ENTOMIMETICS

TRANSFERENCES FROM INSECT'S MORPHOLOGY AND BEHAVIOR TO DESIGN

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Beyond their formal characteristics, insects possess physical properties that have allowed them to adapt and survive in hostile environments. Entomimetic seeks to transfer these properties to design, allowing architecture to learn from those living beings that have faced the environment with their own skins and structures. In other words, those living beings carrying their own architectures.

KEYWORDS · biomimetics, optimization, reproducibility, sustainability, architecture

The *Onymacris unguicularis* beetle lives in the Namibian desert, where water is not even scarce: it simply does not exist at all. So, how does it survive? Its body acts as a fog-catcher that, when related to the nearby sea breeze, produces the condensation needed for procuring this vital element. There is no doubt that in a global scenario where aridity is increasing, those successful strategies to access fresh water will be increasingly in demand. But like this beetle, there are many plants and animals' species that show forms and behaviors that allow them to successfully obtain water. What if we could transfer these forms and behaviors to objects or buildings design? We could, for example, facilitate human life or enhance land productivity in arid areas.

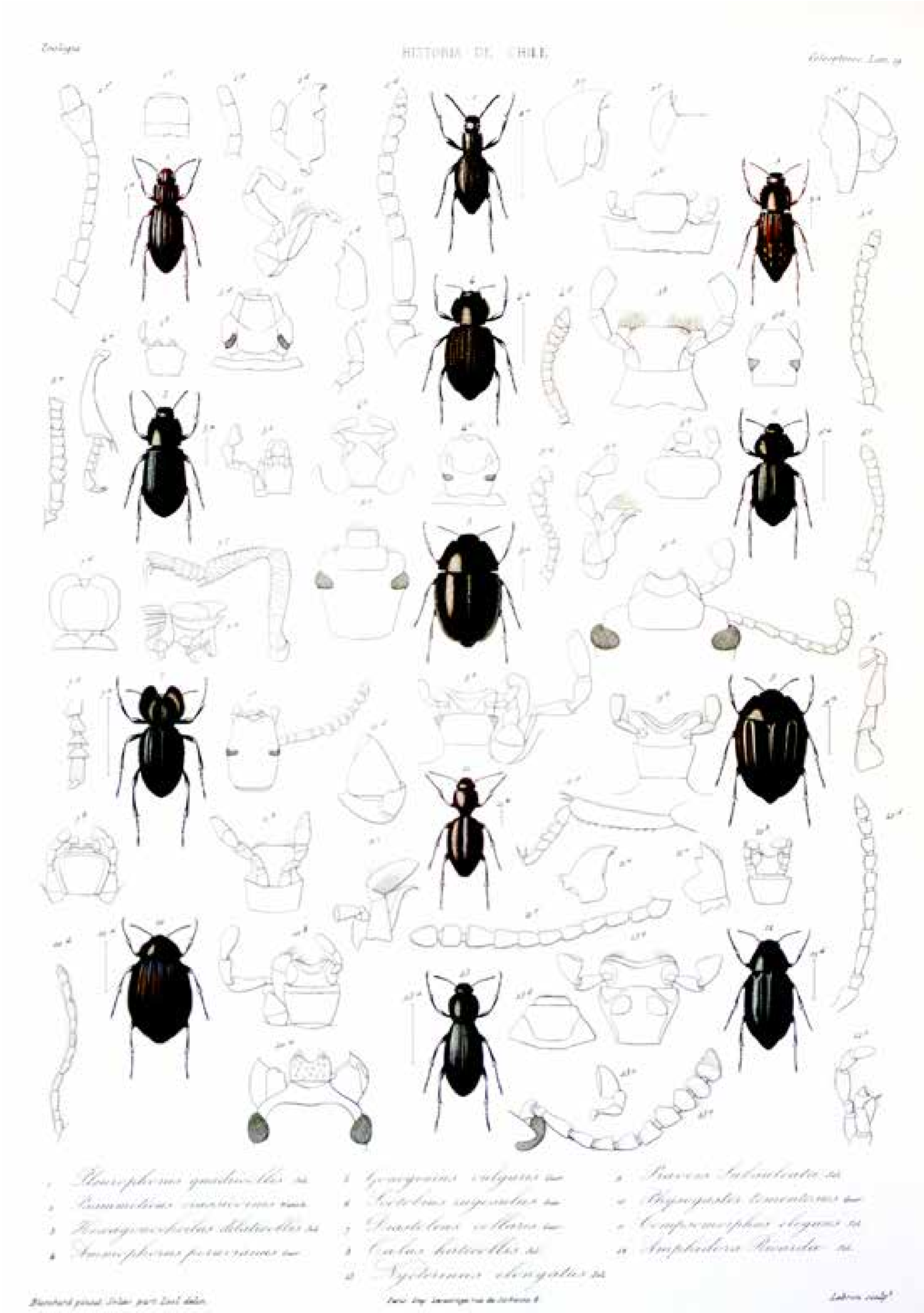


FIG 1 Dibujos de una serie de especies de escarabajos y sus componentes
Drawings of a series of beetles species and their components.
Fuente / *Source*: GAY, Claudio. *Atlas de la Historia Física y Política de Chile*. Paris, Imprenta de E. Thunot y C°, 1854. Lámina / *Plate* N°19.

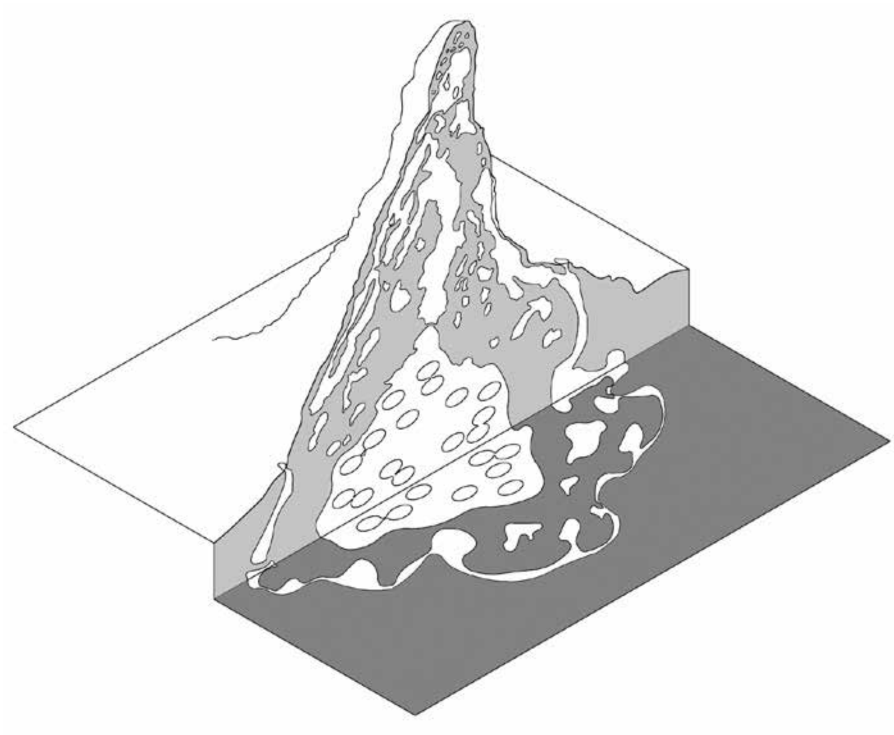


FIG 2 Isométrica cortada de un termitero de *Macrotermes michaelseni*, donde se pueden observar los distintos elementos que componen su sistema de ventilación. / *Isometric section of a* Macrotermes michaelseni *termite nest, showing the different elements building its vent system.* Concepto / *Concept*: Alejandro Soffia Dibujo / *Drawing*: Leonardo Suárez

Let's observe now the many butterfly species that are active during the night (*Heterocera* Suborder), sometimes called moths. For them, the night's darkness is the best ally against their predators. Thus, their body is essentially opaque and, in most cases, dark. For the same reason, and to avoid flashes that could expose them, their eyes – the only bright surface of their body – have a micro-texture that prevents reflection. Specifically, the nanometric conformation of their eyes surface contains a texture that completely absorbs any possible luminosity, thus remaining hidden as they fly in the dark. What if building components generating energy or heat through solar radiation could occupy the same principle of light absorption? They would likely optimize the sun's rays and produce much more energy than they do today.

Both these cases – beetles (*Coleoptera* Order) and butterflies (*Lepidoptera* Order) – belong to the hexapods subclass but are perhaps the most dissimilar morphological expressions within the same taxon[1] (FIG. 1). They have forms or behaviors that can solve the same design problem we face in the paradigm of sustainable development. Although the observation of natural components is not a recent fact, the contemporary approach to what has been called biomimetics

1 A taxon corresponds to each of the hierarchically ordered categories that group living organisms according to their morphological characteristics. Thus, *order* and *class* are categories, however *class* associates a smaller amount of common characteristics and, therefore, a greater quantity of species. Meanwhile, *order* includes organisms that share many morphological characteristics and, consequently, is a smaller group in species types. To sum up, *order* ranks below *class* hierarchically.

FIG 3 Ilustración que grafica las tres escalas que componen el fenómeno adaptativo del termitero de *Macrotermes michaelseni*. En el hexágono superior se puede apreciar la exposición de la estructura a la radiación del sol y el viento, y la conducción de temperatura en el suelo. En el hexágono inferior izquierdo, un aumento para observar los componentes de la estructura de un termitero. En el último hexágono, un aproximación aún mayor para observar los conductos de aire que alojan el intercambio con aire fresco del exterior del termitero.
Illustration showing the three scales of the Macrotermes michaelseni *termite nest's adaptive phenomenon. In the upper hexagon, the structure's exposure to sun radiation and wind, and the temperature transmission to the ground. In the lower left hexagon, a detail of the termite nest's structural components. In the last hexagon, a zoom in to observe the air ducts that exchange fresh air from the outside.*
Concepto / *Concept*: Alejandro Soffia
Dibujo / *Drawing*: Leonardo Suárez

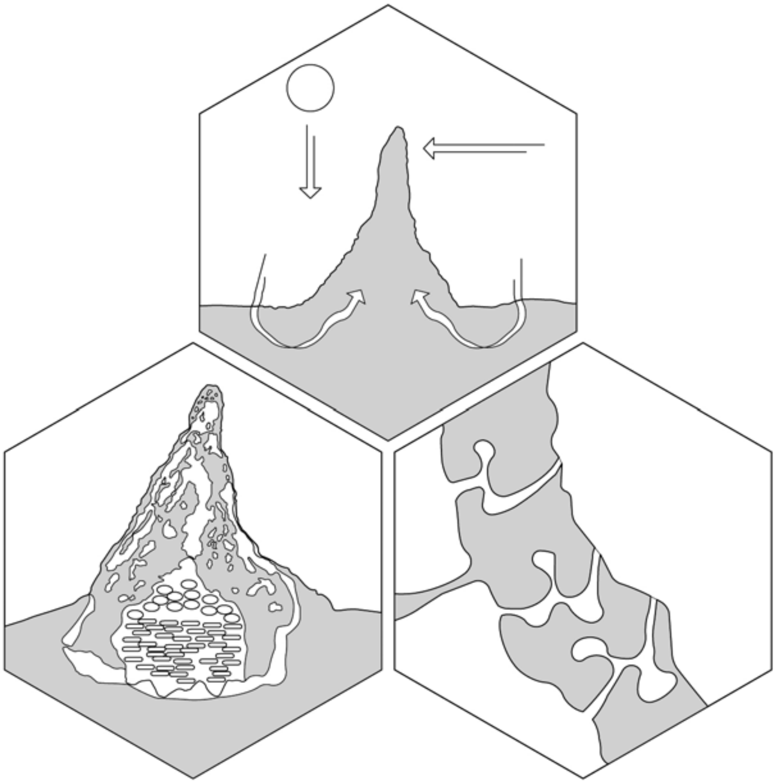
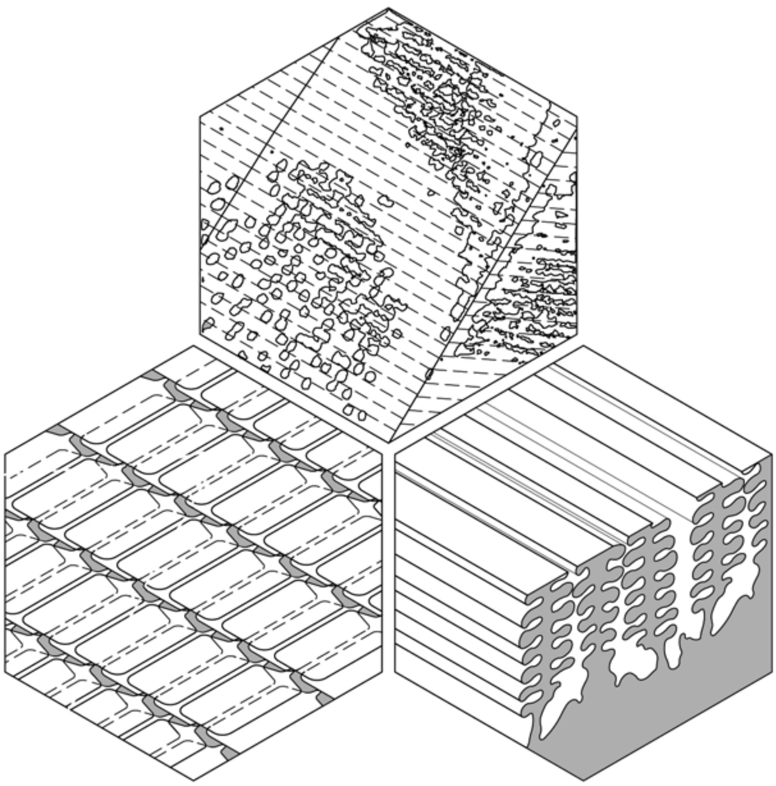


FIG 4 Ilustración que grafica las tres escalas que componen el fenómeno adaptativo de las mariposas *Morpho*. En el hexágono superior se puede apreciar la composición por escamas de las superficies del ala de una mariposa cualquiera. En el hexágono inferior izquierdo, un aumento para observar la superposición de escamas de suelo bajo escamas de vidrio en el género *Morpho*. En el último hexágono, una aproximación aún mayor para observar una isométrica cortada del espesor de una escama de suelo. Allí se puede observar una microestructura que replica la superposición de superficies para multiplicar la luz incidente.
Illustration showing the three scales of the Morpho *butterflies' adaptive phenomenon. In the upper hexagon, the scaly composition of any regular butterfly wing surface. In the lower left hexagon, a zoom in to observe the overlap of ground scales under glass scales in the* Morpho *genus. In the last hexagon, a greater zoom in to observe an isometric section of a soil scale's thickness. It shows a microstructure that replicates the superposition of surfaces to multiply incident light.*
Concepto / *Concept*: Alejandro Soffia
Dibujo / *Drawing*: Leonardo Suárez



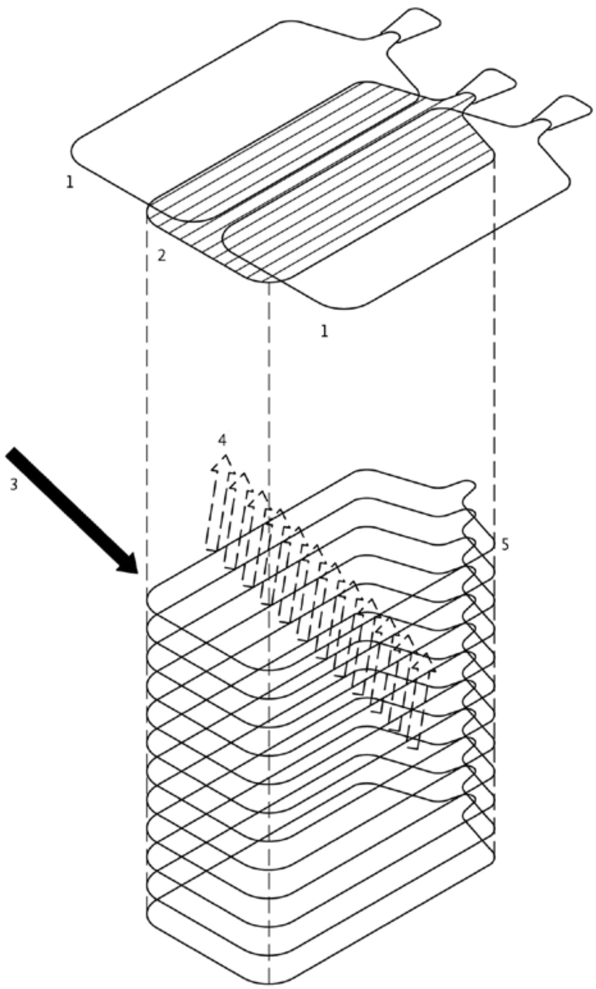


FIG 5 Isométrica explotada que grafica el fenómeno de multiplicación de la luz solar sobre el ala de una mariposa *Morpho*.
Isometric showing the phenomenon of sunlight multiplication on the wing of a Morpho *butterfly.*
Concepto / *Concept*: Alejandro Soffia
Dibujo / *Drawing*: Leonardo Suárez

LEYENDA / *LEGEND*

1. Escamas superiores de vidrio / *Top glass scales*
2. Escamas inferiores de suelo / *Bottom ground scales*
3. Dirección de la luz incidente / *Direction of incident light*
4. Reflexión de la luz / *Reflection of light*
5. Múltiples superficies que componen la escama de suelo / *Multiple surfaces composing the ground scale*

or biomimesis focuses on nature's forms, behaviors or phenomena that optimize resources, mitigating any negative impact. Then, what is observed in its natural state – or what we can understand as a biological referent – must be transferred technologically through physical principles, forms or performance to design.

Biomimetics operates not only based on living organisms but also abiotic phenomena. That is, it takes as a transference source the sum of elements that form our biosphere, achieving a large number of case studies – be they species or phenomena. However, I will focus on the insect's taxon, as it has proven to be the most successful group in evolutionary terms and, in recent biomimetics development, not only they represent the largest number of transfers (Bushan, 2009), but also the most extensive source of biological references from among the million species described for our planet.

According to the taxonomic system, we will call "entomimetics"[2] the technological transfer that is based on

2 From the Greek *Entomos*, insect and *mímēsis*, imitation.

FIG 6 Ilustración que grafica las tres escalas que componen el fenómeno adaptativo del escarabajo *Stenocara dentata*. En el hexágono superior se puede apreciar la disposición contra la brisa marina que adopta el volumen ovalado del insecto. En el hexágono inferior izquierdo, un aumento para observar la textura granulosa de sus élitros, que multiplica la superficie de roce, y atrapa las gotas de agua con sus cimas hidrófilas. En el último hexágono, un aproximación aún mayor para observar la textura de las superficies de las concavidades presentes en los élitros. En esta escala las cimas son hidrofóbicas por lo tanto favorecen la circulación del agua capturada.
Illustration showing the three scales composing the Stenocara dentata *beetle's adaptive phenomenon. In the upper hexagon, the position against the sea breeze adopted by the insect's oval volume. In the lower left hexagon, a detail of the granular texture of its elytra, which multiplies the friction surface, catching the water drops with its hydrophilic tops. In the last hexagon, a zoom in to observe the texture of the concavities present in the elytra. At this scale the tops are hydrophobic, favoring thus the circulation of the captured water.*
Concepto / *Concept*: Alejandro Soffia
Dibujo / *Drawing*: Leonardo Suárez

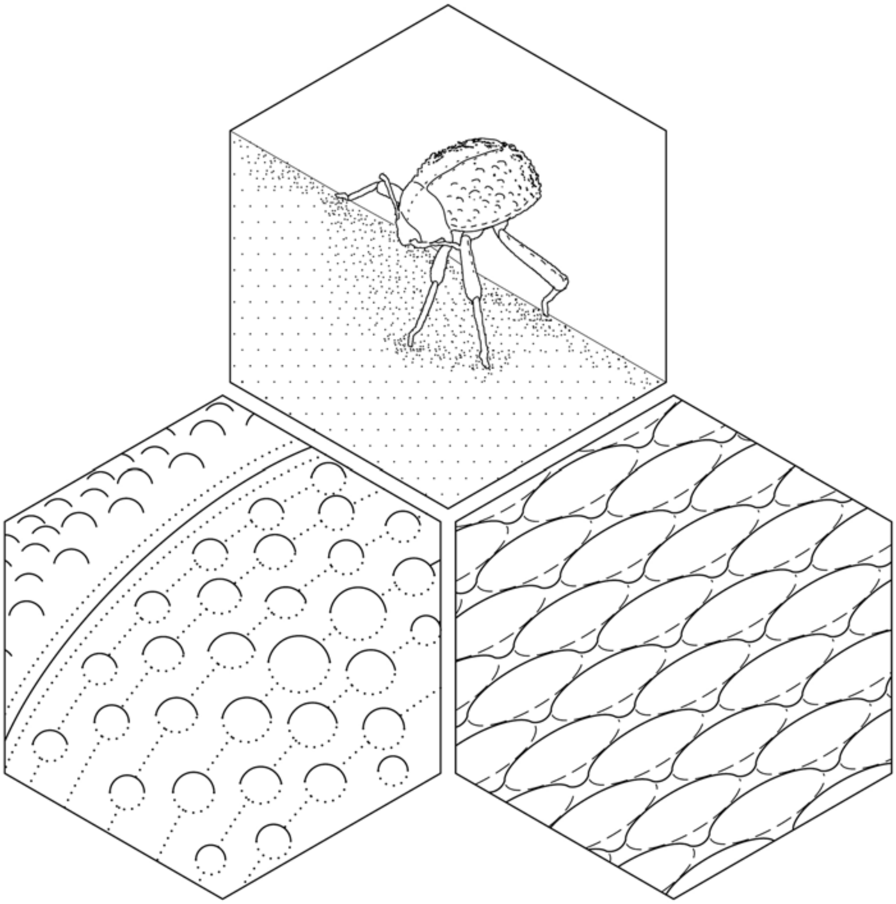
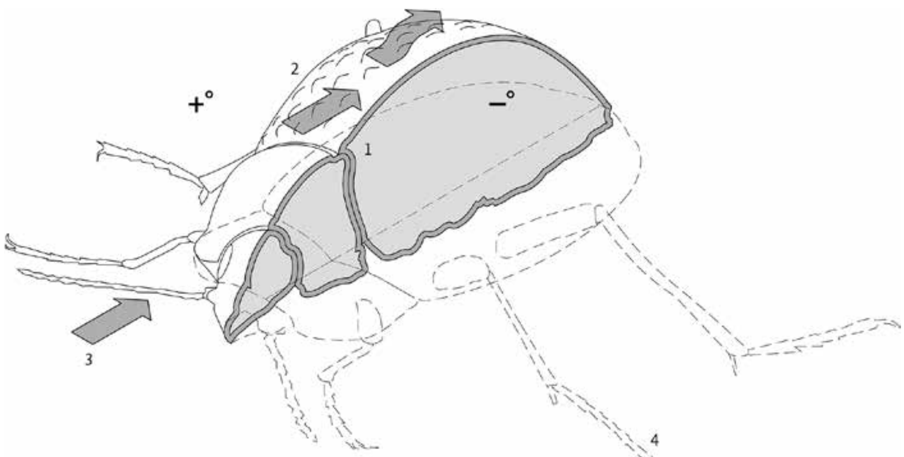


FIG 7 Isométrica cortada a través del eje longitudinal de un escarabajo de la familia *Tenebrionidae*, que muestra la diferencia de temperatura entre el exterior y el exoesqueleto del insecto.
Isometric section through the longitudinal axis of a Tenebrionidae *beetle, showing the temperature difference between the outside and the insect's exoskeleton.*
Concepto / *Concept*: Alejandro Soffia
Dibujo / *Drawing*: Leonardo Suárez

LEYENDA / *LEGEND*

1. Exoesqueleto / *Exoskeleton*
2. Superficie granulosa propia del *Stenocara dentata* presente en su abdomen / *Granular surface of* Stenocara dentata *present on its abdomen.*
3. Dirección de la brisa marina / *Sea breeze direction*
4. Proyección de la posición de las patas que permiten la inclinación del abdomen, que recibe el agua. / *Projection of the position of the legs allowing the inclination of the abdomen, which receives the water.*



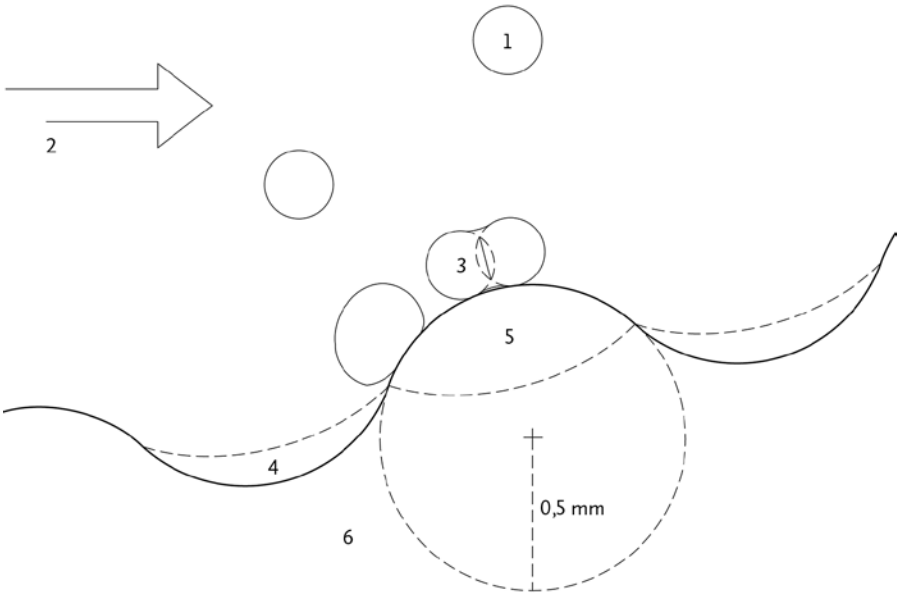


FIG 8 Corte esquemático que muestra el proceso de captura del agua. / *Schematic section showing the water capturing process.*
Concepto / *Concept*: Alejandro Soffia
Dibujo / *Drawing*: Leonardo Suárez

LEYENDA / *LEGEND*:

1. Gotas de agua provenientes de la brisa / *Drops of water from the breeze*
2. Dirección del viento / *Wind direction*
3. Fusión de gotas de agua / *Water drops fusion*
4. Concavidad hidrofóbica del élitro del escarabajo *Stenocara dentata* / *Hydrophobic concavity of the* Stenocara dentata *beetle's elytra*
5. Convexidad hidrófila / *Hydrophilic convexity*
6. Exoesqueleto del escarabajo / *Beetle's exoskeleton*

the observation of insects' morphology or behavior. The areas in which this could contribute to design are diverse. For instance, building components could become quantitative markers of the benefits provided by the biomimetic strategy to construction (measurable at least at mass level), enabling to state that an insect 'x' adaptation affected positively a 'y' percentage of the building. In the case of bioclimatic termites, the influence of its ventilation system impacts greatly on Mike Pearce's Eastgate Center in Harare, Zimbabwe (FIGS. 2, 3). It has been estimated that the building's energy consumption decreased 90% in relation to those of similar morphology.

A technological design-oriented transfer – originated in the observation of an insect's morphology or behavior – can also be measured by the degree of formal abstraction that allows its technical reproducibility with existing means. Thus, there would be abstract products – whose function would be detached from their original form – and products in which a formal match existed between the insect's morphology or behavior and its own shape or performance. For the latter, most of the transfers implemented consist on replicating the microstructures responsible for the virtues of an insect's particular adaptation phenomenon. For example, 'digital scales' are the microscopic reproduction of a butterfly's scale microstructure, transforming it into a pixel; its width, length, height and materials are replicated to achieve effectiveness in the production of a color beam (FIGS. 4, 5).

In products where the transference is a more abstract one, on the other hand, it consists of physical principles, such as water condensation in the case of the 'fog-catcher' beetle (FIGS. 6, 7, 8). From this viewpoint, while the digital scales transfer the physical principle of reflectance, to achieve it they require the reproduction of a mechanical microstructure very similar in morphological terms to that of the biological referent. However, for the fog-catcher beetle, the physical principle of condensation – transferred to Seawater Greenhouses – abandons its form and does not need to reproduce it. **ARQ**

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