Studies of applications to bionics of composite materials in Universita’di Camerino

Coordination

Dr. Carlo Santulli

Carlo Santulli is associate professor in materials science and technology at Università di Camerino since 2012, where it lectures on materials technology, waste management and environmental sustainability in the school of science and technology, and he previously lectured on the experimentation of innovative materials for design in the course of industrial and environmental design. Graduated in chemical engineering section materials (Sapienza 1991), in arts (modern history) (Sapienza 2001), 1991), in arts (modern history (Sapienza 2001), PhD in materials science and engineering (Liverpool 2000), master in environmental decision making (Open University 2004). “Cervello di rientro” (re-entrant researcher) from the United Kingdom in 2006.

Prof. Santulli’s principal research interests are on composite materials, non destructive control, natural fibers, materials sustainability, management and upcycling of waste and biomimetics. He has over 30 years of experience in this field, having worked at Università di Roma - La Sapienza, Joint Research Center – Ispra, University of Liverpool, University of Nottingham, University of Reading and Seconda Università di Napoli. He has also been invited researcher at Katholieke Universiteit Leuven, Ecole des Mines de Saint Etienne, Université de Rouen, Università di Bologna and Universiti Teknologi Malaysia. He has over 250 scientific publications, and an educational book on biomimetics (with Luigi Milani: “Biomimetica: la lezione della natura”), translated also in English and Spanish (Figure 1). He also develops activities for dissemination of themes related to environmental issues and on sustainability in schools and other contexts.

His introduction to biomimetics has been triggered by the knowledge of lignocellulosic fibers as natural structures, starting from jute, hemp, and many other fibers following this. From his arrival in 2001 in Reading as research fellow for five years at Centre for Biomimetics, directed by Giorgio Jeronimidis, he investigated, other than the study of natural fibers, other subjects related to biomimetics, in particular:

- Response to air stream and frequency excitation of mechanical receptors on cricket cerci (Figure 2)
- The development of polymer actuators in polypropylene fabric and cellulose and acrylamide poly-electrolyte gels
- Study of electrolyte polymers for artificial muscles applications (ESA project)

Il contatto con l’ambiente di Reading lo aveva portato ad interessarsi alle applicazioni della biomimetica al design.

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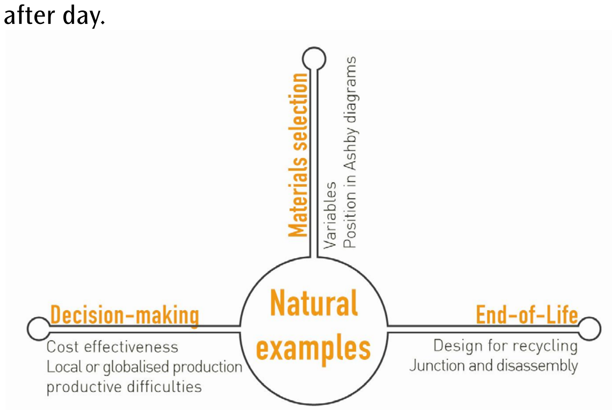
Figure 1 Cover from the book “Biomimetica: la lezione della natura” (CiEsse edizioni, 2012-2019)

In November 2005 he came into contact with Carla Langella, researcher at the Seconda Università di Napoli: with her he started a fruitful collaboration, based on the melting pot, defined as “hybrid design”, between the natural indications and the engineering problems, which are really models of issues existing as for object function and operational life, to which the materials need to respond, adapting their character to them (Figure 2).

The theme of natural materials application and of obtained waste down the line is a subject that has an increasing interest, especially in view of re-interpreting waste according to its “personality” and it might encompass all his research activity. The characteristics of research by Carlo Santulli and his collaborators is to favor a continuous exchange and interaction between biomimetic inspiration and the structural meaning of natural materials, also expressed in the waste that nature offers to us day after day.



The structure of hybrid design and materials role

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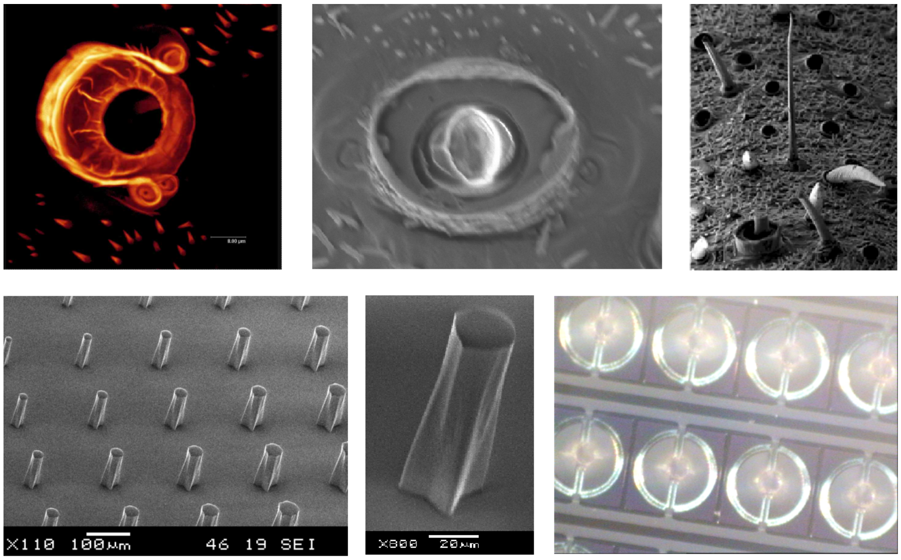

Figure 2 (top) Campaniform (for deformation), filiform (for vibration), conical (chemical) sensors in cricket; (bottom) different views of microchips with tips inspired to cricket sensors

Nature mimicking starts from the comprehension of observed morphologies under the electron microscope on natural fibers, which naturally brings to a hierarchical structure and an interpretational sense to which of auxetic characteristics: these are independent from the material, yet enable the deflection of the cellular structure, rather than its compression under load, therefore allows them withstanding to complex loading e.g., off-axis torsion, during use.

It is not a case that natural structures have always cellular structures with concave polygon cells, sometimes with largely variable number of sides, as reported in Figure 4, whereas in Figure 5 also the presence in section of micro-tubular structure rolled and peeled back is reported.

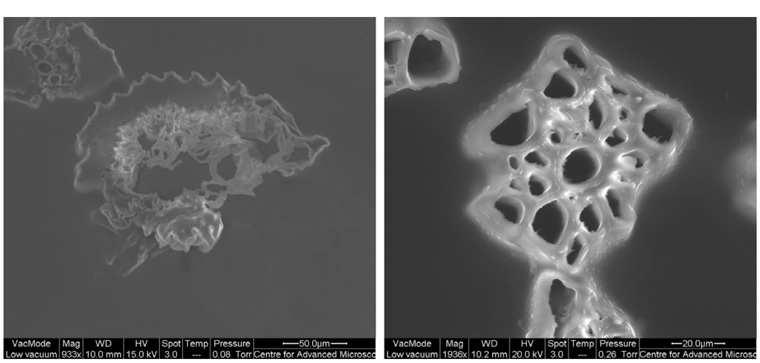

Figure 4 Section view of pineapple fiber (left) and of okra bahmia fiber (right)

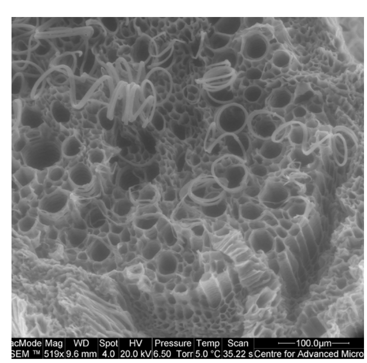

Figure 5 Section view of a celery fiber

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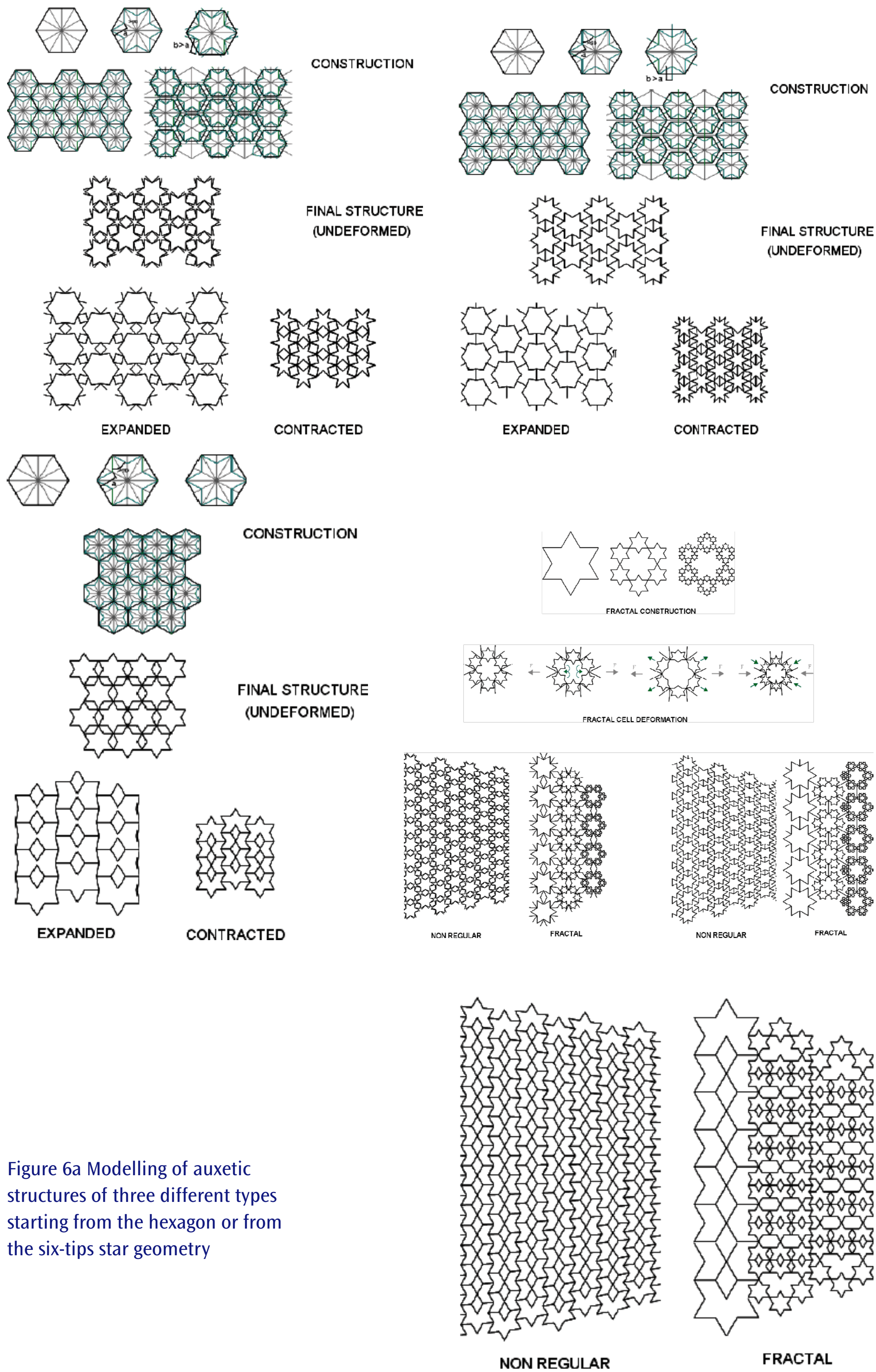

Figure 6a Modelling of auxetic structures of three different types starting from the hexagon or from the six-tips star geometry

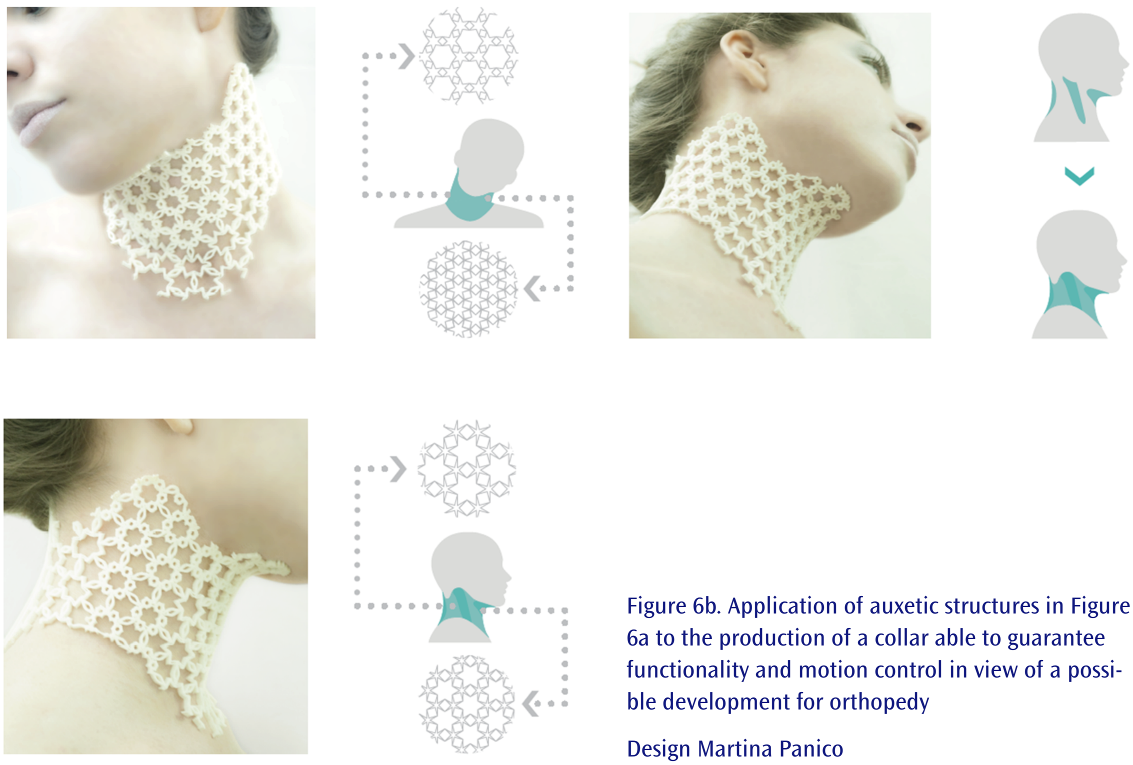

Figure 6b. Application of auxetic structures in Figure 6a to the production of a collar able to guarantee functionality and motion control in view of a possible development for orthopedy

Design Martina Panico

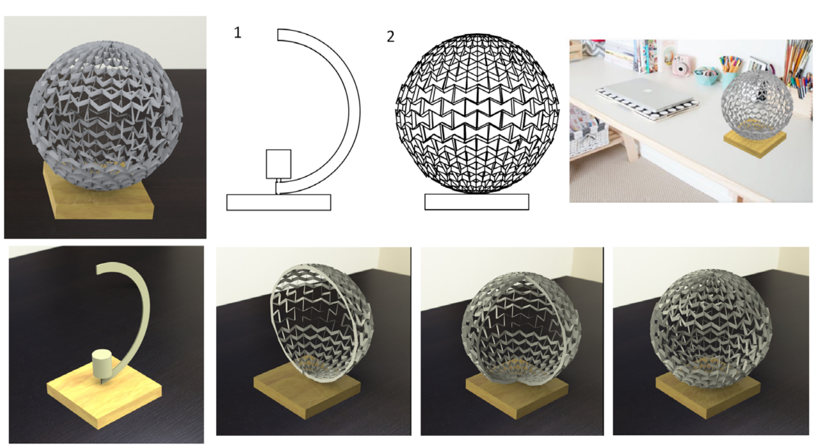

Figure 7 Auxetic lamp “Moon” (Design Giorgia Alluzzi)

Reasoning on the auxetic structures and their application into design has continued over the years with some design projects, again in collaboration with Carla Langella (Figure 6a and b), or also autonomously in the school of architecture and design in Università di Camerino (Figure 7).

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Over the years, other reflections have been developed on issues present in nature, in particular for example on reversible types of junctions, such as those of diatoms (Figure 8), the modes of spillage and absorption of water with non-linear geometries (Figure 9),

The use of concealing by crypsis for projects linked with road safety exploiting the bioluminescence, on which a concept has been developed for the global evaluation of its functions for its possibilities in design (Figure 10).

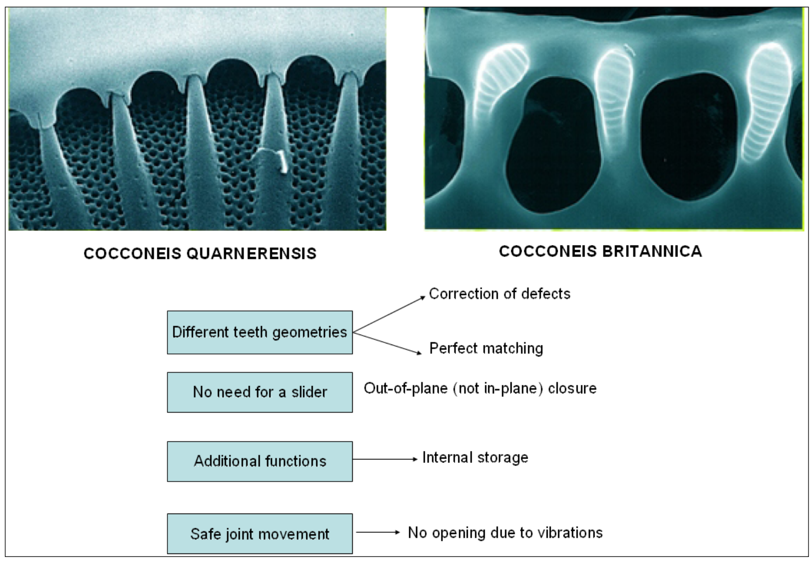

Figure 8 Evaluation of the different junction characteristics of two diatoms of the Cocconeis family and comparison with the characteristics of zipper

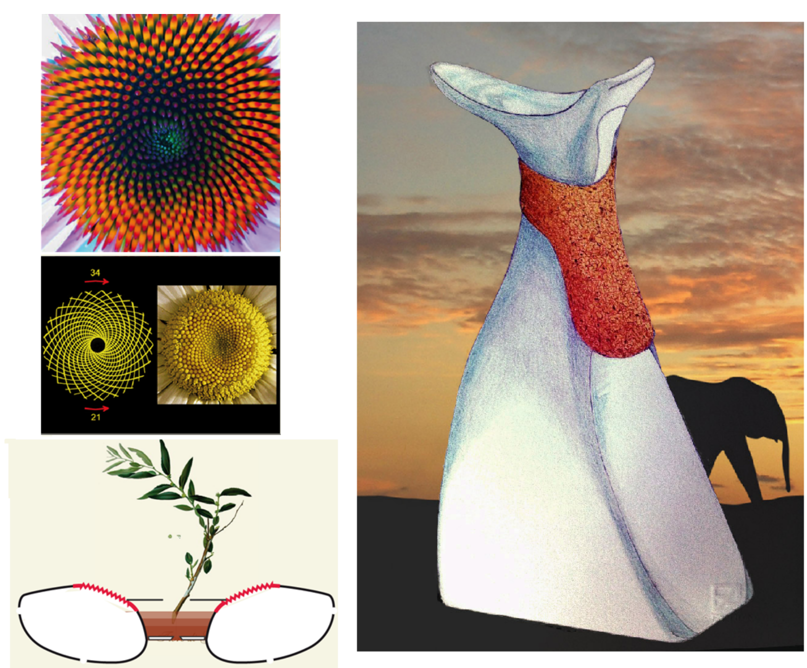

Figure 9 (left) Scheme of pot for irrigation inspired to sunflower flosculi; (right) Jar with mouth inspired to the elephant trunk opening (design by Giulia Pressi)

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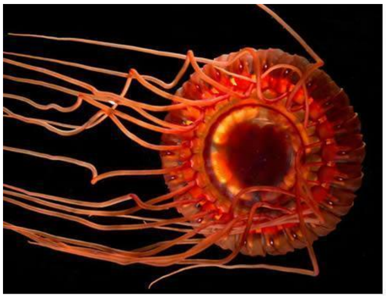

Atolla wyvillei (medusa)

Euprymna scolopes (seppia)

Mycena lux coeli (fungo)

Panellus stipticus (fungo)

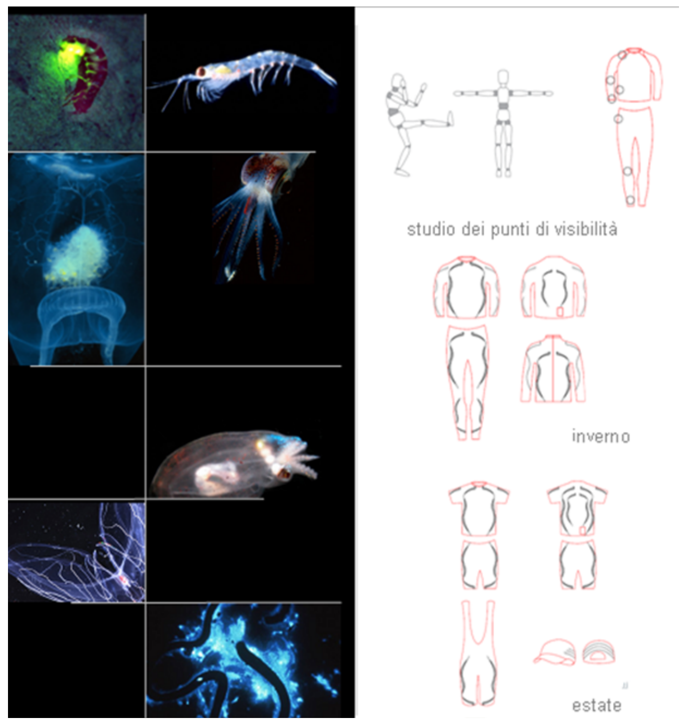

Figure 10 Different types of bioluminescence and possible application to the visibility of an individual in conditions of danger

The real influence of bio-inspiration of product development has been examined though in another project, conducted with the collaboration of the designer Teresa Carnevale, to try to clarify how much the properties derived from nature can assist into bringing the product to be more effective: the results have been controversial, and show more than anything else that the efficacy of biomimetics can be methodological and didactical, going beyond the fact that this process would translate in a product totally bio-inspired (Figure 11). There is in effect also a potential for possible hybridization between nature and technology, and underlying to this there is the problem of natural design, which disregards the material to be used, yet tends to employ just a few of them and in a way to allow the development and structural modification during the life of the species.

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Confronto Materiali con Proprietà Traspirante

Proprietà tipica di quei materiali che eliminano acqua e altri liquidi attraverso i pori in forma di piccole gocce o di vapore acqueo

LEGENDA
Materiali bio-ispirati
Materiali non bio-ispirati

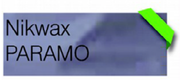
	Tipo	Bio ispirazione	Sostanze	Tecnologia	Limiti	Utilizzi
 C_Change SCHOELLER	***Tessuto membrana***	***Pigna***, le sue alette si aprono e si chiudono in base alla temperatura e all'umidità	Speciale ***membrana polimerica*** (il nome è un segreto industriale)	La membrana si ***contrae*** ad un temperatura che va ***da 20 a 10 °C***, invece si ***espande*** ad una temperatura che va ***da 10 a 20 °C***	Può essere usato ***senza essere accoppiato*** ad altri tessuti	Usato in ***abbigliamento spotivo***
 Goretex GORE	***Tessuto membrana***	***Farfalla Morpho***, le sue ali leggere e delicate resitono alla pioggia e si dispiegano da crisalide fino a 16 cm	- Membrana polimerica in ***PTFE*** - Sostanze ***olefobiche***	La membrana ha ***1,4 milioni di pori per cm²***, più piccoli di una goccia d'acqua ma più grandi di una molecola di vapore acqueo	Usato ***unicamente*** accoppiato ad altri tessuti	Usato in ***abbigliamento spotivo*** dove leggerezza, elasticità e non ingombro sono essenziali
 Nikwax PARAMO	***Tessuto membrana***	***Pelliccia dei mammiferi***, i loro peli idrorepellenti spingono via l'acqua dal corpo, mantenendo il giusto comfort termico	- Strato ***Liner Pompa*** in ***poliestere*** - Strato esterno in ***microfibra***	Il tessuto è costituito da ***fibre direzionali asimmetriche*** che sfruttano il principio della ***capillarità*** per spingere l'acqua all'esterno	Usato accoppiato ad altri tessuti come la ***microfibr***a o il ***pile***	Usato in ***abbigliamento sportivo***
 Geox GEOX	***Tessuto membrana***	——	Speciale ***membrana polimerica*** (il nome è un segreto industriale)	La membrana ha ***un miliardo di pori per cm²***, più piccoli di una goccia d'acqua ma più grandi di una molecola di vapore acqueo	Usato accoppiato alla suola in ***gomma forata***	Usato solo per la produzione di ***calzature***

Figure 11
Comparison of a material with transpiring properties with a similar material that does not declare explicitly a bio-inspired character

Joining together all these considerations brought to elaborate a way of reasoning on the modalities and the educational goals for an introduction of biomimetics, in synergy with natural materials, and therefore end-of-life and more recently the use of waste, which had been elaborated with the the "Triplaerre" project, starting in 2009, and had many applications in schools and societies/clubs for environmental divulgation in the Italian context (Figure 12).

The work that can be predicted in the future tends to merge bio-inspiration with use of materials and natural waste according to their "personality", according to a methodology that would tend didactically to obtain a more resilient design with possible implications of approaching circular economy, then total re-use, then biodegradation.

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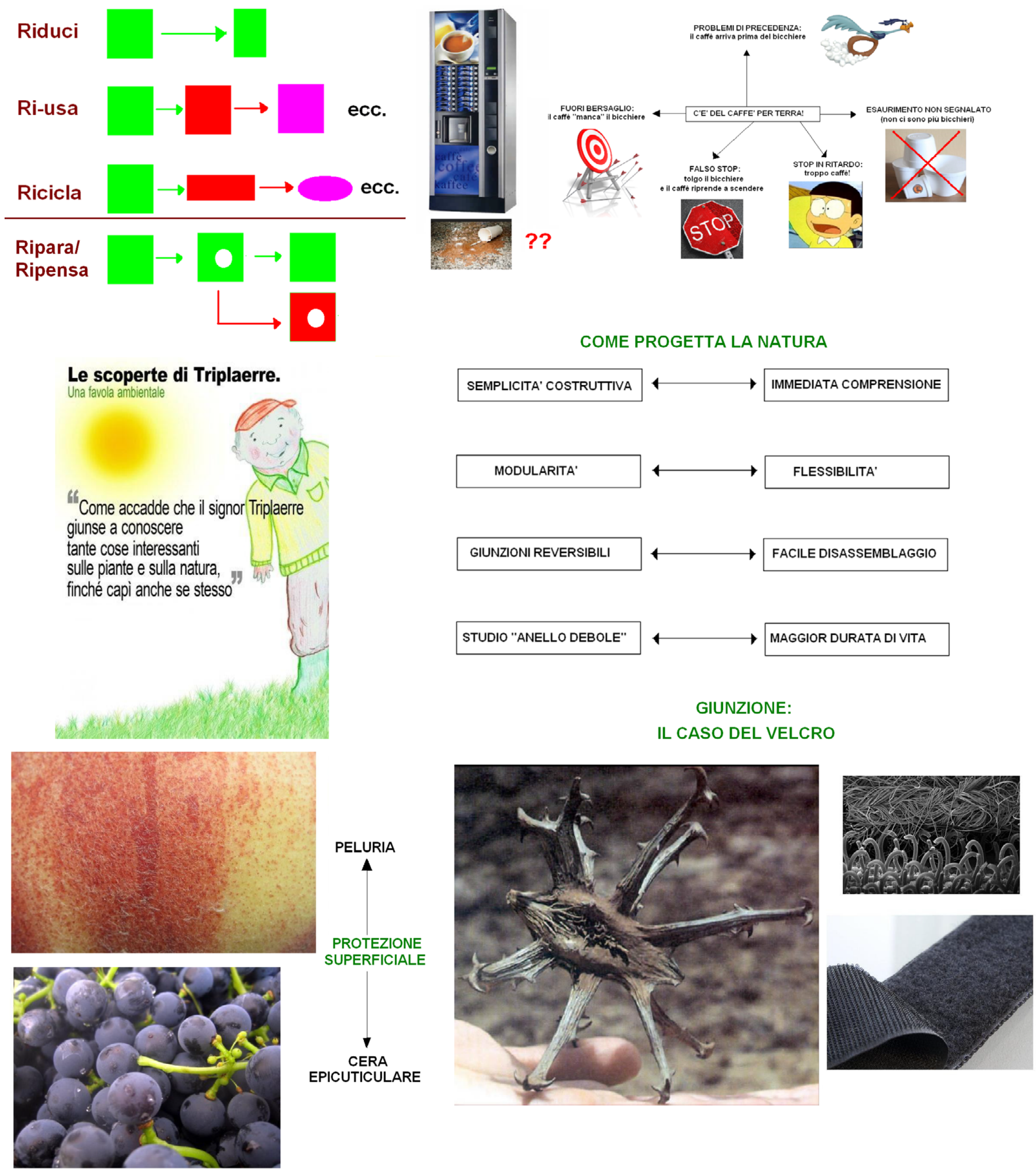

Figure 12 General scheme of environmental education through an approach able to consider the didactic goals of biomimetics.