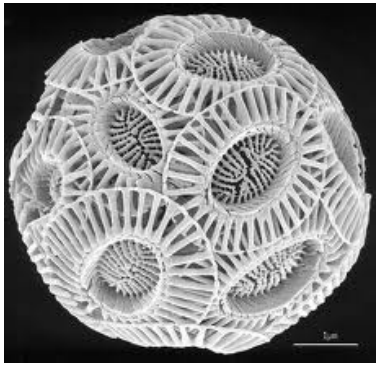
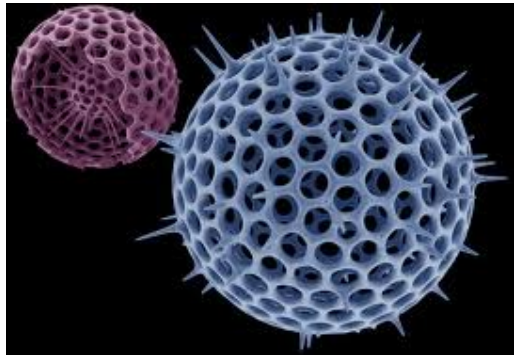
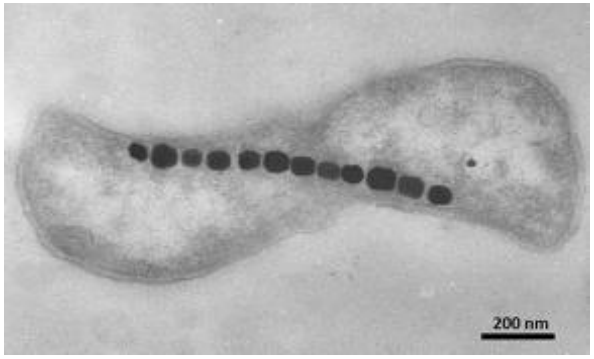






“Bei der Produktion jeder einzelner ihrer Kreaturen ... vermengt die belebte Natur die **Harmonie der Schönheit** und die **Harmonie der Zweckmäßigkeit** und formt eine einzigartige Form, die **aus der Sicht eines Ingenieurs perfekt** ist.”

M. Tupolev

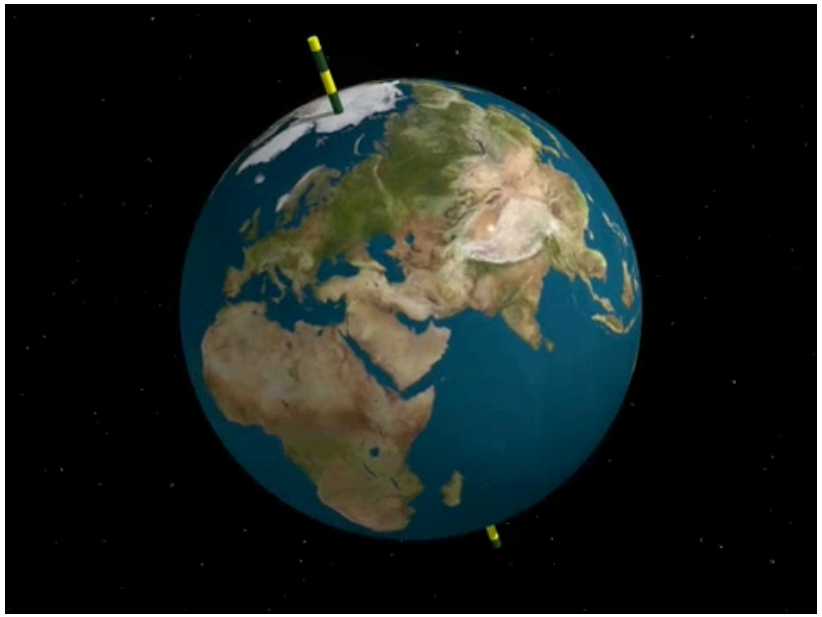
Bionik: Lernen von der Natur

Ille C. Gebeshuber

Aramis Technologies, Malaysia (2009-2015)
Universiti Kebangsaan Malaysia (2009-2015)
Vienna University of Technology, Austria (from 1999)

gebeshuber@iap.tuwien.ac.at

Eine Reise zum Äquator



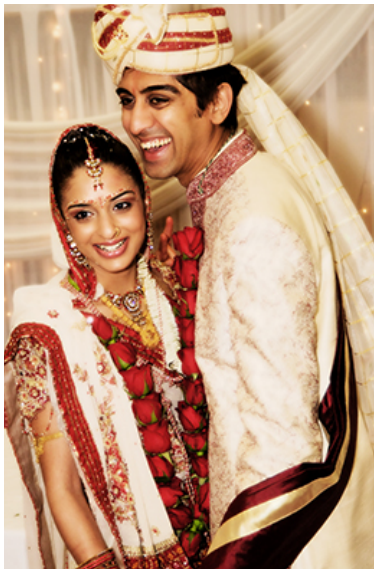
http://www.roger-mueller.ch/assets/images/Weltkarte.gif

http://www.josleys.com/htmlgalleries/globe/Sphere.JPG

Malaysien

http://www.defenseindustrydaily.com/images/GEO_Malaysia_Singapore_Malacca_Map_lg.jpg

Malayen, Chinesen und Inder



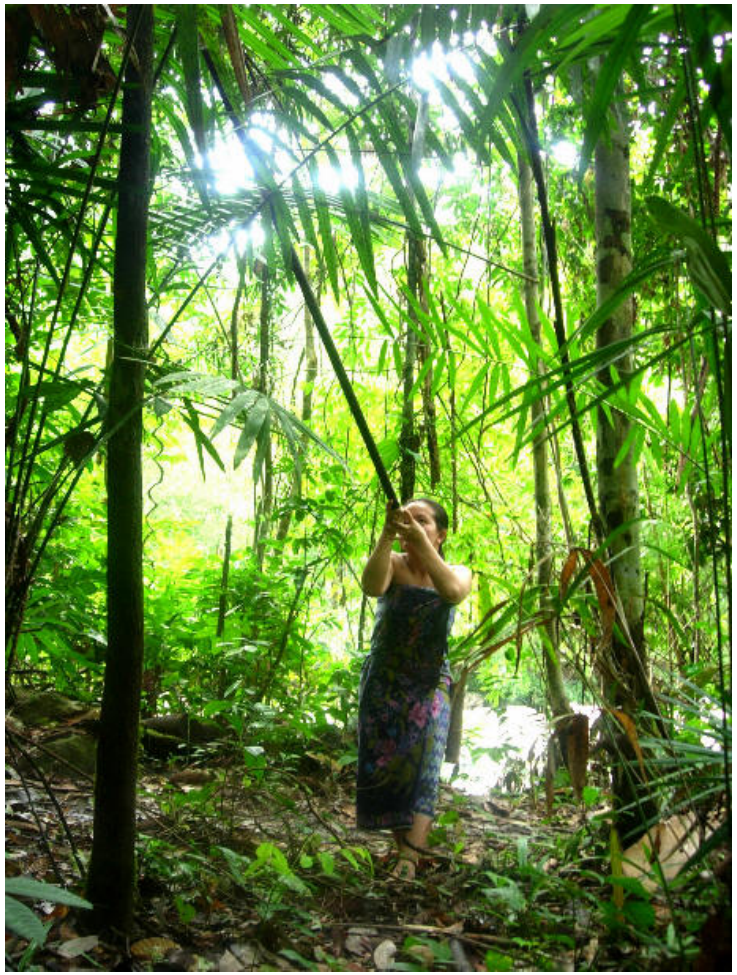
http://farm4.static.flickr.com/3204/2920212185_168f5c44dd.jpg
http://www.marryabroad.co.uk/Assets/General/marryeurope.jpg
http://www.brunomedici.com/images/F&C-Man_213.jpg
http://www.pixcellence.co.uk/assets/images/HinduWeddingPhotography_4404b.jpg
http://toshiokhoo.com/wp-content/gallery/a-malay-wedding/mw-09.jpg

Ein vielfältiges Land

http://ericstona.files.wordpress.com/2007/04/kuala-lumpur.jpg

http://www.malaysia-travel-info.com/images/Perhentian-Islands.jpg

Orang Asli



http://www.impressions.com.my/endau/erwest5.jpg

http://farm4.static.flickr.com/3204/2920212185_168f5c44dd.jpg

http://www.backpackingmalaysia.com/images/gallery/Orang_Asli_Village2.jpg

Was ist eine Gelse?

http://static.panoramio.com/photos/original/15707908.jpg

Was ist eine Gelse?

http://www.ariva.de/flugzeug_a259374

http://www.ekir.de/pep/images/668.jpg

http://magazin.naturspot.de/pict/nasenaffe.gif

http://sum1.onreact.com/bilder/auge.jpg http://amstetten.evang.at/Bilder/zungezeigen.jpg

http://4.bp.blogspot.com/_NdzbS_1Yx4s/R-PY40uX7II/AAAAAAAAAGE/hcn44-mDKHY/s320/grammophon2.jpg

http://www.tz-online.de/bilder/2008/11/25/22210/1841099979-ohr_475px.9.jpg

Was man anzieht im Regenwald

Auf großer Regenwaldexpedition

Rattan

http://www.vega-direct.at/IMAGE_POOL/wga/0810/rattanarm_wga_0810_ue01a_2.jpg

Tropische Früchte

http://2.bp.blogspot.com/_olhzL-oEec4/SWd8dwM9NJI/AAAAAAAAAIk/COE3ZwrRsAU/s400/mangostien.jpg

http://www.hot-screensaver.com/wp-myimages/malaysia-durian.jpg

http://www.stockfood.de/bilder-fotos/Verschiedene%20tropische%20Früchte%20und%20Gewürze-245009.jpg

Essbare Vogelnester

http://daviegan.files.wordpress.com/2009/07/swiftletdg.jpg

http://www.purenessbirdnest.com.sg/images/cavehousebirdnest.jpg

Blaue Moosfarne

Tiere und Pflanzen im Regenwald

http://www.MIR.com.my/VThian

http://bioweb.uwlax.edu/bio203/s2009/houk_step/wallaces-flying-frog.jpg

Tiere und Pflanzen im Regenwald

http://www.cringel.com/files/images/adia-2007-08-04-DSC-2814-hornbill-in-bird-park-malaysia-kuala-lumpur-cringel.com.jpg

http://1.bp.blogspot.com/_lFELKwm4ZV8/Sjh4GChSJII/AAAAAAAAC1s/my5-o3oHDuo/s400/DSCF7115+Rajah+Brooke+Birdwing.jpg

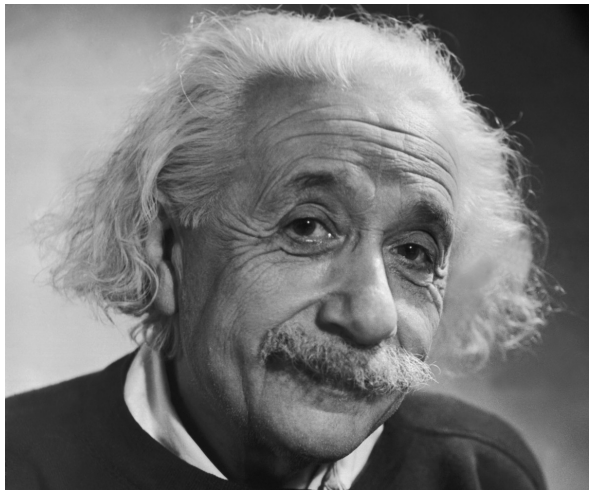
ttp://1.bp.blogspot.com/_yzw2AzY2du4/So_p9xUoUDI/AAAAAAAADV0/XqxLiF4T13M/s400/Rajah-Brookes-Birdwing-(Fem.jpg

http://eatk0okies.files.wordpress.com/2008/03/rambutan.jpg

Blutegel

http://www.bitkisel.gen.tr/katalog_resimleri/Cali-vita.jpg

Spinnen



Wir können Probleme nicht mit derselben Art des Denkens lösen, die verwendet worden ist bei der Generierung der Probleme.

Albert Einstein

Motivation

- Unsere Sichtweise der **Umwelt** hat sich verändert. Zuerst nahmen wir die Umwelt als eine Konstante wahr, die Ressourcen zur Verfügung stellt und die als Senke für unseren Abfall fungiert. Nun betrachten wir unsere Umwelt auf komplexere Art und Weise, und wissen, daß sie **durch unsere Aktivitäten beeinflusst wird – und dass wir völlig von ihr abhängig sind**.
- **Probleme**: Industrialisierung, Massenausterben der Arten, potentieller Kollaps des marinen Ökosystems, globale Herausforderungen, Grenzen des Planeten, usw.

Barnosky A.D. *et al.* (2012) **Approaching a state shift in Earth's biosphere**. Nature 486, 52-58.
Barnosky A.D. *et al.* (2011) **Has the Earth's sixth mass extinction already arrived?** Nature 471, 51-57.
Rockström J. *et al.* (2009) **A safe operating space for humanity.** Nature 461, 472-475.
Steffen W. *et al.* (2015) **Planetary boundaries: Guiding human development on a changing planet.** Science 347, 6223.

Wertebasierte Wissenschaft

- Verantwortlichkeit
- Globale Ethik
- Nachhaltigkeit

- Die TeilnehmerInnen des 5. Wissensateliers sind hochgradig interdisziplinär, und bauen Brücken zwischen Wissenschaft, Technologieentwicklung und Wirtschaft – ein guter Start!

Gebeshuber I.C. (2016) *Value based science: What we can learn from micro- and nanotribology.* Tribology - Materials, Surfaces and Interfaces 10(1), 10-18.

Innovision

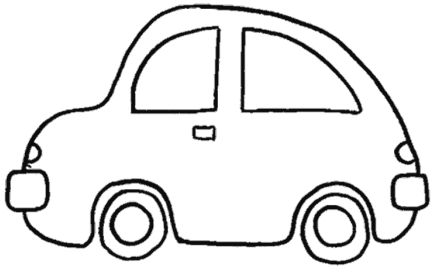
** Nicht nur schneller, kleiner, billiger. **

Der Pfad von der Innovation zur Innovision ist durch einen neuen Rahmen des Denkens charakterisiert, der die Grundvoraussetzung für die Entwicklung von Lösungen ist.

Dieser neue Rahmen des Denkens basiert auf Lektionen aus der belebten Natur.

Gebeshuber I.C. (2016) *Ecotribology: Development, Prospects, and Challenges.* In: Eco-Tribology - Research Developments, (Ed. J. Paulo Davim), Springer, 1-39.

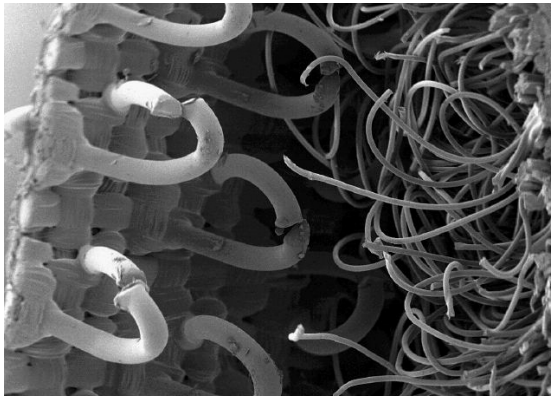
Konstruktionen – menschengemacht



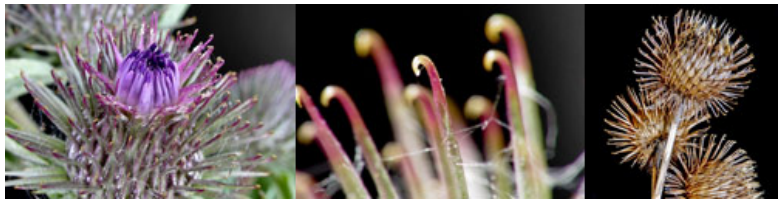
Konstruktionen – natürlich

Biomimetik

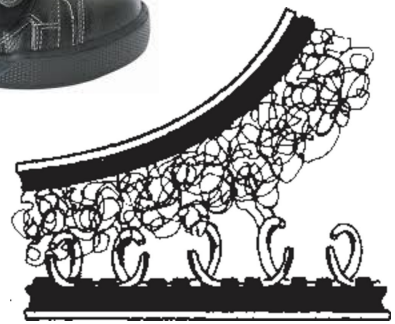
Biomimetik

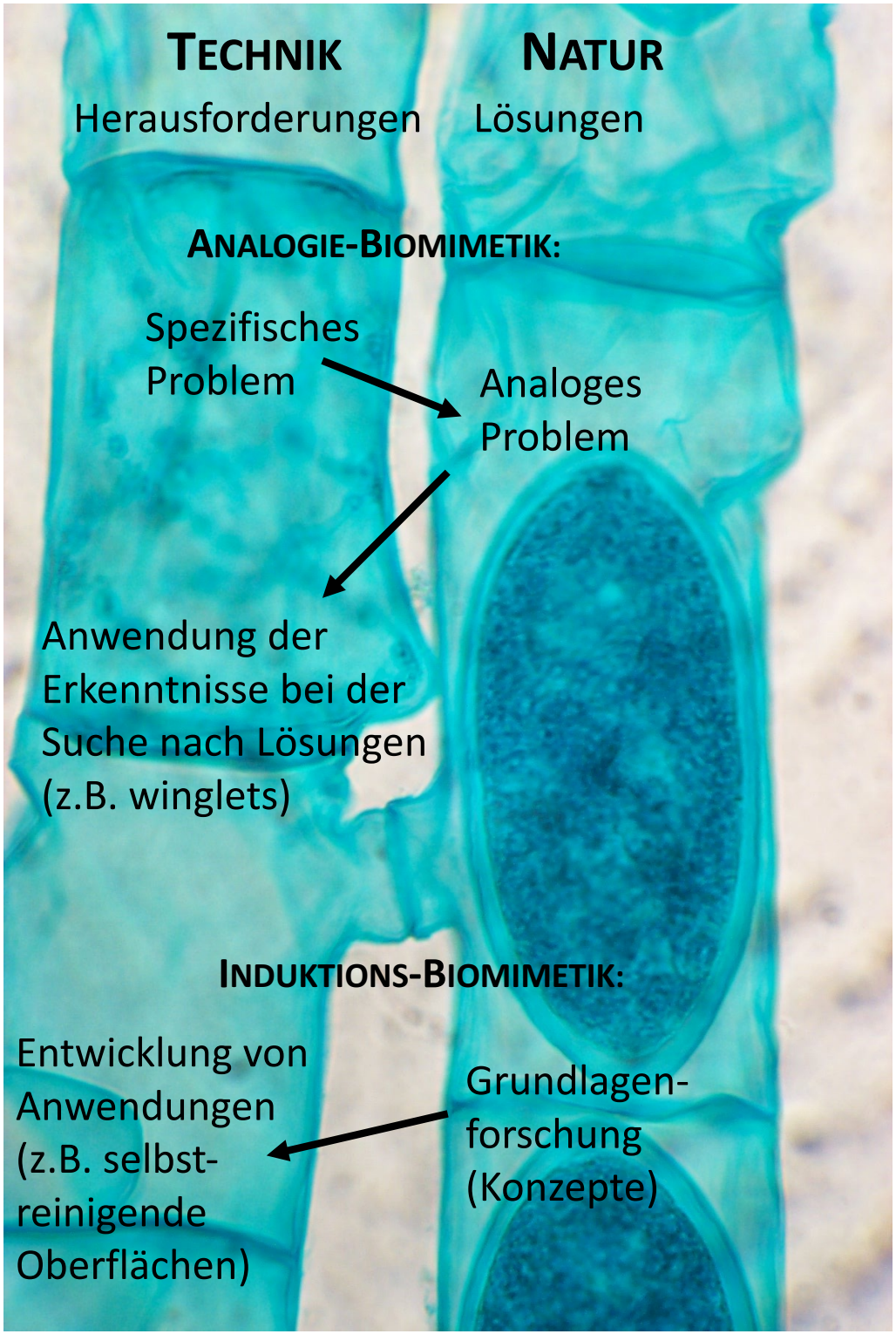


Biomimetik ist die Abstraktion
von gutem Design in der belebten Natur.



Zentrum für Biomimetik, UK





Gebeshuber I.C. and Drack M. (2008) *An attempt to reveal synergies between biology and mechanical engineering.* Proc. IMechE Part C: J. Mech. Eng. Sci. 222(7), 1281-1287.

Materialien

Bergbau mit Pflanzen – eine Inspiration
für biomimetisches Metallmanagement

Table 5: Hyperaccumulators in phytomining. Source: van der Ent et al. [183] with modifications, together with the metal concentration in selected hyperaccumulators.

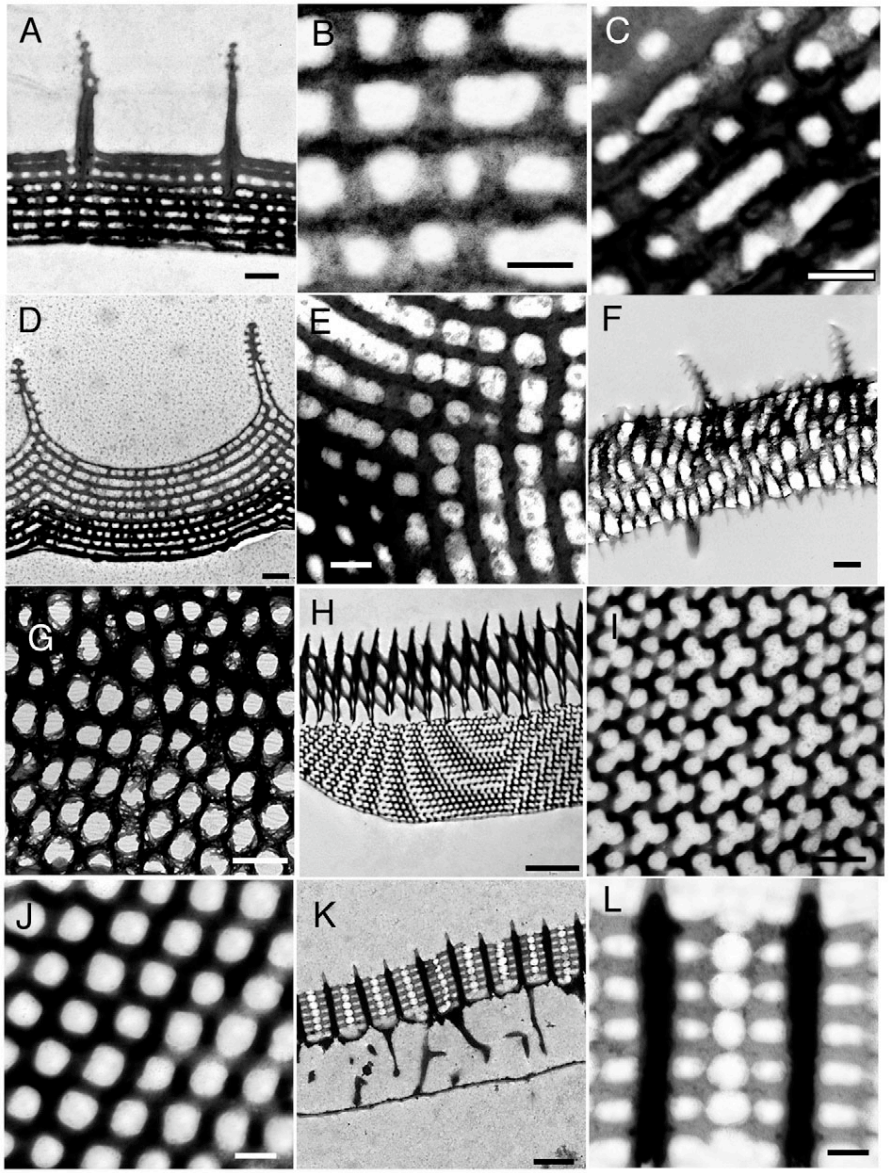
Metal	Number of hyperaccumulator species recorded	Hyperaccumulation threshold (mg kg^{-1})	Selected hyperaccumulator species	Concentration of metals (mg/kg d.w.)
			Sebertia acuminate [167, 179]	
			Streptanthus polygaloides [184, 185]	
			Alyssum bertolonii [186, 187]	13400
Nickel	450	1000	*Berkheya coddii* [187]	17000
			Thlaspi geosingense [188]	
			Alyssum tenium [19]	
			Alyssum troodii [19]	
Cobalt	30	300	*Haumaniastrum robertii* [189]	10200
Copper	32	300	*Helianthus annuus* L. [190]	
			Haumaniastrum katangense [169]	8356
Zinc	12	3000	*Thlaspi calaminare* [181]	10000
			Thlaspi caerulescens	
Zinc and Cadmium			*Sedum alfredii*	
			Polycarpaea longiflora [19]	
			Allium sativum L. [191]	
Cadmium	2	100	*Thlaspi caerulescens* [19]	3000
			Solanum nigrum [192]	
			Rorippa globosa [174]	
Gold (induced hyperaccumulation)		1	*Brassica juncea* *Barkley coddii* [193, 194]	10
Manganese	12	10000	*Macadamia neurophylla* [195]	55000
Lead	14	1000	*Thlaspi rotundifolium* subsp. [181]	8200
Thallium	2	100	*Biscutella laevigata* *Iberis intermedia* [193, 196]	4055

Karman S.B., Diah S.Z.M. and Gebeshuber I.C. (2015) *Raw materials synthesis from heavy metal industry effluents with bioremediation and phytomining: A biomimetic resource management approach.* Adv. Mat. Sci. Eng. #185071, 21 p.

Strukturen

Optimierte funktionale Mikro- und Nanostrukturen –
inspiriert durch Organismen


© seabagg
http://www.flickr.com/photos/seabagg/3923303391/

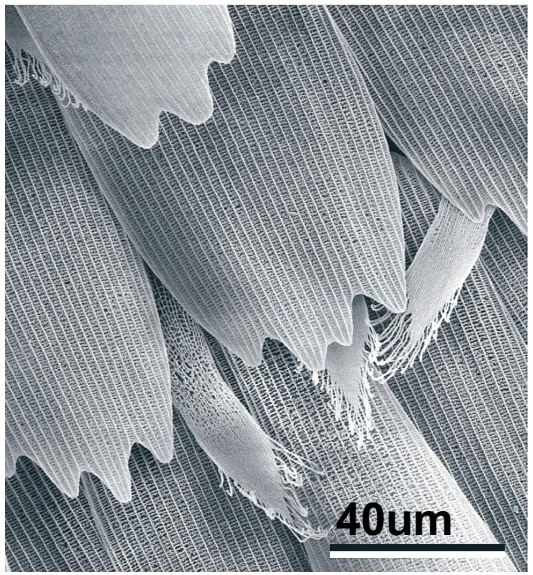


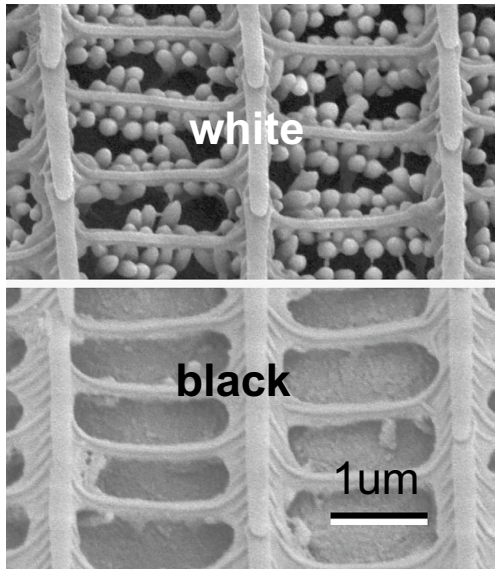
Scale bars:
500nm (A,D, F,G),
200nm (B,C,E,J,L),
2um (H), and 1um (K).

Prum R.O., Quinn T. and Torres R.H.
Anatomically diverse butterfly scales all produce structural colours by coherent scattering
J. Exp. Biol. 209, 748-765, 2005

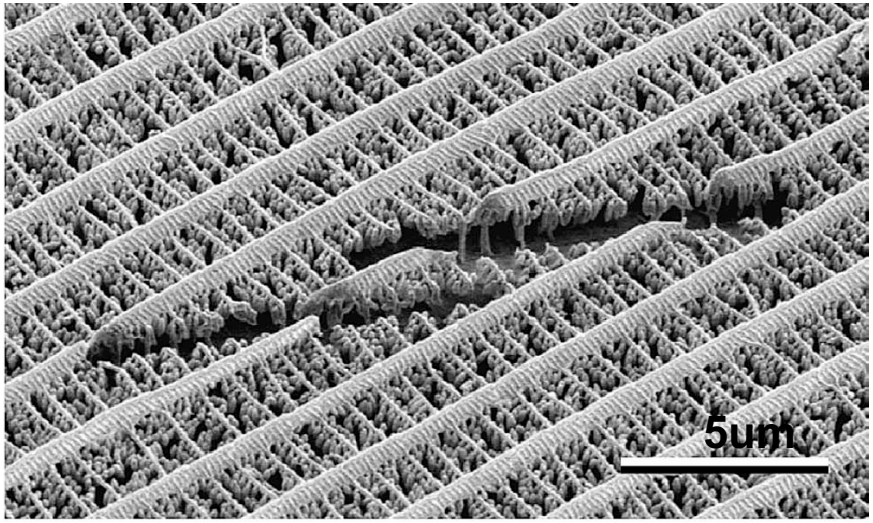

© Foozi Saad

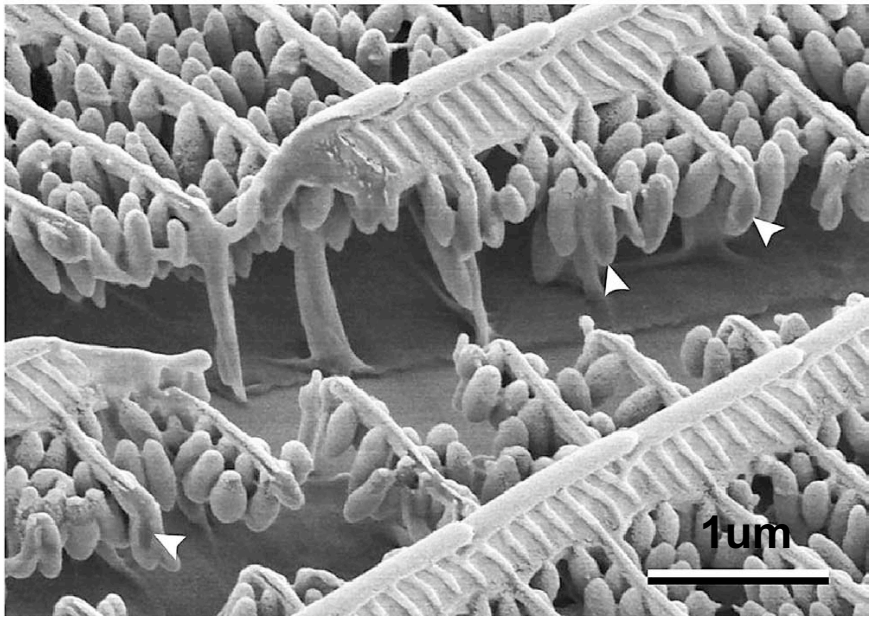
Kohlweißling





Die elongierten eiförmigen Strukturen verursachen die mattweiße Farbe und erhöhen die Reflektivität.



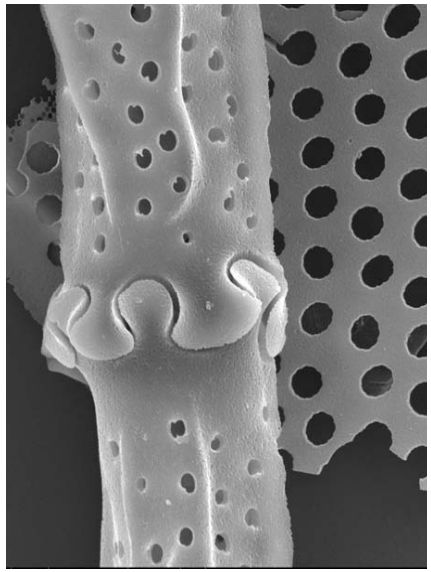


Stavenga D.G., Stowe S., Siebke K., Zeil J. and Arikawa K.
Butterfly wing colours: Scale beads make white pierid wings brighter
Proc. Royal Society B Biol. Sci. 271(1548), 1577-1584, 2004

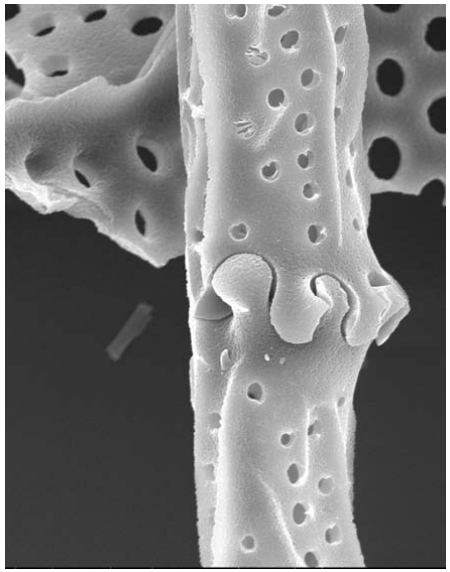
Prozesse

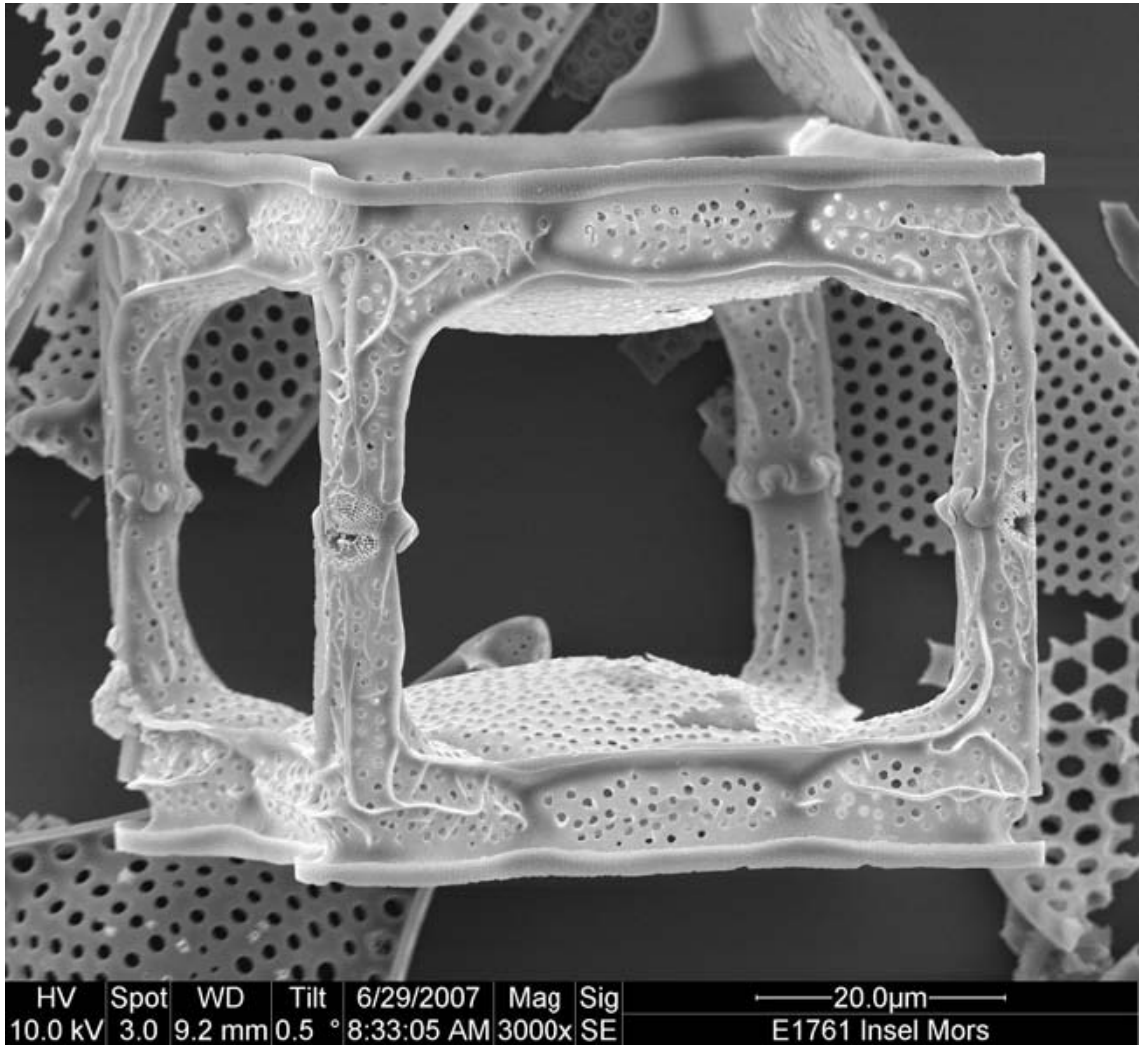
Biomineralisation unter Umgebungsbedingungen

Biomineraliaation



© R.M. Crawford
and F. Hinz





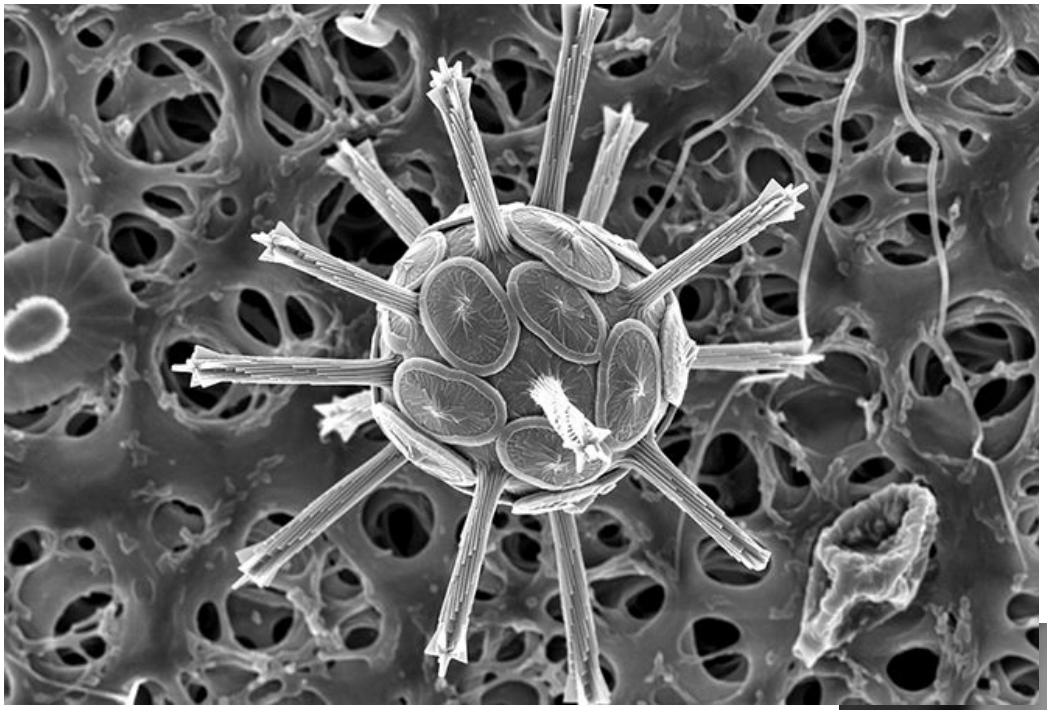
I.C. Gebeshuber **Biomineralization in marine organisms: status, challenges and prospects for biotechnology**. Springer Handbook of Marine Biotechnology, 2015.

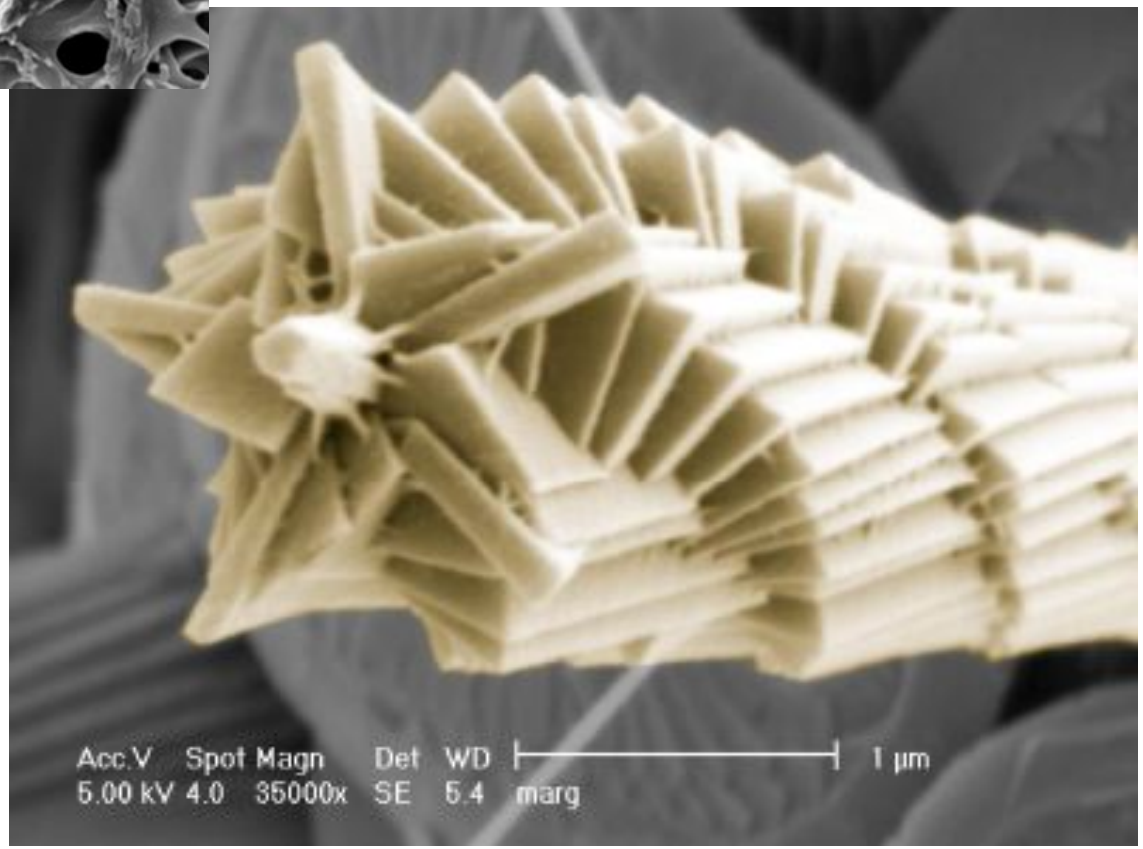
Biomineralisation

Mehr als 70 verschieden Biomineralien!
Metalle, Legierungen, Keramiken, Polymere und Verbundstoffe.
Mit der Hilfe von Proteinen @ unter Umgebungsbedingungen.

- Karbonate wie Kalzit $CaCO_3$ in Muscheln.
- Phosphate wie Hydroxyapatit $Ca_5[OH(PO_4)_3]$ in Knochen.
- Oxide wie Magnetit Fe_3O_4 in magnetotaktischen Bakterien.
- Sulfate wie Coelestin $SrSO_4$ in Radiolarien.
- Sulfide wie Pyrit FeS_2 in magnetotaktischen Bacterien.
- Gediegene chemische Elemente wie Gold Nanokristalle Au in Hefen and Schwämmen.
- … und viele mehr!

I.C. Gebeshuber **Biomineralization in marine organisms: status, challenges and prospects for biotechnology**. Springer Handbook of Marine Biotechnology, 2015.

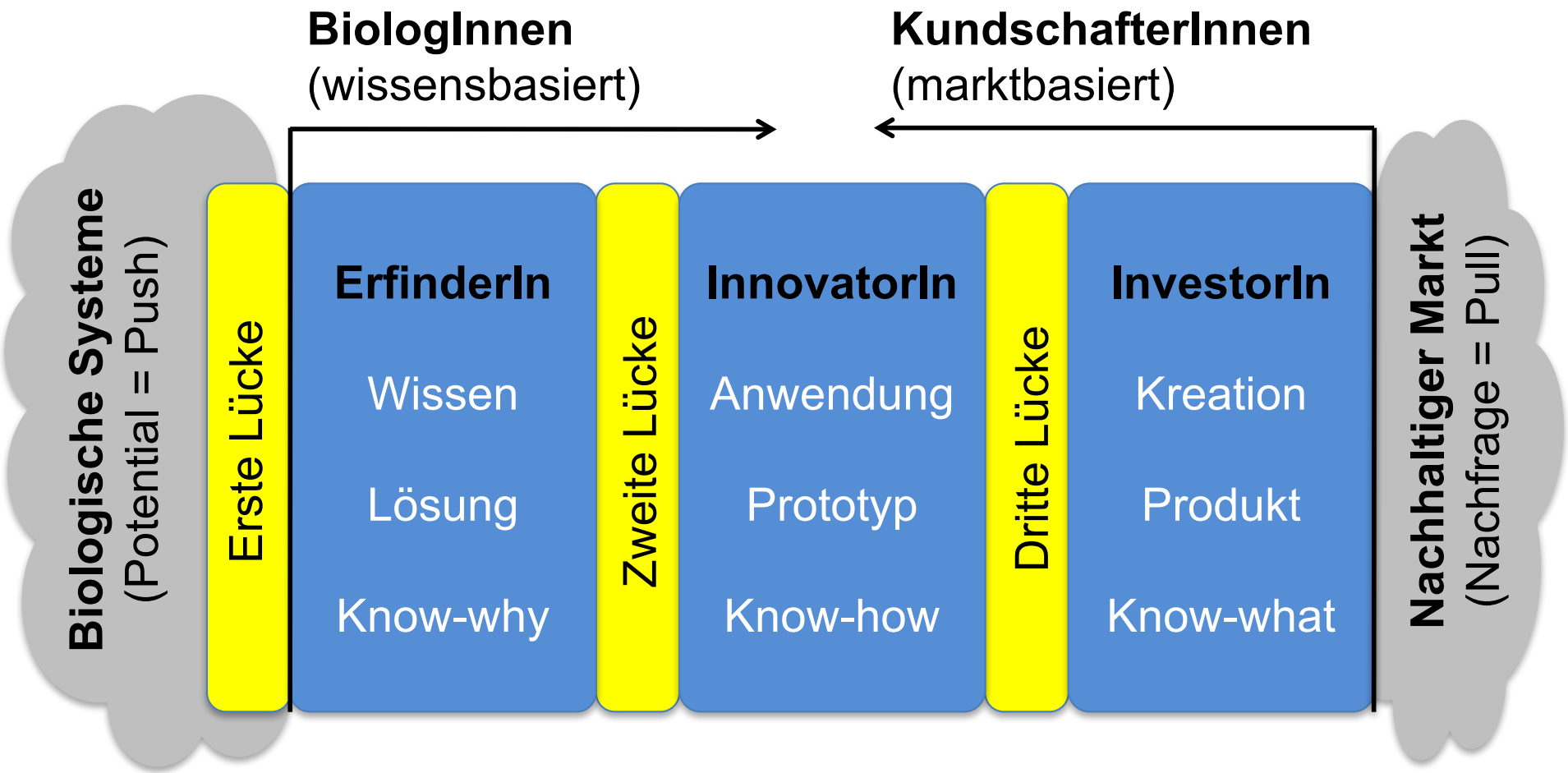




Young J.R. and Henriksen K. (2003) *Biomineralization within vesicles: The calcite of coccoliths.* Rev. Mineralogy Geochem. 54, 189-216.


© Iwan Ramawan

Der Weg zur Nachhaltigkeit



Life's Principles - Design Lessons From Nature

1. Earth's operating conditions:
    - 1.1. Water-based
    - 1.2. Subject to limits and boundaries
    - 1.3. In a state of dynamic non-equilibrium
2. Life creates conditions conducive to life
    - 2.1. Optimizes rather than maximizes
        - 2.1.1. Multi-functional design
        - 2.1.2. Fits form to function
        - 2.1.3. Recycles all materials
    - 2.2. Leverages interdependence
        - 2.2.1. Fosters cooperative relationships
        - 2.2.2. Self-organizing
    - 2.3. Benign manufacturing
        - 2.3.1. Life-friendly materials
        - 2.3.2. Water-based chemistry
        - 2.3.3. Self-assembly
3. Life adapts and evolves
    - 3.1. Locally attuned and responsive
        - 3.1.1. Resourceful and opportunistic
            - 3.1.1.1. Shape rather than material
            - 3.1.1.2. Simple, common building blocks
            - 3.1.1.3. Free energy
        - 3.1.2. Feedback loops
            - 3.1.2.1. Antennae, signal, response
            - 3.1.2.2. Learns and imitates
    - 3.2. Integrates cyclic processes
        - 3.2.1. Feedback loops
        - 3.2.2. Cross-pollination and mutation
    - 3.3. Resilient
        - 3.3.1. Diverse
        - 3.3.2. Decentralized and distributed
        - 3.3.3. Redundant

General Biomimetic Principles

Can be applied by engineers who are not at all involved in biology.

1. Integration instead of additive construction
2. Optimization of the whole instead of maximization of a single component feature
3. Multi-functionality instead of mono-functionality
4. Fine-tuning regarding the environment
5. Energy efficiency

Nachtigall W. (2009) **Vorbild Natur: Bionik-Design für funktionelles Gestalten.** Springer, Berlin.

General Biomimetic Principles

Can be applied by engineers who are not at all involved in biology.

6. Direct and indirect usage of solar energy
7. Limitation in time instead of unnecessary durability
8. Full recycling instead of piling waste
9. Interconnectedness as opposed to linearity
10. Development via trial-and-error processes

Nachtigall W. (2009) **Vorbild Natur: Bionik-Design für funktionelles Gestalten.** Springer, Berlin.

Principles for Sustainable Biomimetics

1. *Evolve to survive*

Sustainability can be ensured when information to ensure enduring performance is continually incorporated and embedded.

2. Resource efficiency regarding material and energy

Skillfully and conservatively take advantage of local resources and opportunities.

3. Adaptation to changing conditions

Appropriately respond to dynamic contexts.

Biomimicry 3.8 in Gebeshuber I.C. (2012) **Green Nanotribology and sustainable nanotribology in the frame of the global challenges for humankind.** in: Green Tribology - Biomimetics, Energy Conservation, and Sustainability, Springer, pp. 105-125.

Principles for Sustainable Biomimetics

4. Integration of development with growth

Invest optimally in strategies that promote both development and growth.

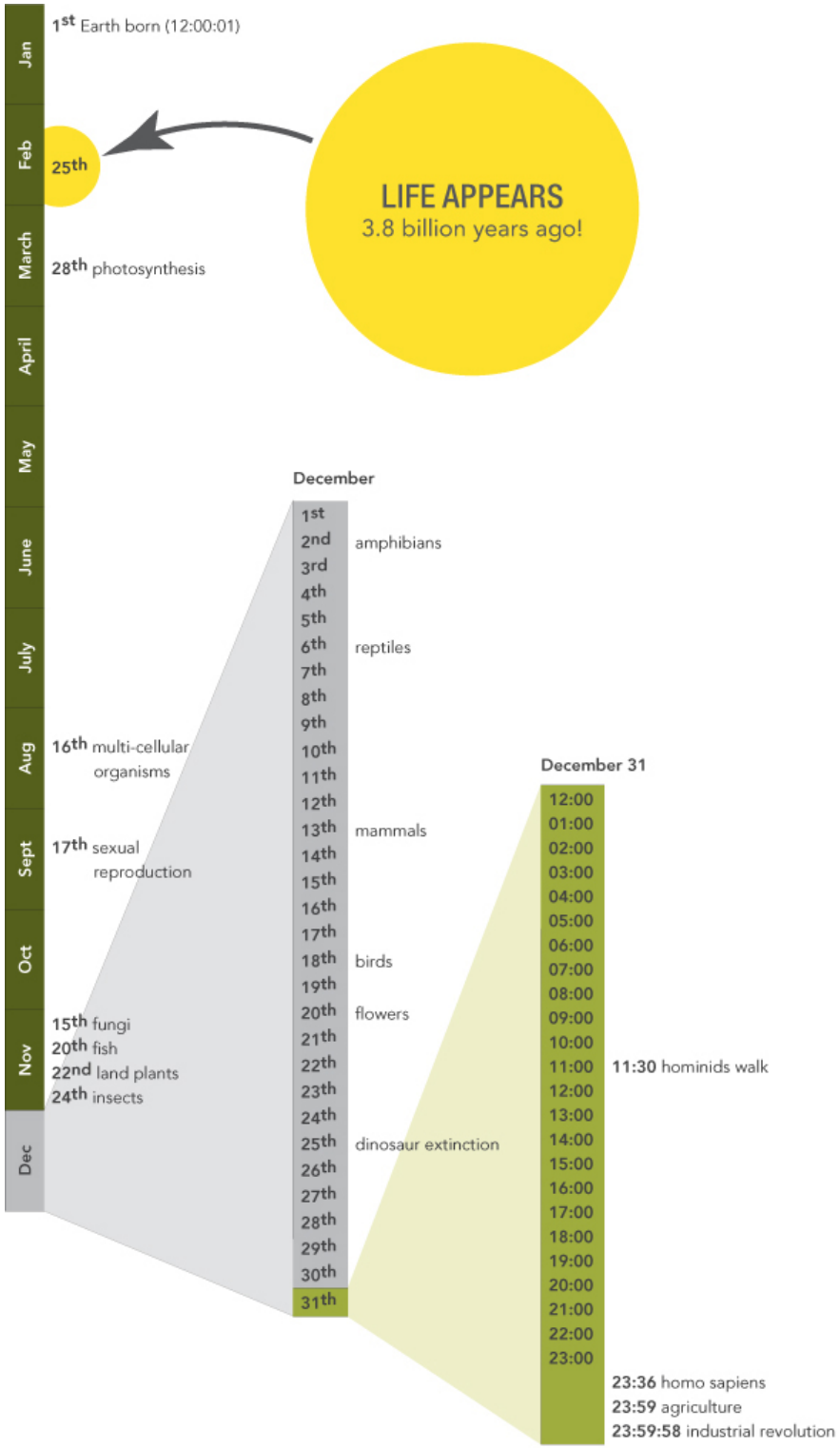
5. Responsiveness and being locally attuned

Fit into and integrate with the surrounding environment.

6. Usage of life-friendly chemistry

Use chemistry that supports life processes.

Biomimicry 3.8 in Gebeshuber I.C. (2012) **Green Nanotribology and sustainable nanotribology in the frame of the global challenges for humankind.** in: Green Tribology - Biomimetics, Energy Conservation, and Sustainability, Springer, pp. 105-125.



http://ben.biomimicry.net/wp-content/uploads/2013/02/Biomimicry38_Lifes_Birthday_Geological_Timeline6.jpg

Recommended Reading

- **Nano Risk Governance:**
  Gebeshuber I.C. (2014) Grüne und nachhaltige Nanotribologie, in: Nano Risiko Governance Der gesellschaftliche Umgang mit Nanotechnologien (Eds. Gazsó A. and Haslinger J.), Springer
- **Biomimetics – Materials:**
  Karman, Diah and Gebeshuber (2015) Phytomining, Adv. Mat. Sci. Eng.
- **Biomimetics – Structures:**
  Gebeshuber and Lee (2016) Nanostructures for Coloration, Springer Encyclopaedia of Nanotechnology, Springer
- **Biomimetics – Processes:**
  Gebeshuber (2015) Biomineralization in Marine Organisms, Springer Handbook of Marine Biotechnology, Springer
- **Sustainable Biomimetics:**
  Gebeshuber I.C. (2012) Green Nanotribology and sustainable nanotribology in the frame of the global challenges for humankind. Green Tribology, Springer