts.

While cosmetics already engage in dialogue with living organisms - through its application substrates, the origin of its raw materials or its quest for naturalness - the challenge today is to go further. Biomimicry appears as a genuine driver of innovation: it allows the creative potential of the sector to be renewed while being part of a comprehensive and sustainable health approach, where performance and responsibility advance together.

The result of the work of the Cosmimetic Group, an alliance of industrial players committed to an ambitious vision of bio-inspired cosmetics and coordinated by Ceebios, this guide goes beyond the sole framework of cosmetics. The principles and methodologies presented have cross-cutting applications across the entire field of ingredient chemistry: health, food, innovative materials... all areas where living things become a source of inspiration, efficiency and the future.



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AREA OF APPLICATIONS

COSMETICS
HEALTH
CHEMISTRY-MATERIALS
FOOD

DEVELOPMENT STAGE

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DEMONSTRATOR
FIELD EXPERIMENTATION

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L'ORÉAL · NAOS · GREENTECH · mibelle biochemistry · Pierre Fabre · LUCAS MEYER COSMETICS · GROUPE ROCHER · STÉARINERIE DUBOIS

ORGANIZATION
COSMIMETIC GROUP

CONTACT
LAURA MAGRO

CITIES
FRANCE

WEBSITE
CEEBIOS.COM

E-MAIL
LAURA.MAGRO@CEEBIOS.COM

Design Guide for Bio-Inspired Cosmetic Ingredients



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#1

ORIGIN

MYSTERIES OF THE LIVING WORLD AND BIO-INSPIRED CURIOSITIES

Innovation in the beauty industry is driven by trends (natural ingredients, biotechnology, digital technology, etc.) and by meeting consumer needs (product effectiveness, attention to ingredients, well-being, etc.). In such a highly competitive market, how can companies stand out with innovative, disruptive offerings?

Biomimicry is an approach that involves transforming a biological observation into a potential innovation. Two complementary approaches are developed to:

- Address a specific problem,
- Let oneself be surprised by new properties in living organisms.

This second approach facilitates the exploration of a largely unexplored reservoir of some 2 million species, with an evolutionary history spanning 3.8 billion years, in every corner of our planet, with the aim of opening new avenues for innovation.

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Example

- Super hydrophobicity: the water-repellent effect of certain biological coatings .

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#2

ORIGIN

THE LIVING WITHOUT BORDERS



The cosmetics industry often limits its sources of inspiration to the human body and to organisms selected as sources of raw materials (seeds, flowers, roots, bark, etc.). Fish, birds, insects, mollusks... a significant portion of biodiversity thus escapes its attention.

Biomimicry invites us to explore the entire living world: all species, at all scales, in all ecosystems. It is, therefore, first and foremost a source of boundless inspiration, drawing from any biological model.

The next step in the process involves translating the mechanisms, structures, and properties observed in living organisms into an innovative solution that complies with ethical standards (both social and environmental), particularly regarding the sourcing and production of raw materials.

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Examples

- Animal model: antimicrobial properties of the penguin's stomach for food preservation
- Endangered species: reflectance of edelweiss fibers for sun protection
- Scarce resources: Tyrian purple, found in small quantities in shells, for coloration

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#3

ORIGIN

FUNCTIONAL INGREDIENTS HOTSPOTS



In the cosmetics and pharmaceutical industries, the search for substances with desirable properties typically involves molecular screening (testing collections of up to a billion molecules). How can we navigate this biological big data more effectively?

In the methodological approach of biomimicry, focusing on functionality is the step that bridges the gap between biology and innovation in other fields of application.

This functionality-driven exploration of living organisms helps identify biological contexts that are particularly conducive to identifying ingredients of interest. Species-specific traits, geographical characteristics, or responses to environmental stresses trigger the production of functional ingredients.

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Examples

- Geographic characteristics: Oxygenation properties of intertidal species (Hemarina)
- Species-specific characteristics: Protection and resistance of extremophile species
- Climate: Antioxidant properties in the bark of boreal forests (cold, UV, etc.) (Lucas Meyer Cosmetics)

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PROPERTIES

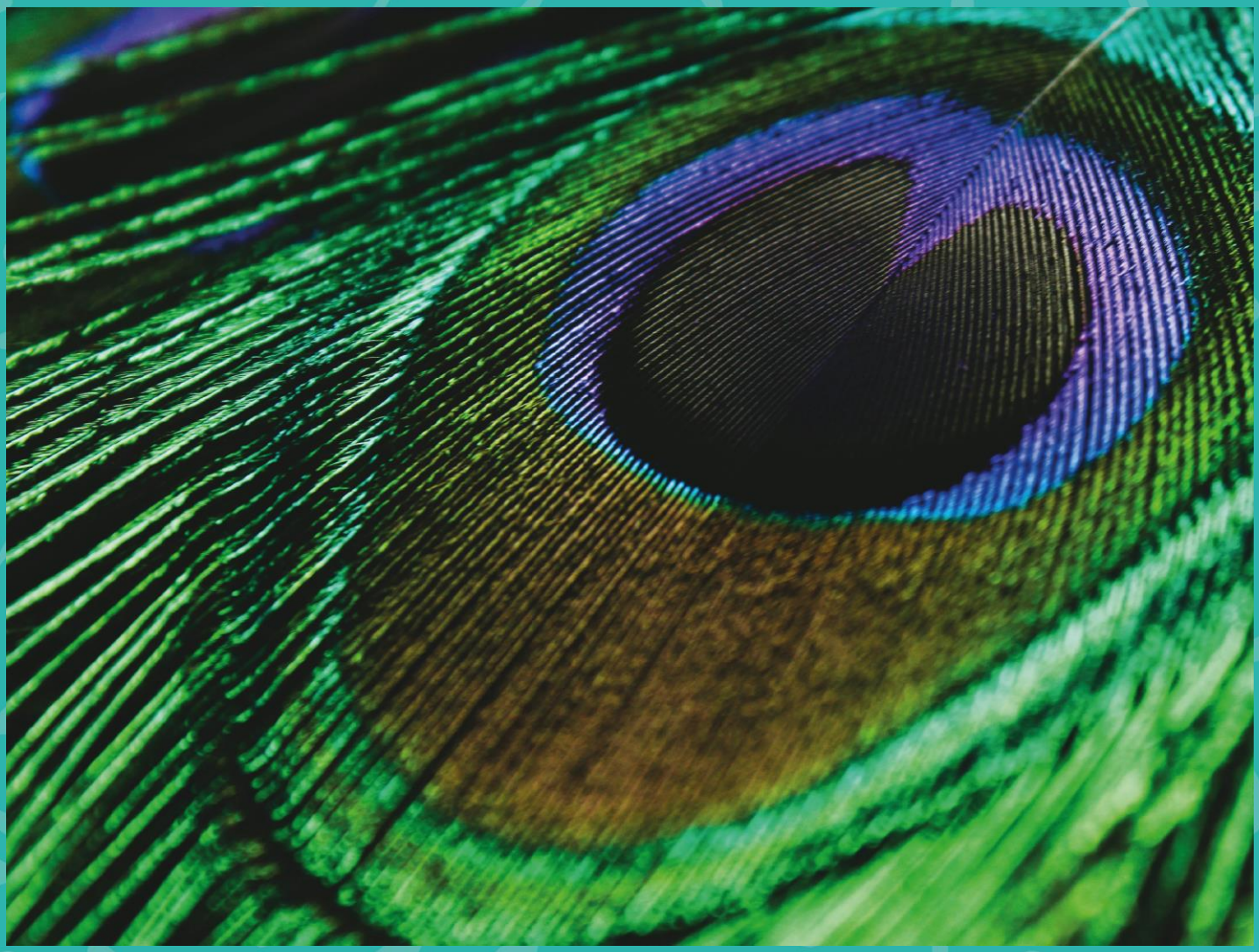
(BIO)DIVERSITY OF MECHANISMS : FROM CHEMISTRY TO PHYSICS

The development of a new cosmetic formula relies primarily on the unique molecular combination of active ingredients and excipients. What if innovation allowed us to go beyond the very concept of ingredients?

The evolutionary history and diversity of living systems have given rise to a wide variety of mechanisms for producing the same property: chemical, physical, biological ... Their combination is invaluable for providing versatility and adaptability.

It is therefore possible to seek alternatives to ingredients and biochemistry by focusing on physical organization of matter, and on the scales of the involved mechanisms and structures (from nanometers to millimeters), and the temporal nature of these phenomena.

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Examples

- Optics: Pigment-free colors (Sparxell, Seprify)
- Preservation: Antimicrobial properties via surface treatment (Sharklet) & Encapsulation and controlled release of ingredients (BiomimGel)
- Response to environmental conditions: Reactivity to a stimulus (immediacy), acclimatization (at the individual level), and adaptation (at the population level, through heredity)
- Wound healing: A combination of physical mechanisms (vasoconstriction: fluid mechanics related to platelet aggregation) and biological mechanisms (cell renewal, tissue maturation).

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PROPERTIES

ALL-IN-ONE SOLUTION THROUGH MULTIFUNCTIONALITY OF LIFE



The formulation of a complex product sometimes resembles the mere juxtaposition of ingredients in order to combine their individual functions. Consumers' growing scrutiny of product ingredients, along with the need to simplify the management of raw materials and environmental waste, calls for a drastic simplification of ingredient lists on labels.

Life is the result of a delicate balance between universality (70% of genes shared between humans and sea urchins) and diversity (no fewer than 950 species of sea urchins). Biochemistry and biomolecules reflect this duality, featuring common building blocks combined with numerous variations.

Evolutionary history and diverse contexts have endowed biological molecules with a certain versatility that allows them to accommodate trade-offs in properties. This multifunctional potential is a key asset for minimalist cosmetics.

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Examples

- Collagen: a similar structural component of various tissues for diverse mechanical properties: bone (strong and lightweight), cornea (viscoelastic), tendons (deformable under low stress, rigid under high stress)
- Mixed RNAs: numerous roles in the expression of the genetic code (transport, translation, regulation, etc.)

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PROPERTIES

SEARCHING FOR THE STRUCTURE-FUNCTION LINK

Despite the wide variety of industrial materials (formulations, soft materials, packaging, etc.), there is a high degree of uniformity in the organization of the material (chemical composition, microstructure). In contrast, biological materials exhibit highly complex structural arrangements at all scales: a simple crustacean shell is organized at 8 to 10 different scales ranging from the nanometer to the millimeter scale (fiber alignment, multilayer organization, spiral configuration, controlled porosity, etc.)...

In living organisms, starting at the molecular level, the spatial organization of matter contributes to confer one or more biological functions (structural or metabolic). Biomimicry allows us to navigate the complexity of biology in order to:

- Simplify living systems to return to their essential target function, thereby bypassing part of the evolutionary history that gave rise to this complexity;

- Take advantage of this property: a higher level of organization allows different interesting properties to emerge from simple building blocks.

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Examples

- Targeted action: the function and specificity of enzymes and hormones depend on the three-dimensional folding of their active sites

- Macromolecules: their spatial organization enables large molecules to function as structural materials (long fibers in elastin and collagen, etc.) or storage materials (branched structures for energy in glycogen; tightly folded structures for genetic information in nucleic acids)

- Mechanical strength of composites: the abalone shell (mother-of-pearl) is composed of 95% calcium carbonate, a mineral similar to chalk (brittle, with low tensile strength), and 5% protein (soft material). The multilayered arrangement of micrometric mineral plates surrounded by an organic binder gives the shell an overall mechanical strength far greater than that of its individual components.

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TRANSFORMATION

SYNERGY EFFECTS: THE INGREDIENT IN ITS ELEMENT



The purification of plant extracts or the extraction of active ingredients are standard steps in the processing of natural raw materials for cosmetic use. By isolating a molecule, these processes allow it to be concentrated and its activity to be enhanced; however, this approach forgoes potential synergies present in the original context.

Biochemistry is a complex set of processes in equilibrium. The physicochemical environment (presence of inhibitors or catalysts, pH, temperature, etc.) plays a decisive role in regulating biological activity.

Beyond the ingredient itself, biomimicry encourages a more systemic, multi-scale perspective that also takes into account contextual factors that are more conducive to the desired function. In a biomimetic approach, this may involve recreating the right conditions or, more naturally, eliminating certain purification steps.

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Examples

- Phase transition : in spider abdomen, pH variation under flow drive the production of silk fibers
- Regulatory molecules: activators and inhibitors affect enzymatic activity

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#8

TRANSFORMATION

LIFE'S MANUFACTURING



Although often less visible than product innovation, process innovation presents a major opportunity to reduce environmental impacts and costs, thereby providing significant competitive advantages.

Can we produce our materials in the same way that living organisms build the structures that make them up? Can we view a cell as a miniature chemical factory? Can we draw a parallel between the material-energy balance of a company or a region and the metabolism of an organism or an ecosystem?

Biomimicry draws inspiration not only from biological systems but also from the processes in which they operate, as well as their methods of production and transformation. This involves relying on the same physical and chemical mechanisms and adhering to the same constraints (local, energy-efficient, controlled toxicity, etc.) .

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Examples

- Bio-inspired processes: biomineralization, sol-gel processes, self-assembly, encapsulation, 4D printing...

- Principles of green chemistry: clarifying the requirements of biological chemistry to help the industry transition toward more sustainable processes

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#9

IMPACT

BIOMIMICRY & NATURAL SUBSTANCES, A WINNING COMBINATION ?



Alongside the rise of biomimicry, the cosmetics industry has standardized concepts related to natural ingredients: bio-based and minimally processed. What synergies should be fostered at the intersection of these concepts and biomimicry?

While naturalness refers to a very material-based approach to biological substances, biomimicry is a much more conceptual approach: drawing on the structures and mechanisms of living organisms to rethink our systems. The implementation of a bio-inspired solution can be more or less closely aligned with living organisms: an eco-designed artificial system, nature-based solutions, or, in a hybrid approach, the use of biotechnology.

Naturalness and biomimicry can thus coexist through the synergistic combination of natural substances transformed by bio-inspired processes and integrated into biomimetic mechanisms. The solutions proposed in this coherent approach are more likely to align with the dynamics of the environment in which they will be deployed. They have greater potential to meet the needs of circularity, sustainability, and safety.

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Example

- Biomimetic structures and natural materials: white materials inspired by the shells of *Cyphochilus* beetles, made from plant-based cellulose (Seprify)

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IMPACT

FROM PERFORMANCE TO ROBUSTNESS

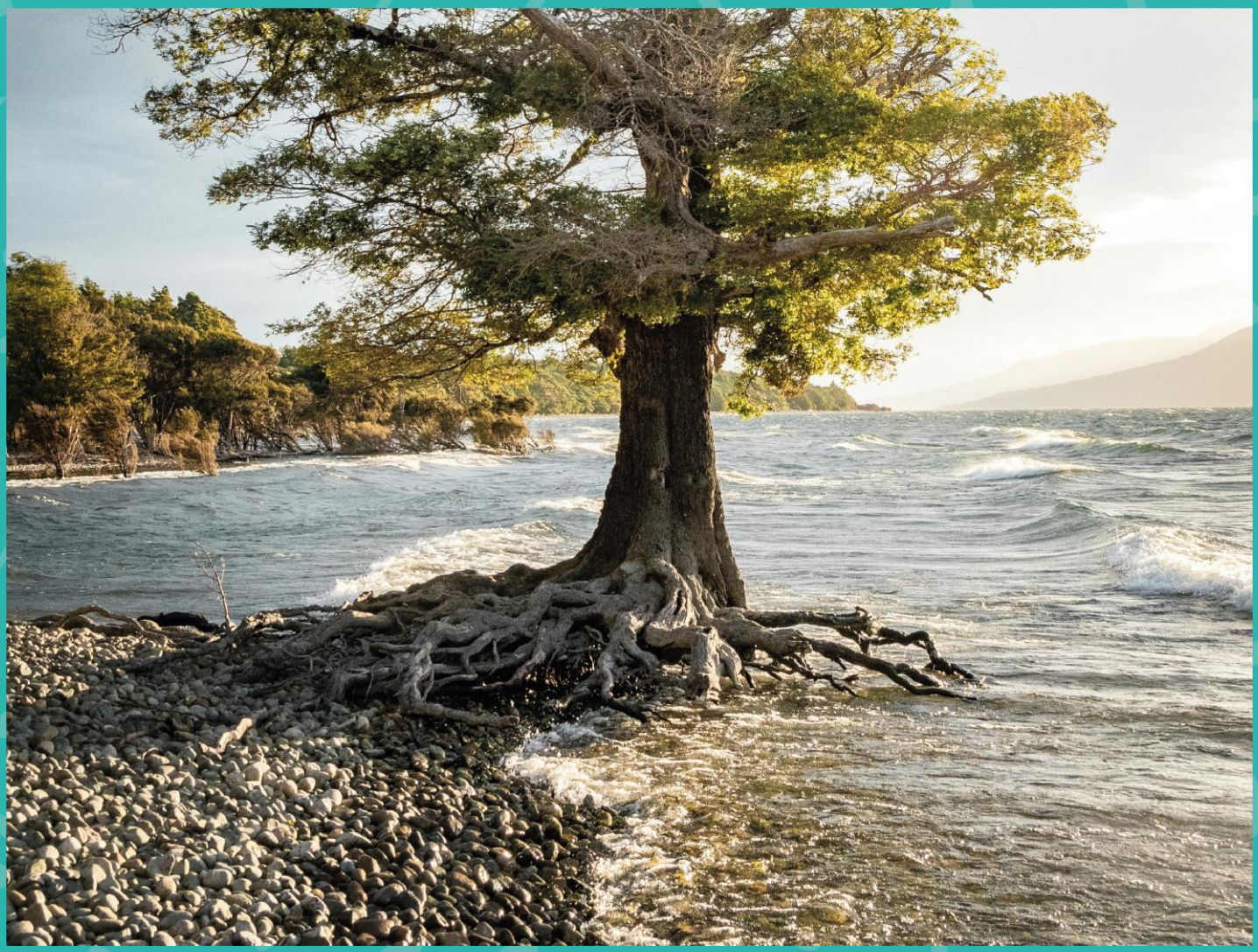


For health and safety, competitiveness, and customer satisfaction reasons, all industries are focused on improving the performance of their products and processes. However, taking this optimization to the extreme in an increasingly volatile world can have adverse effects.

The concept of performance is directly linked to the context in which it is implemented. "Under given conditions, a system said to be high-performing is one of the best at performing a given function." But as soon as conditions change, this performance can prove to be very fragile. On the contrary, the robustness observed in living systems—as defined by Olivier Hamant—is a more suitable response to a fluctuating world. It involves being able to maintain a property under varying conditions... The goal is to be able to maintain a property under a much wider range of conditions. Biomimicry encourages us to rethink the criteria for innovation, shifting our focus from performance to robustness.

Depending on the scale (molecular, anatomical, ecosystemic), the resilience of biological systems is based on concepts such as diversity, redundancy, decentralization, regeneration, and self-repair.

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Example

- In mammals, the optimal operating temperature for enzymes is closer to 40°C (performance), corresponding to a febrile state, rather than that of normal metabolism (robustness).

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