NACHHALTIGwirtschaften

Biologische Kenndatenblätter [biological data base]

Annex 2.4
Zusammenfassende Beschreibung der Phänomene inklusive der wirksamen Prinzipien und Referenzen der selektierten Vorbilder

[Phase 2: Recherche biologischer Vorbilder + wirksamer Prinzipien]. Arbeitsergebnisse

P. Gruber

Berichte aus Energie- und Umweltforschung

46d/2013

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Biologische Kenndatenblätter
[biological data base]

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Zusammenfassende Beschreibung der Phänomene inklusive der wirksamen Prinzipien und Referenzen der selektierten Vorbilder

[Phase 2: Recherche biologischer Vorbilder + wirksamer Prinzipien].
Arbeitsergebnisse

Dr. Petra Gruber
transarch

Wien, Juni 2010

Ein Projektbericht im Rahmen des Programms

HAUS der Zukunft

im Auftrag des Bundesministeriums für Verkehr, Innovation und Technologie

Vorwort

Der vorliegende Bericht dokumentiert die Ergebnisse eines Projekts aus dem Forschungs- und Technologieprogramm *Haus der Zukunft* des Bundesministeriums für Verkehr, Innovation und Technologie.

Die Intention des Programms ist, die technologischen Voraussetzungen für zukünftige Gebäude zu schaffen. Zukünftige Gebäude sollen höchste Energieeffizienz aufweisen und kostengünstig zu einem Mehr an Lebensqualität beitragen. Manche werden es schaffen, in Summe mehr Energie zu erzeugen als sie verbrauchen („Haus der Zukunft Plus"). Innovationen im Bereich der zukunftsorientierten Bauweise werden eingeleitet und ihre Markteinführung und -verbreitung forciert. Die Ergebnisse werden in Form von Pilot- oder Demonstrationsprojekten umgesetzt, um die Sichtbarkeit von neuen Technologien und Konzepten zu gewährleisten.

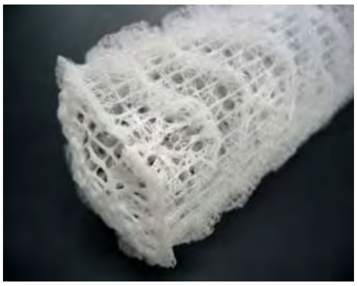
Das Programm *Haus der Zukunft Plus* verfolgt nicht nur den Anspruch, besonders innovative und richtungsweisende Projekte zu initiieren und zu finanzieren, sondern auch die Ergebnisse offensiv zu verbreiten. Daher werden sie in der Schriftenreihe publiziert und elektronisch über das Internet unter der Webadresse **www.HAUSderZukunft.at** Interessierten öffentlich zugänglich gemacht.

DI Michael Paula
Leiter der Abt. Energie- und Umwelttechnologien
Bundesministerium für Verkehr, Innovation und Technologie

Name of Organism or Strategy

6 Fibres guide light: Venus flower basket

Images




NEON ja commons.wikimedia.org/ [03/2010]

Organism term

Venus flower basket (glass sponge)
Euplectella aspergillum Owen, 1841

Keywords / Features

fiber optic, fiber structure, glass fiber

Short description

The venus flower basket is a deep-sea organism belonging to the family of glass sponges. Its skeleton consists of a subtle structure made of glass-like fibres that are made at ambient temperatures.

"Here we present a detailed study of the optical properties of basalia spicules from the glass sponge Euplectella aspergillum and reconcile them with structural characteristics. We show these biosilica fibers to have a distinctive layered design with specific compositional variations in the glass organic composite and a corresponding nonuniform refractive index profile with a highindex core and a low-index cladding. The spicules can function as single-mode, few-mode, or multimode fibers, with spines serving as illumination points along the spicule shaft. The presence of a lens-like structure at the end of the fiber increases its lightcollecting efficiency. Although free-space coupling experiments emphasize the similarity of these spicules to commercial optical fibers, the absence of any birefringence, the presence of technologically inaccessible dopants in the fibers, and their improved mechanical properties highlight the advantages of the low-temperature synthesis used by biology to construct these remarkable structures." (Aizenberg et al. 2004)

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Selection of experts

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Link to Facade Specification Matrix

3

Name of Organism or Strategy

6a Light transmission inside sponges

Images

Karakal commons.wikimedia.org [05/2010]

Organism term

Sea orange (Porifera, Sponge)
Tethya aurantium

Keywords / Features

light transmission, fibre, spicula, silica, sponge

Short description

The structure of sponges that live in symbiosis with phototropic organisms contains fibre glass spicules for transmitting light into deeper tissue regions.

"Sponges are the most basal metazoan organisms. As sessile filter feeders in marine or freshwater habitats, they often live in close association with phototrophic microorganisms. Active photosynthesis by the associated microorganisms has been believed to be restricted to the outer tissue portion of the sponge hosts. However, phototrophic microorganisms have also been detected in deeper tissue regions. In many cases they are found around spicules, siliceous skelettal elements of demosponges and hexactinellids. The finding of phototrophic organisms seemingly assembled around spicules led to the hypothesis of a siliceous light transmission system in sponges. The principle ability to conduct light was already shown for sponge derived, explanted spicules. However it was not shown until now, that in deed sponges have a light transmission system, and can harbour photosynthetically active microorganisms in deeper tissue regions. Here we show for the first time, that, as hypothesized 13 year ago, sponge spicules in living specimens transmit light into deeper tissue regions." (Brümmer et al. 2008)

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Selection of experts

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3

Name of Organism or Strategy

7 Brittlestar calcite microlenses guide light

Image

Hlucho commons.wikimedia.org/ [05/2010], *Ophiochoma echinata*

Organism term

Brittlestar, red ophiocoma (Echinodermata, Ophiuroidea)
Ophiocoma wendtii Agassiz, 1836

Keywords / Features

microlense, optic lense, diffuse light receptor, dermal photoreceptor

Short description

"...that certain single calcite crystals used by brittlestars for skeletal construction are also a component of specialized photosensory organs, conceivably with the function of a compound eye. The analysis of arm ossicles in Ophiocoma showed that in light-sensitive species, the periphery of the labyrinthic calcitic skeleton extends into a regular array of spherical microstructures that have a characteristic double-lens design. These structures are absent in light-indifferent species.
Photolithographic experiments in which a photoresist film was illuminated through the lens array showed selective exposure of the photoresist under the lens centres. These results provide experimental evidence that the microlenses are optical elements that guide and focus the light inside the tissue. The estimated focal distance (4±7mm below the lenses) coincides with the location of nerve bundles-the presumed primary photoreceptors. The lens array is designed to minimize spherical aberration and birefringence and to detect light from a particular direction. The optical performance is further optimized by phototropic chromatophores that regulate the dose of illumination reaching the receptors. These structures represent an example of a multifunctional biomaterial that fulfills both mechanical and optical functions." (Aizenberg et al. 2001)

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Selection of experts

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Peter Vukusic, Roy Sambles, Natural Photonics Group, University of Exeter, UK

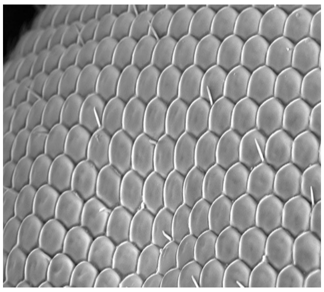
Link to Facade Technology

3

Name of Organism or Strategy

9 Facets in insects

Image



Stephen Lyth 2006, www.flickr.com [03/2010]

Organism term

Insects
Class Insecta

Keywords / Features

compound eye, ommatidia, conical structure, receptors

Short description

"The arthropod compound eye differs fundamentally from the vertebrate eye, both morphologically and functionally. In insects it is constructed of a number of units called ommatidia, each consisting of about eight elongate retinula cells arranged around a central axis, the rhabdom. Surrounding the retinula cells is a sleeve of pigment cells which probably serves to isolate, structurally and optically, the different ommatidia. The proximal ends of the ommatidia rest on a basement membrane, below which lies the optic ganglion and through which penetrate nerve fibers and branches of the tracheal system. At the distal end of each ommatidium is a transparent conical structure, the crystalline cone, the consistency of which varies considerably among the different groups of insects. Overlying the crystalline cones and directly in contact with the external world is the cornea, a transparent layer whose surface is sculptured into numerous tiny facets, one for each ommatidium. Incident light penetrates a corneal facet and crystalline cone, undergoing some refraction, and then passes through the length of the rhabdom." (Goldsmith et al. 1957)

Different compound eye arrangements exist:
"(A) Basic eye with receptors in pigment tubes (ark clams, sabellid tube worms and starfish). (B) Apposition compound eye (diurnal insects and crustaceans). (C) Refracting superposition eye (nocturnal insects, krill and mysid crustaceans). (D) Reflecting

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Selection of experts

Link to Facade Technology

3

Name of Organism or Strategy

24 Eyes are anti-reflective: elephant hawk-moth

Image

Nigel Jones, www.asknature.org [12/2009]

Organism term

Large elephant hawkmoth
Deilephila elpenor Linnaeus 1758

Keywords / Features

anti-reflective surface, nanostructure, light capturing

Short description

Eyes of nocturnal moths are anti-reflective due to nanoscale structuring.

"The outer surface of the facet lenses in the compound eyes of moths consists of an array of excessive cuticular protuberances, termed corneal nipples...The nipple distances were found to vary only slightly, ranging from about 180 to 240 nm, but the nipple heights varied between 0 (papilionids) and 230 nm (a nymphalid), in good agreement with previous work. The nipples create an interface with a gradient refractive index between that of air and the facet lens material, because their distance is distinctly smaller than the wavelength of light...The corneal nipples presumably mainly function to reduce the eye glare of moths that are inactive during the day, so to make them less visible for predators...The optical action of the corneal nipple array is a severe reduction of the reflectance of the facet lens surface. Accordingly, it increases the transmittance, and therefore the initial interpretation of the nipple array was that it helps to enhance the light sensitivity of the light-craving moths (Miller 1979)." (Stavenga et al. 2006)

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Selection of experts

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Link to Facade Technology

3

Name of Organism or Strategy

24a Lotus surfaces - matt but translucent surface

Image

W. Barthlott, www.lotus-effekt.de/funktion/mikro.php [05/2010]

Organism term

Sacred Lotus
Nelumbo nucifera

Keywords / Features

Cuticle, Epicuticular wax, Lotus-Effect, Nelumbo, optical properties

Short description

"Plant surfaces are characterized by a high diversity of structures which determine their optical properties, such as shiny, gleaming, silky, matt or iridescent. Replicas with different optical properties have been generated by using plant surfaces as templates and an improved replica technique. The technique allows the replication of complex surface structures with overhangs, cavities, and fragile or soft structures in a fast and cost-efficient way. Structures from some millimetres to some nanometres can be replicated. The transfer of complex architectures with different optical properties from plant surfaces onto technical surfaces implies a great potential for the development of new biomimetic surfaces with new optical properties." (Schulte et al. 2009)

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Selection of experts

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Wilhelm Barthlott, Uni Bonn, D

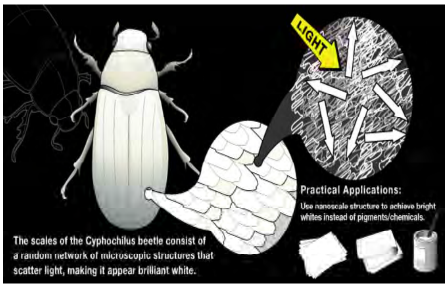
Link to Facade Technology

3

Name of Organism or Strategy

37 Scales create brilliant white: Cyphochilus beetles

Image



Andrea Leggitt www.asknature.org [12/2009]

Organism term

Cyphochilus
Cyphochilus spp.

Keywords / Features

brilliant white shell, paper white, scattered structures, nanostructure

Short description

"...We report the identification of whiteness resulting from a three-dimensional (3D) photonic solid in the scales of Cyphochilus spp. beetles. Their scales are characterized by their exceptional whiteness, their perceived brightness, and their optical brilliance, but they are only 5 mm thick. This thickness is at least two orders of magnitude thinner than common synthetic
systems designed for equivalentquality whiteness...The whiteness of Cyphochilus spp. originates from elongated flat white scales that imbricate its body, head, and legs (Fig. 1A). These scales are about 5 mm thick, 250 mm long, and 100 mm wide. Their interiors are composed of a random network of interconnecting cuticular filaments with diameters of about 250 nm...The relatively high void fraction in this Cyphochilus beetle's scales appears to be a vital part of the system's ability to scatter light. It is this, as well as the system's aperiodicity and index contrast of about 0.56, that create such intense optical whiteness for very limited thickness." (Vukusic et al. 2009)

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Selection of experts

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5

Name of Organism or Strategy

Davidia involucrata, or Cornus florida: colour change by layered system

Image


Rasbak commons.wikimedia.org [05/2010]

Organism term

Taschentuchbaum, Dove tree, (Nyssaceae) *Davidia involucrata*
Flowering dogwood, *Cornus Florida*

Keywords / Features

colour chage, leaf colour, flower, layered structure

Short description

"*Davidia involucrata* , an endemic in the mountains of western China. Flowers in this tree species lack a perianth and are arranged in capitula surrounded by large (up to 10 cm) bracts that at anthesis turn from green to white, losing their photosynthetic capability. Flowers are nectarless, and pollen grains are presented on the recurved anther walls for 5–7 days. Flower visitors, and likely pollinators, were mainly pollen-collecting bees from the genera Apis, Xylocopa, Halictus, and Lasioglossum. Capitula with natural or white paper bracts attracted significantly more bees per hour than capitula that had their bracts removed or replaced by green paper. Experimental immersion of pollen grains in water resulted in rapid loss of viability, and capitula with bracts lost less pollen to rain than did capitula that had their bracts removed, suggesting that the bracts protect the pollen from rain damage as well as attracting pollinators." (Sun et al. 2008)

"Flowering dogwood (*Cornus Florida*) is a small deciduous tree growing to 10 m (33 ft) high, often wider than it is tall when mature, with a trunk diameter of up to 30 cm (1 ft). A 10-year-old tree will stand about 5 m (16 ft) tall. The leaves are opposite, simple, oval with acute tips, 6–13 cm long and 4–6 cm broad, with an apparently entire margin (actually very finely toothed, under a lens); they turn a rich red-brown in fall." (Wikipedia [05/2010])

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Selection of experts

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Gefördert vom Programm „Haus der Zukunft Plus“

Name of Organism or Strategy

43 Humidity changes exoskeleton color: Hercules beetle

Image

Jessie Kiesow Flickr.com [03/2010]

Organism term

Hercules beetle
Dynastes hercules Linnaeus, 1758

Keywords / Features

thin film interference, humidity, colour change

Short description

The Hercules beetle changes the colour of its exoskeleton with humidity from yellow/green to black. The responsible mechanism is thin film interference and a change of layer thickness.

"Among beetles, Coptocyclia, Aspidomorpha, and many other Cassidinae can change the colour of their elytra by varying the amount of water in the cuticle and thereby the thickness of the thin films responsible for the interference colours." (Hinton et al. 1972)

"The elytra from dry specimens of the hercules beetle, Dynastes hercules appear khaki-green in a dry atmosphere and turn black passively under high humidity levels. New scanning electron images, spectrophotometric measurements and physical modelling are used to unveil the mechanism of this colouration switch. The visible dry-state greenish colouration originates from a widely open porous layer located 3µm below the cuticle surface. The structure of this layer is three-dimensional, with a network of filamentary strings, arranged in layers parallel to the cuticle surface and stiffening an array of strong cylindrical pillars oriented normal to the surface. Unexpectedly, diffraction plays a significant role in the broadband colouration of the cuticle in the dry state. The backscattering caused by this layer disappears when water infiltrates the structure and weakens the refractive index differences." (Rassart et al. 2008)

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Selection of experts

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Link to Facade Technology

6

Name of Organism or Strategy

46 Felt-like covering protects from cold: edelweiss

Image

Yann commons.wikimedia.org [05/2010]

Organism term

Edelweiss
Leontopodium nivale subsp. alpinum

Keywords / Features

hair layer, ultraviolet absorption, photonic structure

Short description

Edelweiss has filamentary hair on the leaf surface, that protects from cold.

"The optical properties of the inflorescence of the high-altitude Leontopodium nivale subsp. alpinum (edelweiss) is investigated, in relation with its submicrometer structure, as determined by scanning electron microscopy. The filaments forming the hair layer have been found to exhibit an internal structure which may be one of the few examples of a photonic structure found in a plant. Measurements of light transmission through a self-supported layer of hair pads taken from the bracts supports the idea that the wooly layer covering the plant absorbs near-ultraviolet radiation before it reaches the cellular tissue. Calculations based on a photonic-crystal model provide insight on the way radiation can be absorbed by the filamentary threads." (Vigneron et al 2005)

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Selection of experts

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Link to Facade Technology

6

Name of Organism or Strategy

48 Desert snails reflect most of the suns direct infrared

Image

George Washington Tryon, Jr. 1887, commons.wikimedia.org [03/2010]

Organism term

Sphincterochila boissier i Charpentier, 1847

Keywords / Features

reflectivity, reflectance, radiant energy

Short description

Desert snails reflect most of the suns direct infrared.

"Why does the snail not heat up to the same temperature as the soil surface? The answer lies in its high reflectivity in combination with the slow conduction of heat from the substrate. Within the visible part of the solar spectrum (which contains about one-half of the total incident solar radiant energy) the reflectance of these snails is about 90%. In the near infrared, up to 1350 nm, the reflectance is similar to that of magnesium oxide and is estimated to be 95 %. In the total range of the solar spectrum, therefore, we can say that the snails reflect well over 90 % of the incident radiant energy. Their reflectance in the far infrared is not significant in this context because all the longer wavelengths of solar radiation are absorbed in the atmosphere, and the measured range covers about 98 % of the total incident solar radiation."
(Schmidt-Nielsen 1971)

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Selection of experts

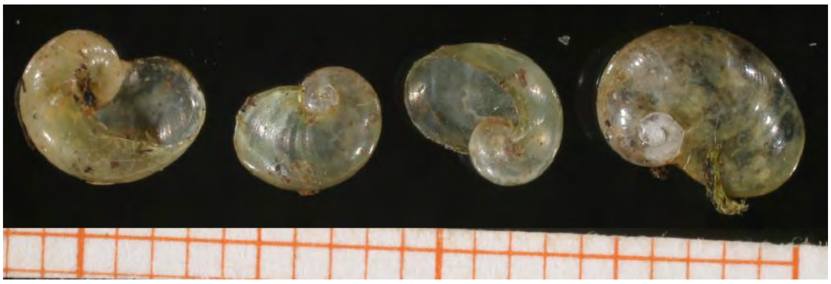
Link to Facade Technology

6

Name of Organism or Strategy

48a Glassnails

Image



Francisco Welter Schultes www.animalbase.uni-goettingen.de [05/2010] Eucobresia diaphana

Organism term

Gletscherglasschnecke (Vitrinidae)
Eucobresia glacialis, Forbes 1837

Keywords / Features

transparent shell, environmental adaptation

Short description

"Glass snails are a family of terrestrial snails, whose glassy translucent shells bears a clear similarity to slugs. Numerous European species of glass snails live on humid habitats on the ground, up to high altitudes in the Alps...Apart from the shell, also the mantle may be developed in different ways: Looking at a living glass snail, one may find that especially among species of Eucobresia and Semilimax...there is a dorsal mantle shield partly covering the shell. A lobe of the mantle also covers the shell spire, so that in some species the shell may almost entirely be overgrown by the mantle, a clear tendency towards a slug. The colour of the mantle as well as of the remainder of the snail's body varies with its environment, so specimens of Eucobresia diaphana glass snails from high altitudes in the Alps are coloured rock grey, in contrary to their blacker relatives from the lowlands." (www.weichtiere.at [05/2010])

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www.weichtiere.at [05/2010]

Selection of experts

Link to Facade Technology

6

Name of Organism or Strategy

57 Hairy leaves of desert plants - reflect

Image

Adampauli commons.wikimedia.org [05/2010] *Salvia spec.*

Organism term

Non succulent desert plants
for example *Saliva spec.*

Keywords / Features

boundary layer, reflection, convection

Short description

Hairy leaves of desert plants generate a boundary layer between the plant surface and the surrounding atmosphere.

"In deserts and arid environments, the leaves of non-succulent plants show several morphological adaptations (xeromorphic characters) to minimize water loss during the hot, dry rainless season. Most xeromorphic leaves have stomata on both sides (amphistomatous leaves), which increases the uptake of carbon dioxide and therefore the rate of photosynthesis. The leaves are of small size, with thick cuticles, and often with hairy or waxy surfaces. Both hairy and waxy surfaces play a special role in control uptake of energy by radiation...In dry areas, convective cooling is an important mechanism of heat transfer. The latent heat flux from the vegetation depends largely on convection, driven by the wind and depends on leaf shape, size and wind speed. Higher wind speeds causing turbulences in the plant boundary layer leads to forced convection, which is based on mass flow. Most non-succulent desert plants have small leaves which are expected to develop a small boundary layer thickness and therefore have a high boundary layer conductance for heat and mass transfer. Trichomes and waxes on plant surfaces can reduce the uptake of radiation energy by reflection and, therefore control the temperature of the organisms."
(Koch et al 2008)

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Selection of experts

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Link to Facade Technology

6

Name of Organism or Strategy

72 Leaf orientation controls sun exposure: plants

(Opening and closing of leaves - Heliconia)

Image

arboretum.arizona.edu

Organism term

Plantae

Plantae

Keywords / Features

reversible plant movements

Short description

Many plants can change the orientation of their leaves according to the sun, in order to maximise light capturing and photosynthesis or to avoid overheating.

"Since daylight is essential for this process, every plant must, as far as possible, position its leaves so that each collects its share without interfering with any others the plant may have. This may require changing the posture of the leaves throughout the day as the sun moves across the sky. The accuracy with which a plant can position them may be judged simply by gazing up at the canopy in a wood. The leaves form a near-continuous ceiling, fitting together like the pieces of a jigsaw."
(Attenborough 1995)

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8

Name of Organism or Strategy

94 Window cells allow sunlight into plant: Lithops

Image

Stan Shebs commons.wikimedia.org [12/2009] *Fenestraria aurantica*

Organism term

Stone plant (Mesembryanthemaceae)
Lithops spp.

Keywords / Features

light transmittance, translucent, crystals, conduction cooling

Short description

The pillar-like leaves of half buried stone plants allow photosynthesis by filtering sunlight down deep into the plants tissue, while at the same time cooling down via thermal coupling with the surrounding soil.

"These so-called stone plants (Lithops spp.) live largely buried in the soil of the Namib desert and the Karoo scrubland of South Africa; they protrude only about 2 mm above the surface but extend downward about 30 mm, as in figure 2. A translucent window on the top of each of the paired leaf-analogs admits light into the interior, with the photosynthetic tissue (the chlorenchyma) lining the bottom somewhat as our retinas line the inner rear surface of our eyeballs. Turner and Picker (1993) found that daily temperature cycled between extremes of 12°C and 46°C, as very nearly did plant surface, plant interior, and the surrounding soil 1 cm below the surface – all rose rapidly though the morning, peaked in the afternoon, and slowly dropped through the night...Thus by combining its thermal mass with that of the surrounding soil, Lithops buffers its daily temperature changes and, most importantly, reduces peak daytime temperatures. In addition, it takes advantage of the steep vertical thermal gradient in the soil, coupling not to the hotter surface but to the cooler soil a short distance beneath and by locating its most metabolically active tissues well down from that hot surface." (Vogel 2005)

References

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x

Link to Facade Technology

3

Name of Organism or Strategy

120 Aquatic birds pass heat from artery to vein before it can escape through feet

Image

Apalsola commons.wikimedia.org [05/2010] *Larus fuscus* Linnaeus, 1758

Organism term

aquatic birds

Keywords / Features

countercurrent heat exchange, blood vessels, thermoregulation

Short description

"'Countercurrent' heat exchangers occur naturally in the circulation system of fish and whales. Arteries to the skin carrying warm blood are intertwined with veins from the skin carrying cold blood, causing the warm arterial blood to exchange heat with the cold venous blood. This reduces the overall heat loss in cold waters... Wading birds use a similar system to limit heat losses from their body through their legs into the water." (en.wikipedia.org [03/2010])

"In birds, heat exchange in the limbs is very important, especially for birds that stand or swim in cold water. Unless the blood flowing to this thinskinned peripheral surfaces went through a heat exchanger, the heat loss would be very great indeed. However, because of the heat exchanger the loss is minimal. A gull placed with its feet in ice water for 2 hours lost only 1.5% of its metabolic heat production from the feet, a quite insignificant loss." (Schmidt-Nielsen 1975)

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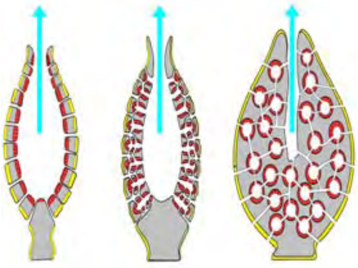
Link to Facade Technology

13a

Name of Organism or Strategy

153a Sea sponge - water stream through organism

Image



Philcha commons.wikimedia.org [04/2010]

Organism term

Marine sponges
Porifera, Grant 1836

Keywords / Features

sponge structure, porous, flow transport

Short description

"Most sponges work rather like chimneys: they take in water at the bottom and eject it from the osculum ("little mouth") at the top. Since ambient currents are faster at the top, the suction effect that they produce does some of the work for free. Sponges can control the water flow by various combinations of wholly or partially closing the osculum and ostia (the intake pores) and varying the beat of the flagella, and may shut it down if there is a lot of sand or silt in the water.
Although the layers of pinacocytes and choanocytes resemble the epithelia of more complex animals, they are not bound tightly by cell-to-cell connections or a basal lamina (thin fibrous sheet underneath). The flexibility of these layers and re-modeling of the mesohyl by lophocytes allow the animals to adjust their shapes throughout their lives to take maximum advantage of local water currents." (en.wikipedia.org [04/2010], Ruppert 2004)

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Name of Organism or Strategy

156 Ventilation by structure: mound-building termites

Image

Alchemist-hp commons.wikimedia.org [05/2010]

Organism term

Mound-building termites
Macrotermes michaelseni

Keywords / Features

passive ventilation, porous material, cooling

Short description

Mounds of macrotermitine termites maintain internal conditions stable by ventilation in internal structure and use of wind.

"The macrotermitine termites build some of the most spectacular animal-built structures on the planet. These termites control a significant portion of the flows of carbon and water through arid savanna ecosystems. These remarkable structures are not the residence for the colony--very few termites actually are found in them. Rather, they are accessory organs of gas exchange, which serve the respiratory needs of the subterranean colony, located about a meter or two below the mound...Functionally, these mounds are devices for capturing wind energy to power active ventilation of the nest. They are adaptive structures, continually molded by the termites to maintain the nest atmosphere. This ability confers on the colony emergent homeostasis, the regulation of the nest environment by the collective activities of the inhabitants." (Turner www.esf.edu [12/2009])

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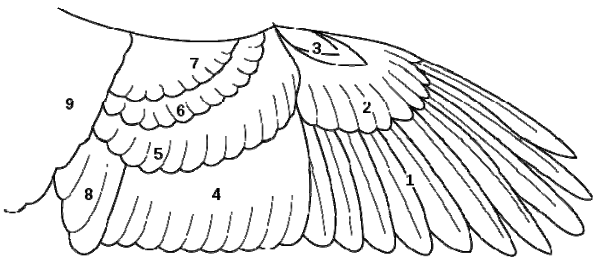
20

Name of Organism or Strategy

163a Birds - passive mechanisms for laminar flow control

Image



commons.wikimedia.org [05/2010]

Organism term

birds, aves

Keywords / Features

passive flow control, feathers, laminar flow

Short description

"Birds have various adaptations for flight, including a lightweight skeleton, two large flight muscles... as well as a modified forelimb (wing) that serves as an aerofoil...Wing shape and size generally determine a bird species' type of flight; many birds combine powered, flapping flight with less energy-intensive soaring flight." (en.wikipedia.org [05/2010])

"First, we provide an apparently simple example to highlight the problems which we encounter. When a bird lands, a few feathers are deployed in front of the leading edges of the wings. (We do not discuss here the function of the feathers at the wing tips, i.e., the “winglets”. These help to reduce the induced drag on the wing, in particular for slow predatory land birds with a low aspect ratioof their wings.) This helps to keep the flow attached, probably in the same way as slats do on wings of commercial aircraft. (Lachmann 1961). However, Liebe (1996/1997, personal communication) maintains that these feathers may rather operate as boundary layer fences. Or do they work also as vortex generators? Or rather with all three mechanisms combined? Thus, we are caught in the middle of competing and equally plausible ideas, and in this case we do not have a conclusiv answer. We believe, however, that these small feathers are important for the flight control of birds at high lift conditions during landing." (Bechert et al. 2000)

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Bechert D.W. DLR Berlin

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Name of Organism or Strategy

175 Large ears used to cool off: jackrabbit

Image

James Marvin Phelps, commons.wikimedia.org [05/2010]

Organism term

Jackrabbit
Lepus spp.

Keywords / Features

heat dissipation, cooling,

Short description

"The large pinnae ("ears") of jackrabbits, estimated to represent 19 percent of the body surface area in *Lepus californicus* and 25 percent in *L. alleni* , are potentially outstanding sites of conductive, convective, and radiative heat exchange with the environment." (Hill et al. 1976)

"Reradiation to the sky may underlie the peculiarly large and well-vascularized ears of many desert animals – jack rabbits (Lepus spp) in particular. As Schmidt-Nielsen (1964) points out, these animals are too small to cool by evaporating water, and most lack burrows as mid-day retreats. With air temperatures at or even above body temperature, their large ears look paradoxical. But by feeding in open shade, with hot ears exposed to a much colder sky (at an effective temperature of perhaps 13°C), an animal could off-load a large amount of heat." (Vogel 2005)

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Name of Organism or Strategy

176 Shape shades and enhances heat radiation: cactus

Image

Paul Benford www.asknature.org [12/2009] *Echinopsis peruviana*

Organism term

Cactaceae
Cactaceae

Keywords / Features

ribs, geometry, shading, heat radiation, orientation

Short description

The shape and ribs of barrel cacti may provide self-shading and enhance heat dissipation.

"The same applies to the intricate structural designs of cacti, which are exposed to a great deal of heat pressure in the desert. Their heat-reflecting capacity is low, since their surface is greatly reduced so as to cut down on evaporation. Nature has solved the problem by equipping many cacti with cooling ribs. These shade the cactus's surface against the scorching sun and simultaneously improve heat radiation. The alternating planes of light and shade of the vertical cooling ribs of the torch thistle produce rising and falling air currents, which improve heat radiation. And when the sun reaches its highest position, it hits the torch thistle from above, where it presents its smallest surface. A botanist discovered that torch thistles perish of burns when they are placed horizontally in the sun." (Tributsch 1984)

"Spines moderated the amplitude of the diurnal temperature changes of the stem surface, since the daily variation was 17 C for the winter day and 25 C for the summer day with spines compared with 23 C and 41 C, respectively, in their simulated absence. Ribs reduced the daytime temperature rise by providing 54% more area for convective heat loss than for a smooth circumscribing surface." (Lewis et al. 1977)

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25

Name of Organism or Strategy

177 Cuticle acts as cooling mechanism: Oriental hornet

Image

MattiPaavola commons.wikimedia.org [05/2010]

Organism term

Oriental hornet
Vespa orientalis Linnaeus, 1761

Keywords / Features

heat dissipation, thermogenic centre, thermoregulation, heat exchange

Short description

"In the social wasps Vespa orientalis and Paravespula germanica (Hymenoptera, Vespinae), a thermogenic center has been found in the dorsal part of the first thoracic segment. The temperature in this region of the prothorax is higher by 6-9°C than that at the tip of the abdomen, and this in actively flying hornets outside the nest (workers, males or queens) as well as in hornets inside the nest that attend to the brood in the combs. On viewing the region from the outside, one discerns a canal or rather a fissure in the cuticle, which commences at the center of the dorsal surface of the prothorax and extends till the mesothorax. Thus the length of this canal or fissure is ~5-7 mm and it is seen to contain numerous thin hairs whose shape varies from that of the hairs alongside the structure... Additionally there are layers that display lymph-filled spaces and also perforated layers and depressions, and beneath all these is a lace-like layer that also coats the cuticle's hollows. Underneath the cuticle proper, there are numerous large mitochondria and tracheae, which occupy a considerable part of the cuticular epithelium surface. These abundant mitochondria are, most probably, the main element of heat production in the thermogenic center." (Ishay et al. 2006)

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Selection of experts

Jacob S. Ishay, Marian Plotkin, Stanislav Volynchik, Zahava Barkay, Noam Eliaz, David J. Berman Tel-Aviv University

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Name of Organism or Strategy

179 Fractal systems for effective cooling

Image

Mark Charles Langdon, commons.wikimedia.org [05/2010]

Organism term

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Keywords / Features

fractal system, cooling, flow

Short description

"Natürliche Konstruktionen sind über Generationen optimiert (Evolutionstheorie); dabei stellt auch die Minimierung des Energiebedarfs ein Optimierungsziel dar. Im Gegensatz zu den genannten Wärmetauscherbauarten weisen natürliche Konstruktionen – z. B. Blutbahnen oder Leitbündelstrukturen von Blättern – mehrfach verzweigte Strukturen auf, die mathematisch als "Fraktale" beschrieben werden können. Im Rahmen der Promotion wird versucht, solche Strukturen auf die Technik zu übertragen (bionischer Ansatz) und mit konventionellen Bauarten zu vergleichen. Dabei steht die Frage im Mittelpunkt, ob und – falls ja – unter welchen Bedingungen fraktale Hydraulikstrukturen den konventionellen Bauarten hinsichtlich ihrer Energieeffizienz überlegen sind. Insbesondere ist zu untersuchen, ob sich die eingangs genannten Forderungen nach einer gleichmäßigen Volumenstromverteilung bei gleichzeitig geringem Druckverlust mit fraktalen Hydraulikstrukturen realisieren lassen." (Hermann 2005)

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Selection of experts

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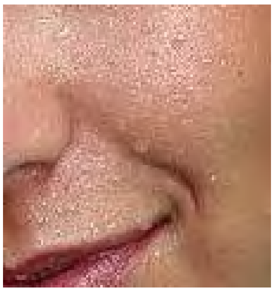
Name of Organism or Strategy

185 Evaporation from skin in larger animals as humans, cattle, etc.

Image



Sergio *Savaman* Savarese / Bibikoff commons.wikimedia.org [05/2010]

Organism term

Mammalia

Keywords / Features

evaporation, transpiration, sweating, skin

Short description

"Vaporization of a liquid (or sublimation of a solid) provides a particularly effective heat transfer mechanism, especially if the liquid has a high heat of vaporization, as does water. Among animals that cool evaporatively, two routes play major roles; each has its points. Evaporation from skin (predominant in humans, cattle, large antelopes, and camels) takes advantage of the skin's large surface area.

The concomitant vasodilation improves convective loss as well. On the debit side, cutaneous evaporation inevitably causes a loss of salt, which then becomes a particularly valuable commodity for herbivores active in hot climates. In addition, its requirement for exposed external surface conflicts with the presence of fur or plumage that might reduce heat loss under other circumstances. Respiratory evaporation entails no salt loss, but it requires pumping air across internal surfaces, which costs energy and produces yet more heat." (Vogel 2005)

ıces

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Name of Organism or Strategy

187 Evaporation cooling of leaves

Image

Noah Elhardt commons.wikimedia.org

Organism term

Plantae

Keywords / Features

evaporation, cooling, transpiration

Short description

"Plants with broad leaves, the ones likely to run into thermal trouble, evaporate water (‘transpire’) at remarkable rates. Leaf temperatures calculated (from admittedly crude formulas) by Gates (1980) point up the thermal consequences of that evaporation. He assumes a wind of 0×1 m s–1 (as noted earlier, about as still as daytime air gets), solar illumination of 1000 W m–2 (again, an overhead unobstructed sun), an air temperature of 30°C, a relative humidity of 50%, and a leaf width of 5 cm. If reradiation were the only way the leaf dissipated that load, it would equilibrate...at a temperature of about 90°C. Allowing convection as well drops that to a still stressful 55°C. A typical level of evaporation cools the leaf to – hot but not impossibly so for a worst-case scenario. Evaporation cools leaves; it could not do otherwise. Typically broad leaves dissipate about as much energy evaporatively as they do convectively." (Vogel 2005)

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Name of Organism or Strategy

Desert plant surfaces - boundary layer influences convection cooling

Image

Stan Shebs commons.wikimedia.org [05/2010]

Organism term

desert plants, plantae

Keywords / Features

Leaf boundary layer, aerodynamic resistance and conductance, diffusion, transpiration, plant-atmosphere interaction, morphological adaptation

Short description

"In deserts and arid environments, the leaves of non-succulent plants show several morphological adaptations (xeromorphic characters) to minimize water loss during the hot, dry rainless season. Most xeromorphic leaves have stomata on both sides (amphistomatous leaves), which increases the uptake of carbon dioxide and therefore the rate of photosynthesis. The leaves are of small size, with thick cuticles, and often with hairy or waxy surfaces. Both hairy and waxy surfaces play a special role in control uptake of energy by radiation..."
(Koch et al 2008)
"Convective cooling is based on the combination of direct energy transfer between plant surface molecules and air molecules (heat conduction), between air molecules in the boundary layer (heat conduction) and "heat removal" by air currents (heat convection)...Both free and forced convection are dependant on various parameters, such as shape and size of the organ and wind speed. These parameters influence the thickness of the boundary layer." (Roth-Nebelsick 2001)

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Selection of experts

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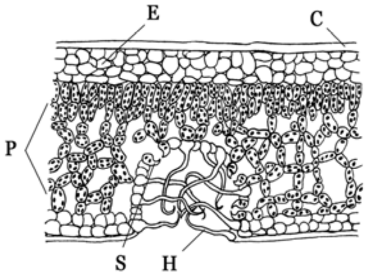
Name of Organism or Strategy

189 Plants in arid climates - position of stomata adapted to climate

Image



Bgqhrsnog commons.wikimedia.org [05/2010]

Organism term

Plantae

Keywords / Features

stomata, environmental adaptaition, ventilation, gas exchange

Short description

"Compared to plants from habitats with higher annual rainfall, desert plants show a reduction in number of stomata per leaf area to reduce the water loss. In succulent plants, stomata are often sunken in pits of the epidermis, thus a chamber above the stomata is formed in which air turbulences are reduced, and therefore the transpiration is minimized, during gas exchange. In Aloe vera, the stomata are superimposed by epicuticular waxes, which significantly reduce the water loss." (Koch et al. 2009)

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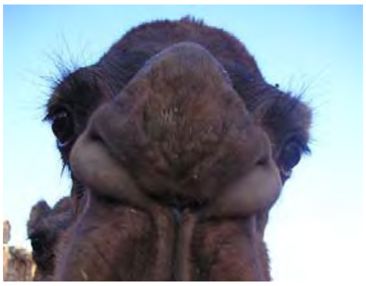
Name of Organism or Strategy

194 Water management in camel nasal surfaces

Image



Bertil Videt commons.wikimedia.org [05/2010]

Organism term

dromedary, desert rodents
Camelus dromedarius Linnaeus, 1758

Keywords / Features

evaporation control, cool, moisture content,

Short description

The specific structure in the camel nose can reduce evaporative water loss.

"We have found that camels can reduce the water loss due to evaporation from the respiratory tract in two ways: (1) by decreasing the temperature of the exhaled air and (2) by removal of water vapour from this air, resulting in the exhalation of air at less than 100% relative humidity (r.h.). Camels were kept under desert conditions and deprived of drinking water. In the daytime the exhaled air was at or near body core temperature, while in the cooler night exhaled air was at or near ambient air temperature. In the daytime the exhaled air was fully saturated, but at night its humidity might fall to approximately 75% r.h. The combination of cooling and desaturation can provide a saving of water of 60% relative to exhalation of saturated air at body temperature. The mechanism responsible for cooling of the exhaled air is a simple heat exchange between the respiratory air and the surfaces of the nasal passageways. On inhalation these surfaces are cooled by the air passing over them, and on exhalation heat from the exhaled air is given off to these cooler surfaces. The mechanism responsible for desaturation of the air appears to depend on the hygroscopic properties of the nasal surfaces when the camel is dehydrated. The surfaces give off water vapour during inhalation and take up water from the respiratory air during exhalation. We have used a simple mechanical model to demonstrate the effectiveness of this mechanism." (Schmidt-

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asknature.org [12/2009]
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27a

Name of Organism or Strategy

195 Trees harvest water from air

Image

Petra Gruber 2007 cloud forest

Organism term

Pine, Sequioa

Keywords / Features

water harvesting, humidity, moisture

Short description

"Evaluations of plant water use in ecosystems around the world reveal a shared capacity by many dif- ferent species to absorb rain, dew, or fog water directly into their leaves or plant crowns. This mode of water uptake provides an important water subsidy that relieves foliar water stress...The plants studied include canopy trees, understory ferns, and shrubs. Our results also show that foliar uptake provides direct hydration to leaves, increasing leaf water content by 2–11%. In addition, 60% of redwood forest species investigated demonstrate noc- turnal stomatal conductance to water vapor. Such findings indicate that even species unable to absorb water directly into their foliage may still receive indirect benefits from nocturnal leaf wetting through suppressed transpiration." (Limm et al. 2009)

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Selection of experts

Link to Facade Technology

27a

Name of Organism or Strategy

196 Aireal roots harvest water from air - Velamen radicum specialised tissue

Image

Petra Gruber 2009, Epiphytes

Organism term

Velamen radicum in epiphytic plants, orchids
Orchideaceae

Keywords / Features

water harvesting, humidity, moisture

Short description

"Many epiphytic species are equipped with velamentous roots. In this root type, a whitish, sponge-like and non-living layer, the velamen radicum (a specialized rhizodermis) surrounds the living cortex with the conductive stele. This type of root is especially elaborated in Orchidaceae (Barthlott and Capesius 1975). The dead and empty velamen cells show a complex wall structure with numerous large pores and sculputres. The velamen is sometimes differentiated into several zones and surrounded by an epivelamen which often disintegrates with age...Upon contact with the velamen, the water is conducted rapidly into the velamen by capillary flow, until saturation is achieved...There are several suggestions for form-function relationships of the velamen radicum." (Roth-Nebelsick in Gorb 2009)

References

Gorb S. (ed.): Pull, Push and Evaporate: The Role of Surfaces in Plant Water Transport,Chapter III Transport Roth-Nebelsick A., Springer 2009.

Selection of experts

Link to Facade Technology

27a

Name of Organism or Strategy

13 Complex structures focus reflected light: lobster

Image

Steven G. Johnson commons.wikimedia.org [06/2010]

Organism term

Lobster
Decapoda

Keywords / Freatures

optical system, reflection, concave mirror eyes

Short description

Lobster eyes focus light by means of square tubes that reflect light.

"Most eyes have optical systems that are based on refraction by a lens or a cornea. However, there are two eye types that form images using mirrors. These are concave mirror eyes, similar in principle to a Newtonian telescope, and reflecting superposition compound eyes, where the mirrors are arranged radially in a square array. The concave mirrors are found in scallops (Pecten), where they allow the eye to see moving objects, and in a modified form in a few deep-sea crustaceans. The reflecting superposition eyes are confined to the long-bodied decapod crustaceans—the shrimps, prawns, crayfish and lobsters. Recently this second mechanism has found a number of uses in x-ray optics." (Land 2000)

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Selection of experts

Biomimetic Products and Application Ideas

Application Ideas: x-ray imaging, dayllight systems in buildings

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Gefördert vom Programm „Haus der Zukunft Plus“

Name of Organism or Strategy

39 Pigment filters excessive light: balloonfish

Image

Dan Hershman www.flickr.com [06/2010]

Organism term

Balloonfish, porcupinefish
Diodon

Keywords / Freatures

pigment, filter light

Short description

"Chromatophores around the corneas of balloonfish filter excessive light by releasing a pigment." (www.asknature.org [11/2009])

"The system functions as follows: when the [balloon] fish encounters excessive light, the chromatic cells called 'chromatophore', which are located around the transparent layer (cornea) of the eye, start to release a yellowish dye (pigment). This pigment covers the eye and acts as a filter reducing the intensity of light, which enables the fish to see more accurately. In dark waters, this pigment disappears and the eye receives the maximum possible amount of light." (Yahya 2002)

References

www.asknature.org [11/2009]
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Selection of experts

Biomimetic Products and Application Ideas

Application Ideas: Light filtering systems.

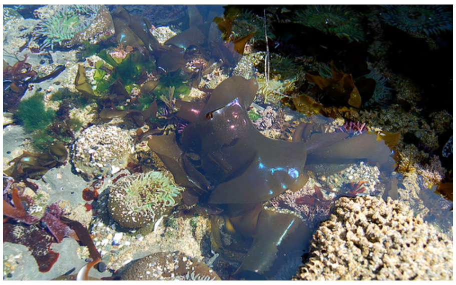
Link to Facade Technology

6

Name of Organism or Strategy

49 Iridae, iridescent red algae: cuticle structure reflects infrared

Image



kqedquest www.flickr.com [06/2010] mazzaella splendens

Organism term

Iridaea flaccida
Mazzaella flaccida

Keywords / Freatures

infrared reflection, thin layer, iridescence

Short description

"...the spacing of the laminae in the cuticle of some iridescent red algae (from micrographs of Gerwick and Lang 1977) hints at infrared reflection; these organisms (Iridaea and others) can be exposed to both air and full sunlight at low tide." (Vogel 2005)

"Transmission electron microscopy of the iridescent algae Iridaea flaccida (S & G) Silva, Iridaea cordata (Turn.) Bory var. cordata and I. cordata var. splendens (S & G) Abbott reveals a multilaminated cuticle covering the thallus. Experimental results show the cuticle: a) can be isolated intact by mechanical scraping or NaOH treatment; b) is iridescent by itself and the denuded thallus is not; and, c) is isolated without any subtending polysaccharide layer, cell walls, or cells. This cuticle acts as a thin layer producing the constructive and destructive light interference which is seen as iridescence. It is formed of alternating electron opaque and translucent layers with a total thickness of 0.5–1.6 µm. Analysis of mechanically isolated cuticle shows that it is composed of protein (50%), carbohydrate (ca. 40%), inorganic salts (5%) and some fatty acids (less than 1.0%). The electron opaque layers may correspond to protein-rich regions and the electron translucent ones to regions rich in carbohydrates. The cuticle does not appear to affect photosynthesis or respiration, but rather, may protect the alga from physical factors such as desiccation and from predator injury. It is likely that the iridescence in other

References

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Selection of experts

Biomimetic Products and Application Ideas

Application ideas: reflective structure and coating

Link to Facade Technology

6

Name of Organism or Strategy

56 Chameleons: temperature induced colour change

Image

Ridard commons.wikimedia.org [05/2010]

Organism term

Chamaeleo dilepis, Chamaeleo jacksonii, Chamaeleo ellioti

Keywords / Freatures

colour change, reflectivity, reflectance, energy balance

Short description

"Skin reflectance at different body temperatures was measured in three species of Kenyan chameleons (Chamaeleo dilepis, Chamaeleo jacksonii, and Chamaeleo ellioti). Total reflectance, calculated by averaging reflectances measured at 290through 2,600 nm, was significantly greater at 35°C than at 20°C in C. dilepis (31% at 20°C to 46% a t35°C) and in C. jacksonii (7% at 20°C to 11% at 35°C). Reflectance changes with temperature were not the same at all wavelengths. Significant change was largely confined to visible and near-infrared spectral regions (600-1,000 nm). Chamaeleo ellioti did not show a significant change in total reflectance with temperature. Energy balance equations and climatic data representing long-term averages for each month of the year were used to assess the potential for alteration of equilibrium body temperature and rate of radiant heat gain by temperature-dependent color change in C. dilepis and C, jacksonii. The observed changes in refleclance produced changes in estimated equilibrium body temperature of 0,7°C in C. dilepis and 0.2°C in C. jacksonii, as averaged over the entire year. Dark chameleons are predicted to heat more rapidly than light chameleons. The dark coloration observed frequently during morning basking in chameleons may serve to reduce the basking period and, hence, reduce time spent at suboptimalperformance temperatures."
(Walton et al 1993)

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Selection of experts

Biomimetic Products and Application Ideas

Application ideas: adaptive change of reflectance in building surfaces

Link to Facade Technology

6

Name of Organism or Strategy

80 Flowers follow sun: snow buttercups

Image

Franz Xaver commons.wikimedia.org [05/2010], ranunculus alpestris

Organism term

Alpine buttercup
Ranunculus adoneus Gray

Keywords / Freatures

phototaxis, solar tracking, photoreception,

Short description

"Flower stalks of snow buttercups track the sun by differential cell growth." (www.asknature.org [12/2009])

"We designed field experiments using solar-tracking Ranunculus adoneus flowers to determine where photoreception occurred, which organs responded, and how movement was achieved. Flower peduncles bend eastward in the morning and gradually unbend over the course of the day. Peduncles were found to bend significantly more frequently in the middle region near the floral bracts, 1–3 cm below the flower, than elsewhere on the peduncle. Because the peduncle tip continued to track the sun even after the flower itself was removed, our experiments concentrated on shielding (or conversely, exposing) various portions of peduncles from (or to) sunlight. Photoreception occurred primarily in the portion of the stem just beneath the floral receptacle. By following the position of landmarks applied to the stem, we found that 40% more growth occurred on the shaded side of bent peduncles, compared to the sunlit side. In contrast, top-shielded peduncles did not solar track well and grew only 25% more on the shaded side than on the sunlit side. This growth differential corresponded to differences in cell length on the two sides of bent peduncles, with significantly longer epidermal cells occurring on the shaded side than on the sunlit side." (Sherry and Galen 1998)

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Selection of experts

Candace Galen, Biological Science, University of Missouri-Columbia
Jim Ehleringer,University of Utah, ehleringer.net/Jim/index.html

Biomimetic Products and Application Ideas

Application Ideas: sun tracking in building elements and solar cells.

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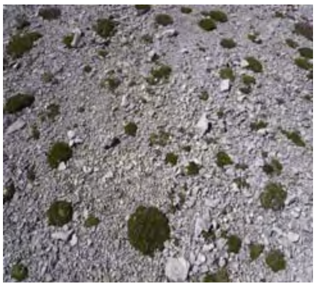
Gefördert vom Programm „Haus der Zukunft Plus“

Name of Organism or Strategy

89 Cushion shaped plant populations – create microclimate

Image



peg@transarch.org

Organism term

alpine plants, cushion plants

Keywords / Freatures

cushion plants, microclimate, positive interaction, community

Short description

Cushion plants growing in high mountain habitats can modify the microclimate within their canopy generating microhabitats more favorable for the recruitment of other plant species, acting as nurse plants.

"Cushion plants are one of the most common growth forms in alpine habitats. Their low stature, dense canopy, and compact form allow them to decouple their microclimate from the surrounding environment, mitigating the effect of low temperatures and drought, enhancing the survival of other species. In this study, we evaluated the modifications on soil temperature and moisture over an entire growing season by two cushion species (Laretia acaulis and Azorella monantha) in alpine communities located at two different elevations in the central Chilean Andes...Cushion plants are one of the most common growth forms in alpine habitats. Their low stature, dense canopy, and compact form allow them to decouple their microclimate from the surrounding environment, mitigating the effect of low temperatures and drought, enhancing the survival of other species. In this study, we evaluated the modifications on soil temperature and moisture over an entire growing season by two cushion species (Laretia acaulis and Azorella monantha) in alpine communities located at two different elevations in the central Chilean Andes." (Cavieres et al 2007)

References

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Selection of experts

Biomimetic Products and Application Ideas

Application ideas: positive interaction of buildings and building parts concerning microclimate

Link to Facade Technology

9a

Name of Organism or Strategy

111 Sequoiadendron - bark is insulating, also against forest fires

Image

JFKCom commons.wikimedia.org [05/2010]

Organism term

Redwood
sequoiadendron giganteum

Keywords / Freatures

fire retardation, tree barks, tannins, sequoia, eucalyptus

Short description

"The fire protection of organic building and thermal insulation materials is a technical challenge, for which new approaches are desirable. Exceptionally fire resistant tree barks from trees such as Sequoiadendron giganteum, Pinus canariensis and from Eucalyptus species, which evolved in fire adapted eco-systems, were studied by thermo-gravimetric techniques in combination with mass spectroscopy and complementary analysis in a temperature range up to 600°C.It turned out that while a technical reference poymer (ABS = acrylnitrilebutadien- styrole) burned by leaving only 2. 6% solid, the most fire resistant tree barks only carbonized leaving up to 60% solid. It is mostly graphite and carbon, which are highly heat insulating and fire protecting as is also known from technical “foaming” graphite layers. A key chemical component that has evolved in tree barks to support fire resistance, besides other properties, is tannin, a polyphenol, which complexes macromolecules and efficiently reduces oxidants and radicals. The oxidation, in a fire, of these large planar molecules is thus suppressed to be transformed into a similarly structured graphitic component with fire retarding properties. Additional adaptations of fire resistant tree barks appear to be a fibrous micro- and nano-structure and optimised infrared optical properties. They may retard heat transfer within the bark via suppression of microscopic conduction and radiation processes." (Tributsch et al 2008)

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Selection of experts

Biomimetic Products and Application Ideas

Application ideas: fire resistant materials, insulating materials for building industry

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Name of Organism or Strategy

115 Underhairs provide insulation: merino sheep

Image

ingermaaike2 www.flickr.com [06/2010]

Organism term

mouflon, sheep (feral), Merino sheep
Ovis aries Linnaeus, 1758

Keywords / Freatures

hair, thermal insulation

Short description

"The wool of Merino sheep forms an insulating layer via underhair that creates hundreds of trapped air pockets." www.asknature.org [12/2009]

"Generally a dense coat of underhairs, as in the wool of a sheep, is particularly effective in temperature control, because hundreds of tiny air pockets become trapped among the hairs and make an insulating layer between animal and climate. Sheep with thick wool, such as the merinos of Australia, can stay warm in freezing weather and, conversely, stay cool in the heat of summer. In both cases the difference between the temperature at the skin and on the wool surface (a distance of 8 cm) may be 40˚C or more. In animals with less thick coats, simply erecting the hair increases the resistance to cold." (Foy and Oxford Scientific Films 1982)

References

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Selection of experts

Biomimetic Products and Application Ideas

Application Ideas: thermal insulation for a wide range of application fields

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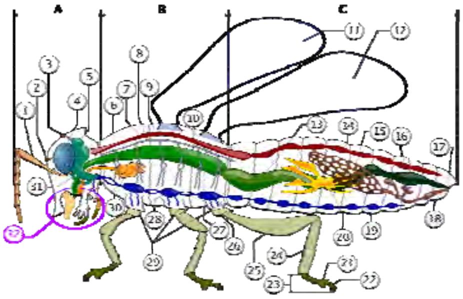
Gefördert vom Programm „Haus der Zukunft Plus“

Name of Organism or Strategy

151 Tracheal system delivers oxygen efficiently: fly

Image



Piom commons.wikimedia.org [06/2010]

Organism term

Diptera
Diptera

Keywords / Freatures

tracheal system, gas transport, cooling

Short description

Insects breathe with a system of tracheas.

"The flight of flies, too, requires high levels of energy. There is also a need for large volumes of oxygen in order to burn this energy. The need for great amounts of oxygen is satisfied by an extraordinary respiratory system lodged within the bodies of flies and other insects. The fly's need of oxygen is so high that there is no time to wait for the oxygen to be delivered to the body cells by the blood. To deal with this problem, there is a very special system. The air tubes in the insect's body carry the air to different parts of the fly's body. Just like the circulatory system in the body, there is an intricate and complex network of tubes (called the tracheal system) that delivers oxygen-containing air to every cell of the body. Thanks to this system, the cells that make up the flight muscles take oxygen directly from these tubes. This system also helps to cool down the muscles which function at such high rates as 1000 cycles per second." (Yahya 2002)

References

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Selection of experts

Biomimetic Products and Application Ideas

Application Ideas: ventilation systems

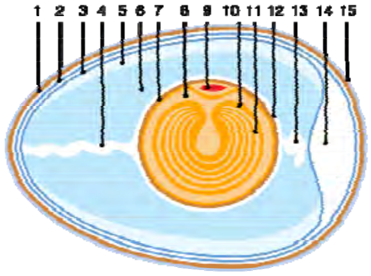
Link to Facade Technology

18

Name of Organism or Strategy

152 Fluid protects eggs: birds

Image



Domsau2 commons.wikimedia.org [06/2010]

Organism term

Aves
Aves

Keywords / Freatures

egg shell structure, albumen, breathable membrane, shock absorption

Short description

"However ordinary it may seem to us, the egg of a chicken has about fifteen thousand pores resembling dimples on a golf ball. The spongy structure of smaller eggs can only be observed under the microscope. These spongy structures give eggs added flexibility and increase their resistance to impact...An egg is a miracle of packaging. It supplies all the nutrients and water that the developing foetus needs." (Yahya 2002)

"The egg's shock absorption, which has received little investigation, is based on the fact that the embryo is surrounded by the albumen, an elastic gelatin-like substance of high water content. The result is a propitious combination of properties: a liquid that cannot be compressed, only displaced, and an elastic substance. When the embryo is pushed against the shell by some forceful impact, the liquid must flow past it and transform the destructive energy into heat. The shock absorption of the egg is further improved by an air cushion located at the thick end of the egg--the same end as the center of gravity. In a falling body the center of gravity moves to the lowest possible point, so in an egg the embryo falls on the air cushion. The air pocket in the egg has another mechanical function. It prevents temperature fluctuations from cracking the shell." (Tributsch 1984)

References

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Selection of experts

Biomimetic Products and Application Ideas

Application Ideas: breathable materials for building and filters, packaging, shock-proof, protection.

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Name of Organism or Strategy

159 Stems move air: Phragmites australis

Image

MPF commons.wikimedia.org [06/2010]

Organism term

Yellow cane, Roseau cane, Reed grass, Phragmites, Giant reedgrass, Giant reed, Ditch reed

Keywords / Freatures

aerenchym, diffusion, pressurized flow, plant aeration

Short description

"Dead stems of Phragmites australis move air to shoot and root meristems by use of differential air pressure." (www.asknature.org [12/2009])

"Through flow can also occur in dormant plants with persistent, standing litter. This has been reported for Phragmites australis. Differences in wind speed at the top and near the bottom in the canopy create a differential internal pressure between tall and short dead shoots. The lower air pressure in taller shoots draws air into the shorter dead shoots, down into the rhizomes, and up the taller dead shoots. In the temperate zone in the early spring, this may be an important mechanism for Phragmites to get oxygen to shoot and root meristems.
Differential air pressure caused by wind blowing across dead culms sucks air into the lower culms through the rhizomes and into the taller culms. B. Pressurization of new culms due to a build up of vapour pressure or higher temperatures causes mass flow of gasses [sic] down the culms into the rhizome and up into more porous older culms. The movement of oxygen from the rhizomes into the roots and out of the roots into the soil is due to diffusion." (van der Valk 2006)

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Selection of experts

Timothy Colmer John S. Pate (Emeritus), School of Plant Biology, Faculty of Natural and Agricultural Sciences, The University of Western Australia

Biomimetic Products and Application Ideas

Application Ideas: passive ventilation systems for buildings

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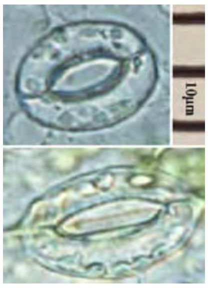
Name of Organism or Strategy

163 Stomata of plants

Image



KuriPop commons.wikimedia.org [06/2010]

Organism term

Plantae

Keywords / Freatures

stomata, environmental adaptaition, ventilation, gas exchange

Short description

"In botany, a stoma (also stomate; plural stomata) is a pore, found in the leaf and stem epidermis that is used for gas exchange. The pore is bordered by a pair of specialized parenchyma cells known as guard cells which are responsible for regulating the size of the opening. The term stoma is also used collectively to refer to an entire stomatal complex, both the pore itself and its accompanying guard cells. Air containing carbon dioxide and oxygen enters the plant through these openings where it is used in photosynthesis and respiration, respectively. Oxygen produced by photosynthesis in the spongy layer cells (parenchyma cells with pectin) of the leaf interior exits through these same openings. Also, water vapor is released into the atmosphere through these pores in a process called transpiration." (en.wikipedia.org [03/2010])

"Compared to plants from habitats with higher annual rainfall, desert plants show a reduction in number of stomata per leaf area to reduce the water loss. In succulent plants, stomata are often sunken in pits of the epidermis, thus a chamber above the stomata is formed in which air turbulences are reduced, and therefore the transpiration is minimized, during gas exchange. In Aloe vera, the stomata are superimposed by epicuticular waxes, which significantly reduce the water loss." (Koch 2009)

References

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Selection of experts

Biomimetic Products and Application Ideas

Application ideas: control mechnisms for ventilation

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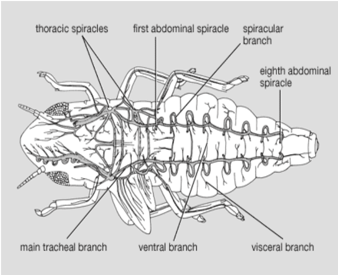
Name of Organism or Strategy

166 Discontinuous ventilation in insects

Image



www.britannica.com [05/2010] G. Grandi, Istituzioni di Entomoligia Generale (1966); Calderini

Organism term

Insects
for example: *Apis mellifera ligustica* Spinola

Keywords / Freatures

discontinuous ventilation, insect ventilation, metabolic rate

Short description

"It is known that many insects emit CO2 in widely spaced ‘bursts’ or discontinuous ventilation events, usually characterized by active abdominal ventilation. We describe the discontinuous CO2 emission characteristics of the honeybee (Apis mellifera ligustica Spinola), and utilize its ‘chill coma’ temperature threshold (12°C) to effect transitions from continuous, diffusive to discontinuous, convective ventilation regimes. Increasing temperature abruptly switched the dynamics of ventilation from diffusive and continuous (11 °C) to convective and discontinuous (>12°C). The ventilation cycle frequency was 7.84mHz and CO2 output per ventilation event (burst phase) was 1.56µl: neither variable was temperaturedependent in the range 12–15 °C. The rate of CO2 emission did not change significantly in the range 7–15 °C, possibly owing to increased membrane leakiness at lower temperatures. At 15°C, honeybee metabolic rate (2.69 W kg-1, mean mass 0.094 g) is similar to that of other similarly sized insects capable of significant endothermy." (Lighton et al 1990)

References

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Selection of experts

Biomimetic Products and Application Ideas

Application ideas: timebased discontinuous ventilation control to reduce heat loss

Link to Facade Technology

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Gefördert vom Programm „Haus der Zukunft Plus“

Name of Organism or Strategy

168 Carotid rete cools brain: Thomson's gazelle

Image

Erik A. Drabløs commons.wikimedia.org [06/2010]

Organism term

Thomson's gazelle, Pronghorn
Gazella thomsonii Günther, 1884, *Antilocapra americana*

Keywords / Freatures

carotid rete, skin, heat exchange, heat dissipation

Short description

"Pronghorn (Antilocapra americana) inhabit the shortgrass prairie of the Great Plains mainly to the east of the Rocky Mountains, with over 60% of the current U.S. population in Wyoming (O'Gara and Yoakum 2004). Their habitat is arid, with sparse vegetation and extreme temperature variations...We have found that pronghorn (Antilocapra americana) use external heat exchange with the environment and internal heat exchange between the carotid artery rete and cavernous venous sinus blood to regulate body temperature...Our physiological findings imply that pronghorn have the anatomical structures needed to accommodate the extremes of weather they encounter...Regulation of these thermoregulatory responses is located in the hypothalamus, which responds to external and brain temperature signals by triggering heat loss or heat gain mechanisms, as appropriate. Brain temperature is the prime origin of responses and its temperature can be regulated by the carotid rete–cavernous sinus system...It consists of an external heat exchange mechanism involving the nasal mucosa and its blood supply, and an internal heat exchange mechanism between the arterial blood in the carotid rete and the venous blood in the surrounding cavernous sinus." (Mitchell et al 2009)

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Selection of experts

Biomimetic Products and Application Ideas

Application Ideas: Use as model for heat exchange in construction of homes and other buildings. Cooling system for computer equipment.

Link to Facade Technology

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Gefördert vom Programm „Haus der Zukunft Plus"

Name of Organism or Strategy

172 Bill used as heat exchanger for thermoregulation: toco toucan

Image

peg@transarch.org

Organism term

Toco Toucan
Ramphastos toco Statius Muller, 1776

Keywords / Freatures

heat dissipation, heat exchange, thermal radiation

Short description

"Bill of toco toucan acts as a heat exchanger to regulate body temperature by adjusting blood flow. (www.asknature.org [12/2009])

"The toco toucan (Ramphastos toco), the largest member of the toucan family, possesses the largest beak relative to body size of all birds. This exaggerated feature has received various interpretations, from serving as a sexual ornament to being a refined adaptation for feeding. However, it is also a significant surface area for heat exchange. The toco toucan has the remarkable capacity to regulate heat distribution by modifying blood flow, using the bill as a transient thermal radiator. Results indicate that the toucan's bill is, relative to its size, one of the largest thermal windows in the animal kingdom, rivaling elephants' ears in its ability to radiate body heat." (Glenn et al. 2009)

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Selection of experts

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Biomimetic Products and Application Ideas

Application Ideas: increasing energy efficiency of buildings

Link to Facade Technology

Name of Organism or Strategy

191 Nasal turbinates reduce water loss: northern elephant seal

Image

Mike Baird commons.wikimedia.org [06/2010]

Organism term

Northern Elephant Seal, northern sea elephant
Mirounga angustirostris Gill, 1866

Keywords / Freatures

nasal, turbinate, countercurrent heat exchange, water loss

Short description

The nasal turbinates of the northern elephant seal reduce water loss via countercurrent heat exchange.

Elephant seals fast completely from food and water for 1-3 months during terrestrial breeding. Temporal countercurrent heat exchange in the nasal passage reduces expired air temperature (Te) below body temperature (Tb)- At a mean ambient temperature of 13'7°C,Te is 20*9°C.This results in the recovery of 71-5 % of the water added to inspired air. The amount of cooling of the expired air (Tb~Te) and the percentage of water recovery varies inversely with ambient temperature. Total nasal surface area available for heat and water exchange, located in the highly convoluted nasal turbinates, is estimated to be 720 cm2 in weaned pups and 3140 cm2 in an adult male. Nasal temporal countercurrent heat exchange reduces total water loss sufficiently to allow maintenance of water balance using metabolic water production alone...Nasal countercurrent heat exchange results in a significant reduction of respiratory evaporative water loss (EWL) in the northern elephant seal. Reduction in Te and calculated water savings are comparable to those reported for several large and small animals adapted to arid habitats (Jackson & Schmidt-Nielsen, 1964; Collins et al. 1971; hangman et al. 1978, 1979). When compared

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Selection of experts

Biomimetic Products and Application Ideas

Application Ideas: water capture systems, avoid water loss in technical systems

Link to Facade Technology

27a

Name of Organism or Strategy

193 Desert shrub: low-energy water removal

Image

LRBurdak commons.wikimedia.org [06/2010]

Organism term

Plantae

Keywords / Freatures

water harvesting, capillary, low energy, negative pressure

Short description

The roots of desert plants extract hard to remove water from soil using negative pressure.

"Plants again. Even in a desert the soil a little ways below the surface contains liquid water. It's called 'capillary water' and is often thought of as firmly stuck to soil particles. The binding, though, is as much physical as chemical - the water in the soil interstices lie in tiny recesses between soil crumbs where it has minimized its exposed interface with air (Rose 1966). For the roots of a plant to extract the water requires making more surface, and thus it takes a very great pull, one that appears as an additional (negative) component of the pressure in the vessels running up a stem or trunk. The lowest (most negative) pressures known in plants occur in desert shrubs, which must suck really hard on the ground to get any water out. The most extreme value on record is, I think, minus 120 atmospheres (Schlessinger et al. 1982) - that would hold up a column water over 1,200 meters (4,000 feet) high. So the pull needed to get water free of soil can exceed both the pull that keeps water moving in the vessels and the pull that counteracts gravity." (Vogel 2003)

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Selection of experts

Biomimetic Products and Application Ideas

Application Ideas: water removal or harvesting

Link to Facade Technology

27a