

la biomimétique

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APPLIQUÉES
LYON



Université Claude Bernard  Lyon 1

Par un Biologiste

Yvan Rahbé, DR INRAE

UMR5240 CNRS MAP

Microbiologie, Adaptation, Pathogénie

UCBL INSA-de Lyon



Biomimétique et Bioinspiration

Une méthode

- Erigée en méthode de recherche scientifique et d'ingénierie, la biomimétique se situe au croisement de la biologie et de la technologie. Elle s'inspire des formes et des matières quelles que soient leurs échelles (nanoscopiques, moléculaires ou écosystémiques)... Elle décode les propriétés, organisations et fonctions du vivant pour proposer des modèles durables éprouvés par des millénaires d'évolution et de sélection naturelle.
- La **bioinspiration** est le développement de nouveaux matériaux, dispositifs et structures inspirés par des solutions trouvées dans les systèmes biologiques et par l'évolution et le raffinement biologiques qui se sont produits sur des millions (milliards) d'années [3.8MY]. L'objectif est d'améliorer la modélisation et la simulation du système biologique afin d'atteindre une meilleure compréhension des caractéristiques structurelles critiques de la nature, comme une aile, pour **l'utiliser dans de futures conceptions** bioinspirées. La bioinspiration diffère du biomimétisme en ce que ce dernier vise à reproduire avec précision les conceptions des matériaux biologiques. La recherche bioinspirée est un retour aux origines classiques de la science : c'est un domaine basé sur l'observation des fonctions remarquables qui caractérisent les organismes vivants, et sur la **tentative d'abstraction** et d'imitation de ces fonctions.

Un principe: l'**analogie**

Bioinspiration

Un interdiscipline, Un dialogue

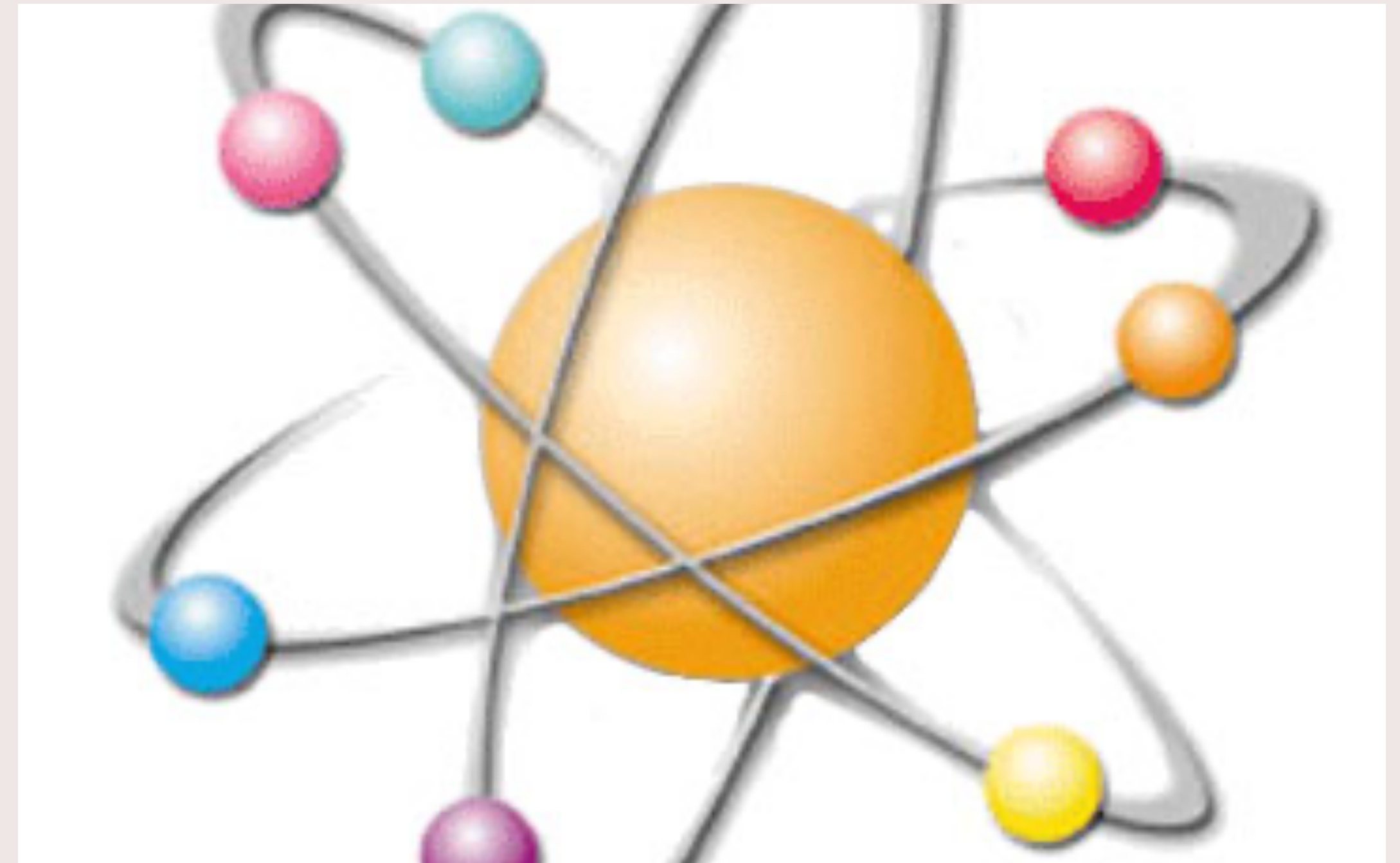
- La Biologie (Vie)



(Biologie)

- Un spécialiste

- Les champs d'applications



(Physique)

- Un autre spécialiste

STEM

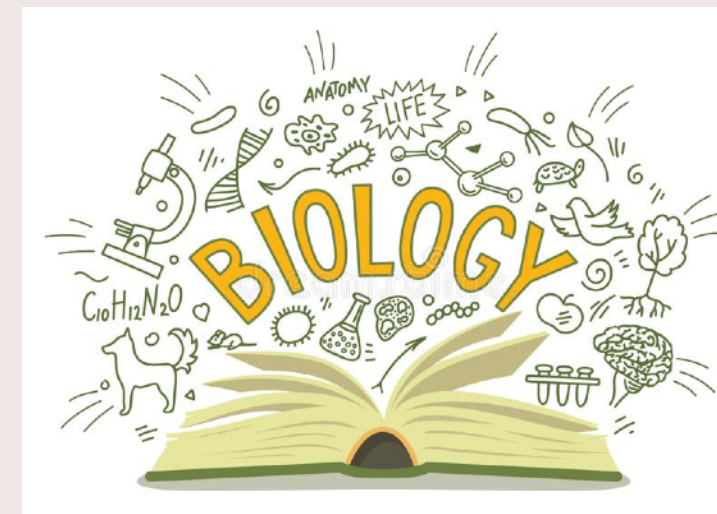
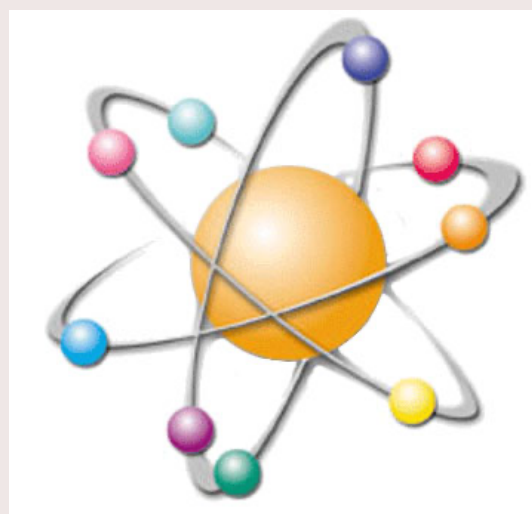
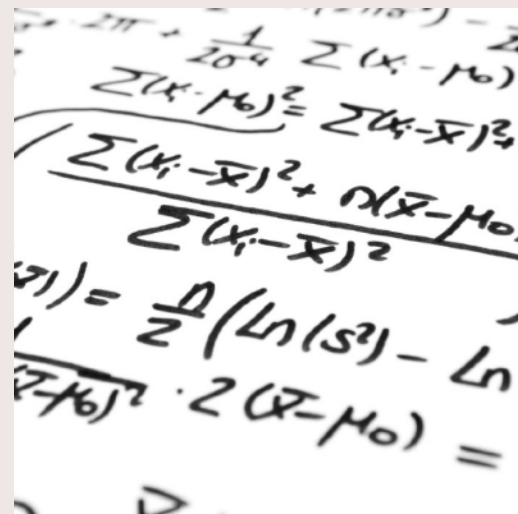
SVT

SS

SH

La biologie est une science historique

Son sujet est un « objet » en construction



L'Evolution biologique est au centre « du sujet »

Rien n'a de sens en biologie, si ce n'est à la lumière de l'évolution

Nothing in Biology Makes Sense Except in the Light of Evolution

Célèbre aphorisme de Theodosius Dobzhansky (1900 – 1975) qui révèle bien ce qu'est la théorie de l'évolution pour un biologiste:
le cadre conceptuel au sein duquel toute donnée scientifique trouve tout son sens

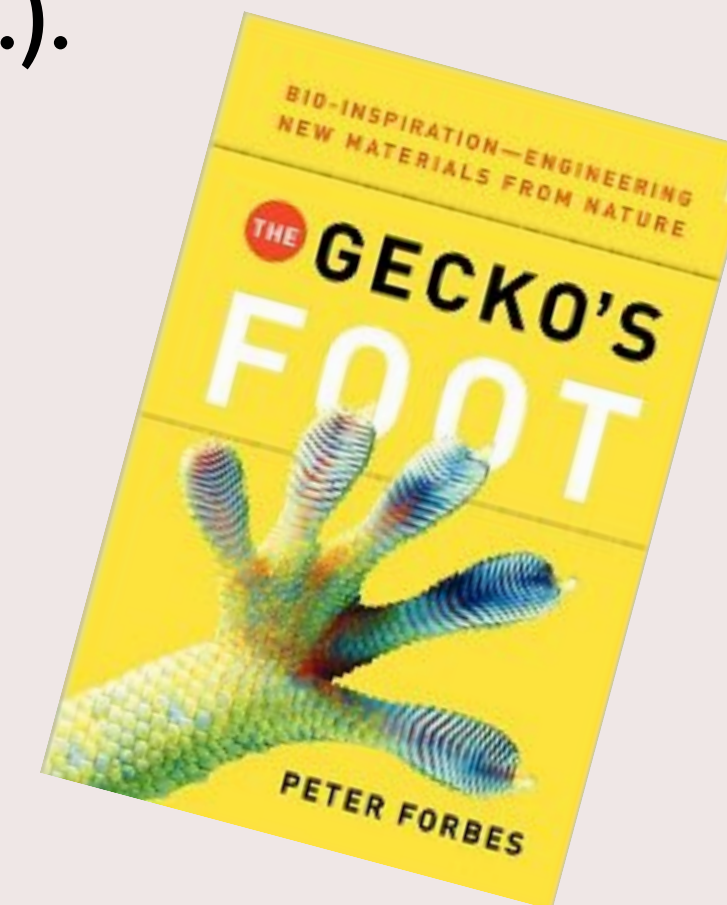
Theodosius Dobzhansky, 1964



en matière de bible

Deux must have ?

- Benyus, J.M., and Sefraoui, C. (2011). Biomimétisme quand la nature inspire des innovations durables traduction [de l'anglais], Céline Sefraoui, (Paris: Rue de l'échiquier).
- Forbes, P. (2006). The gecko's foot : bio-inspiration : engineering new materials from nature, 1st American Edition, (New York: W. W. Norton & Co.).





de quand date le
biomimétisme ?

Sulawesi, 44000 ans

Nature 3.8 Solution

Mantra: vous cherchez une solution, la nature l'a trouvée



BIOMIMICRY 3.8

Biomimicry 3.8 is the world's leading bio-inspired consultancy offering biological intelligence consulting, professional training, and inspiration.



BIOLOGICAL STRATEGIES

INSPIRED IDEAS


RESOURCES

COLLECTIONS

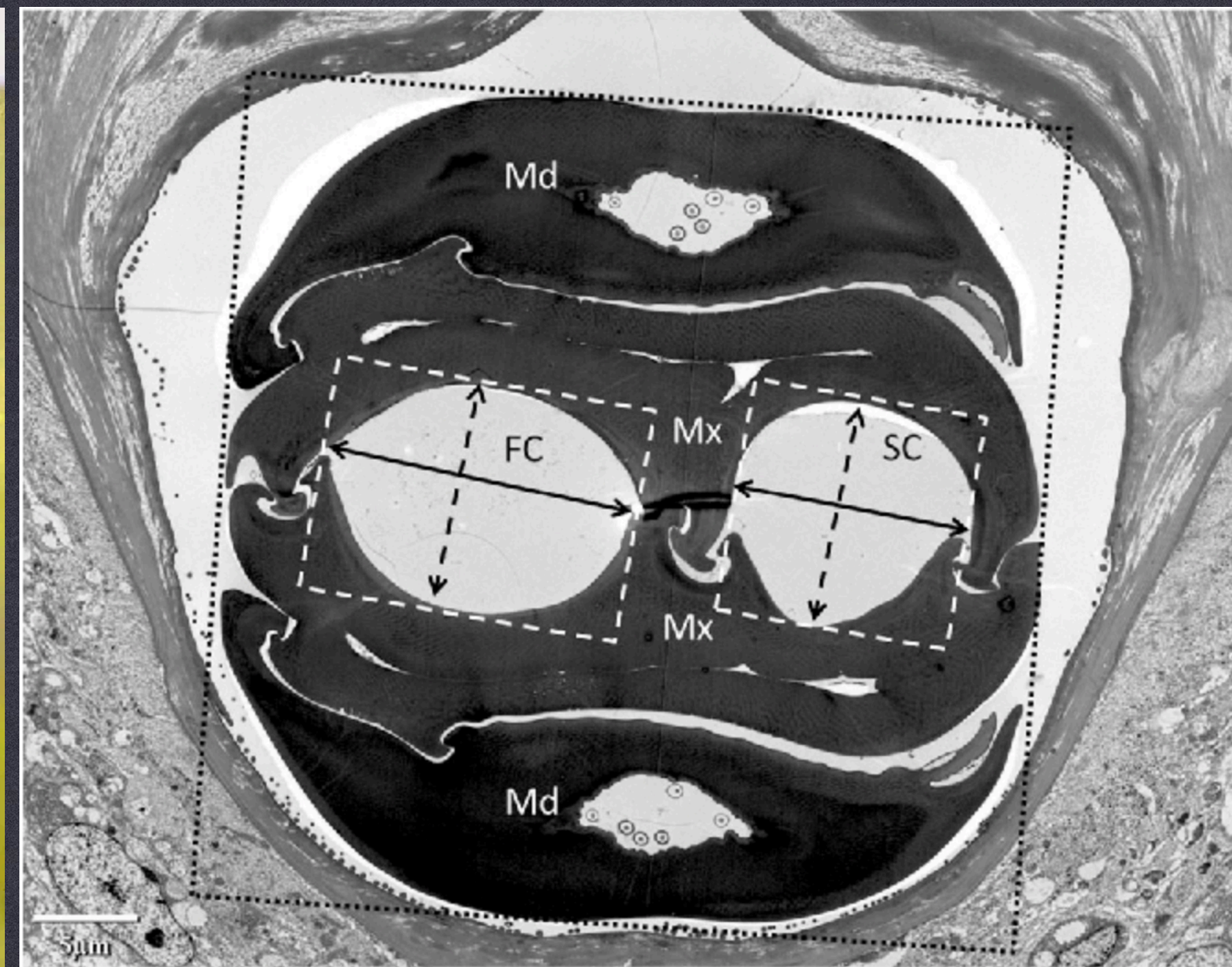


JOIN

SIGN IN



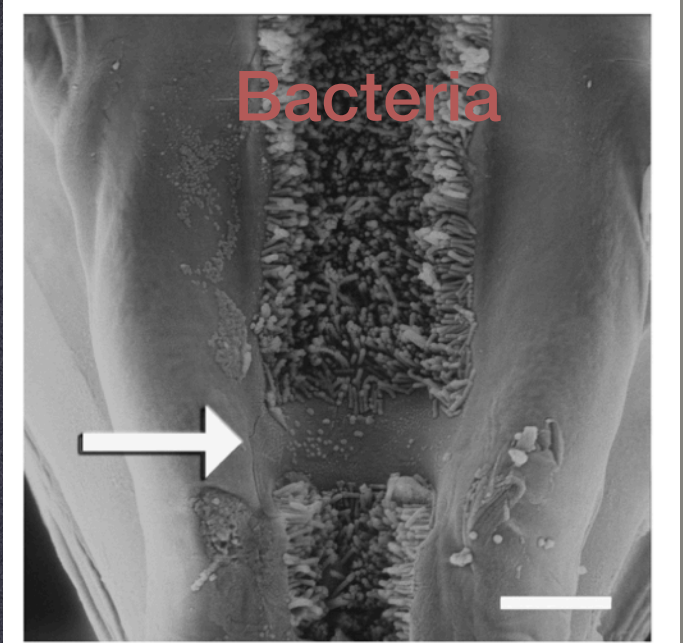
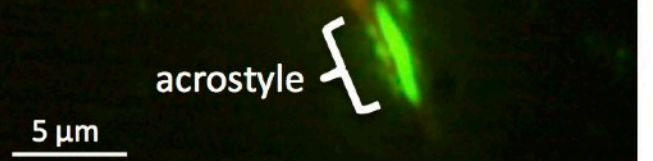
It's time to ask nature.



Stylets and microbes

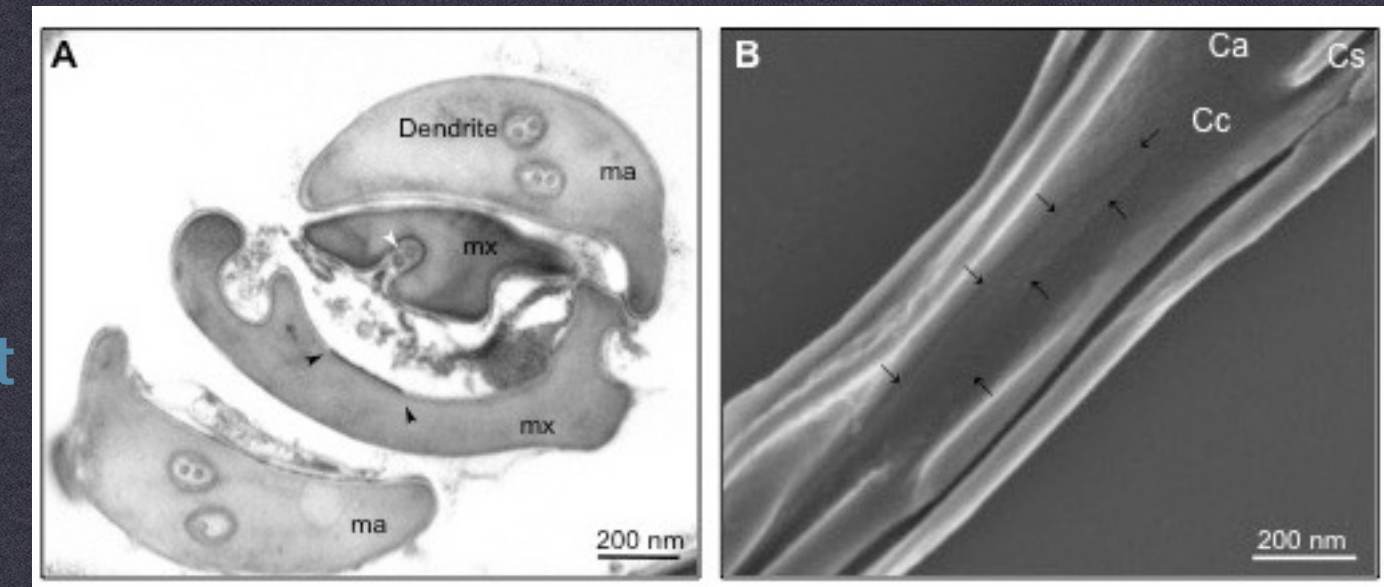
A. pisum maxillary stylets labelled with anti-Stylin-01 (1.11) antibody

Viruses



Bug Stylet

Aphid Stylet



PROJECT

WHAT IS A STYLET ?

1

DATE

2020 OCT 14

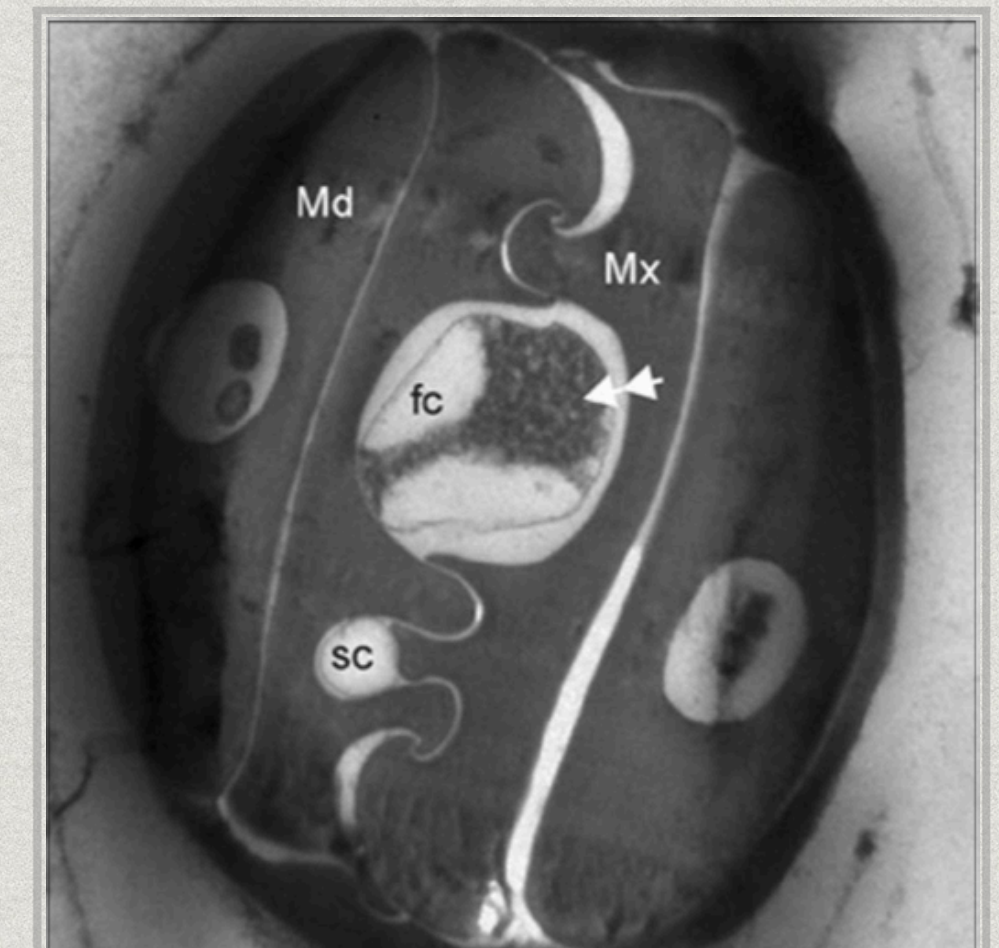
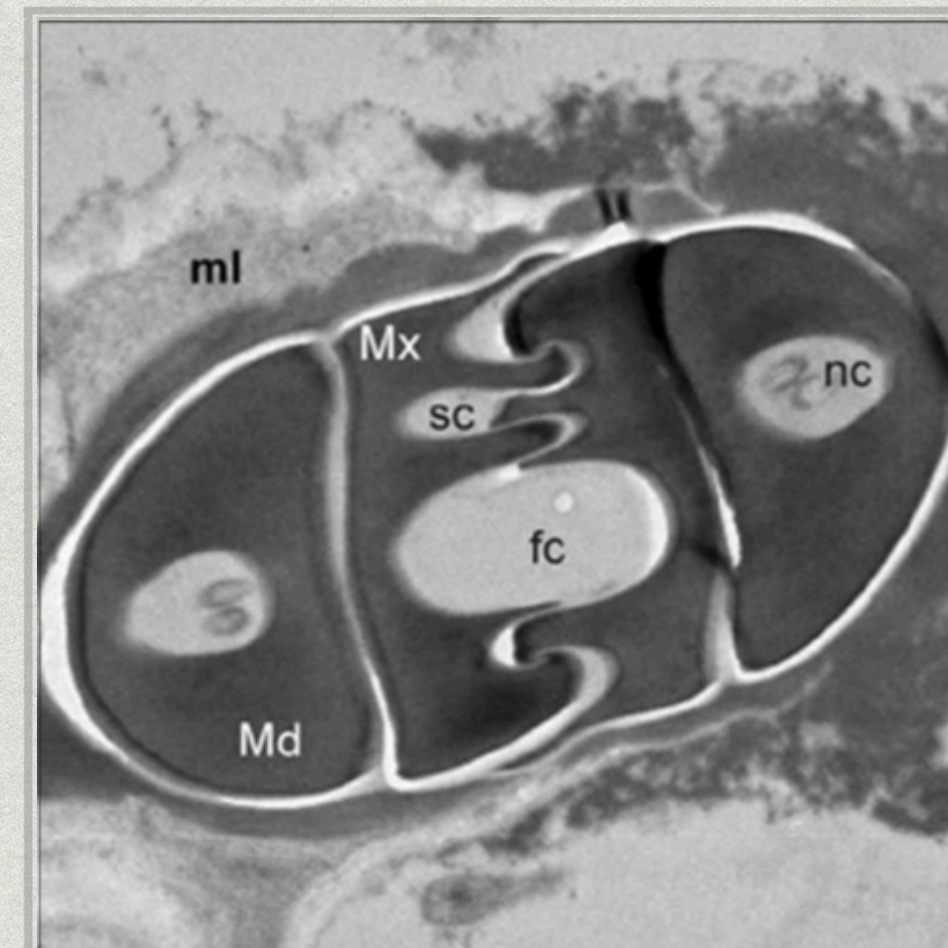
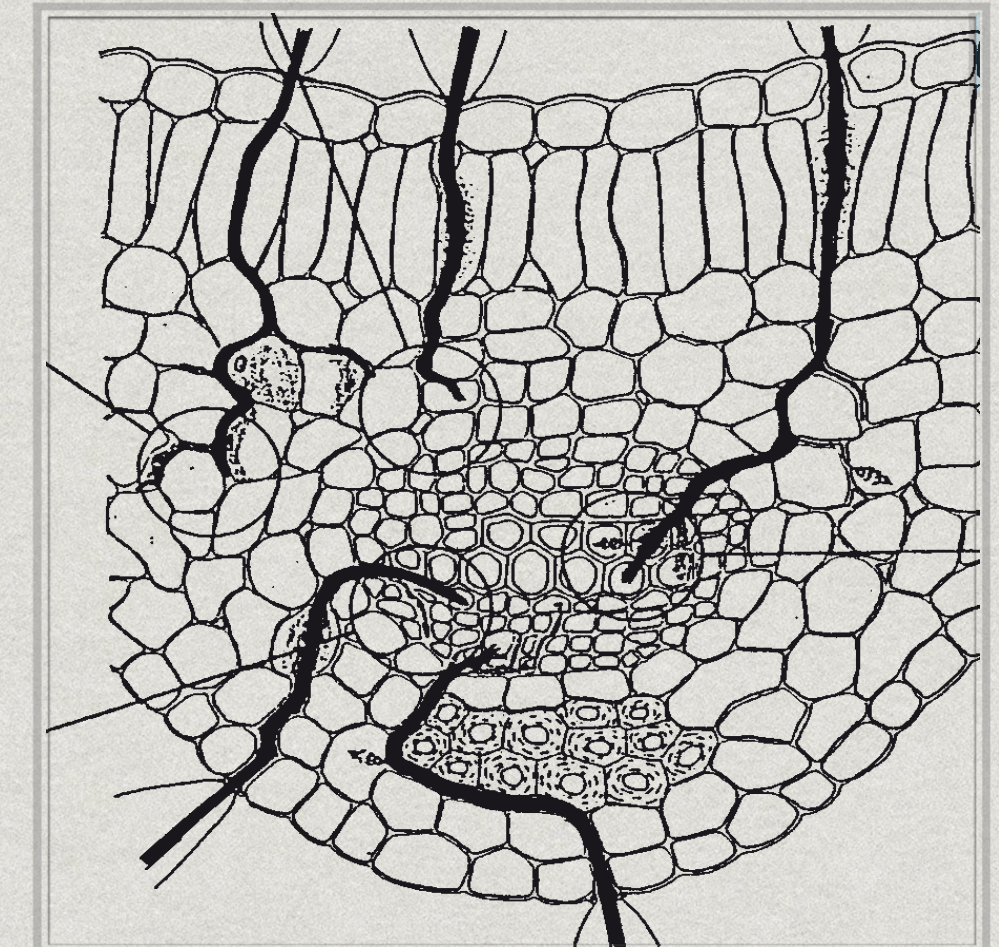
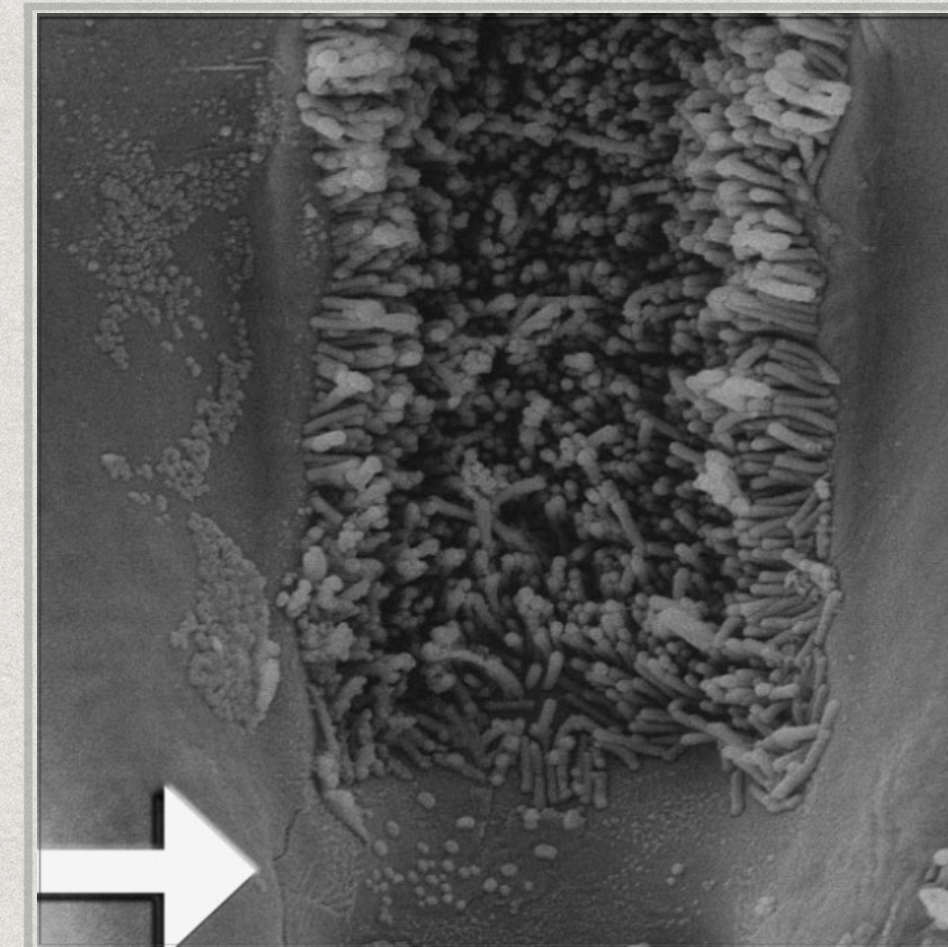
MEETING

NICE BIOMIM'2020

The questions (4 avenues)

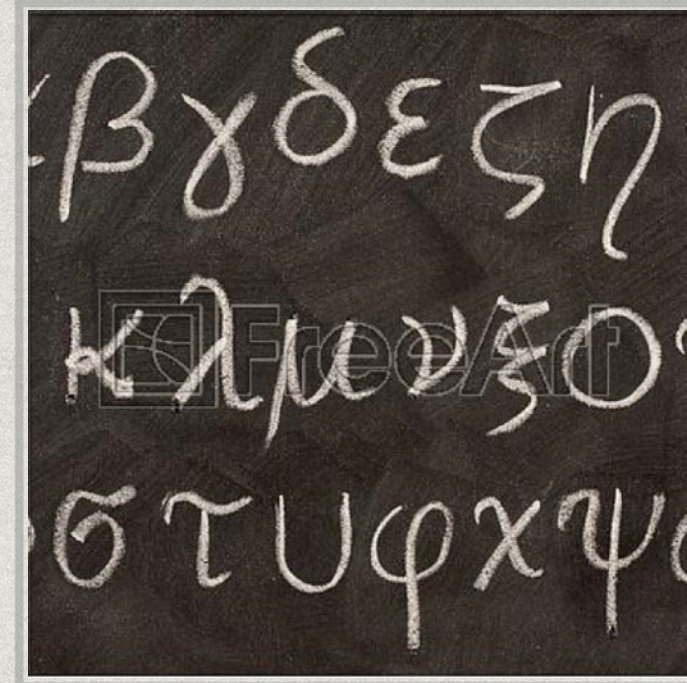
- * **Polymer** sciences (4 slides)
Cuticular (μ)territories as microbial platforms for (plant) diseases transmission
- * **Mechanics** (4 slides)
Aphid stylets as an exceptional precision drilling machine (plant parasitism as an evolutionary driving force for mechanical optimisation)
- * **Sensor(y)** physiology (to come, 1 slide)
Mandibular stylets as proprioceptor devices (?)
- * **μ fluidics** and fluid mechanics (to come, 1s.)
Phloem sap and saliva: optimisation of sugar- and protein-loaded fluids transport through cuticular surface physical and chemical adaptation (?)

Xylella fastidiosa in Sharpshooter



Take home 4message

- * How to (nano) communicate on a surface with a chitin blackboard and a protein alphabet ?



- * How to proprioceive a solid appendix when you are a (soft, living) organism ?



- * How to perform precision drilling with a (simple ?) 4piece structure ?



- * How to (μ)inject / (μ)ingest when you are a (μ)parasite ?



mostly questions of surfaces and scales in biological systems



STRATEGY

Needle-like structure inserts painlessly

Mosquitos



AskNature Team



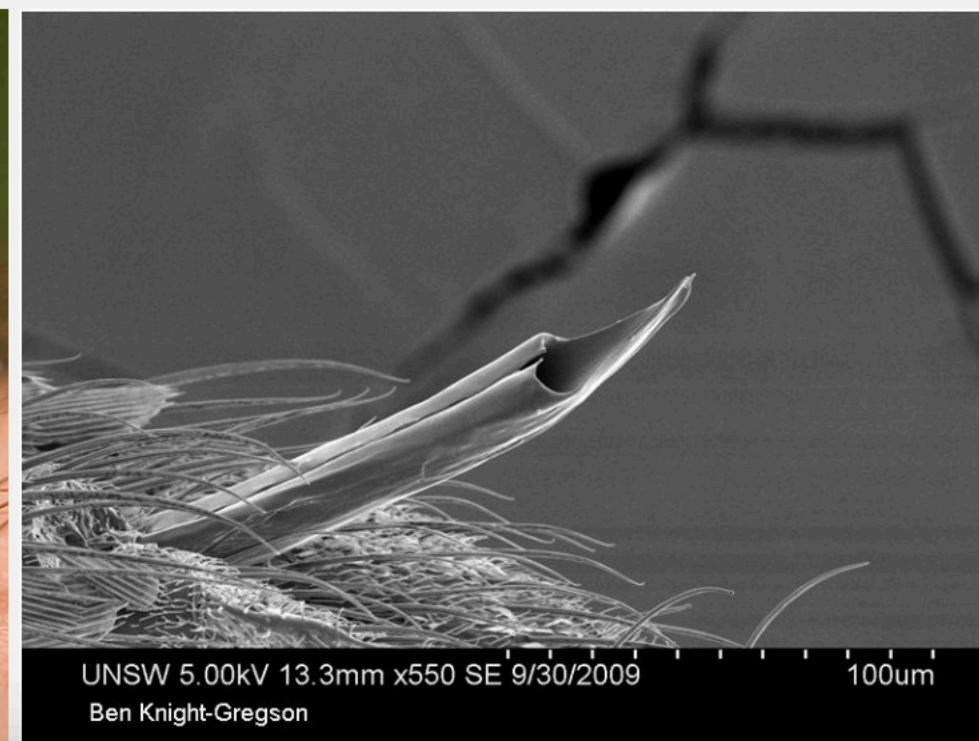
September 14, 2016



Shared with everyone

Move in/on solids

The proboscis of the mosquito inserts painlessly because the jagged edge of the proboscis leaves only small points in contact.



RELATED IDEAS

IDEA

Mosquito inspired microneedle

Kansai University in Osaka, Japan (Seiji Aoyagi)

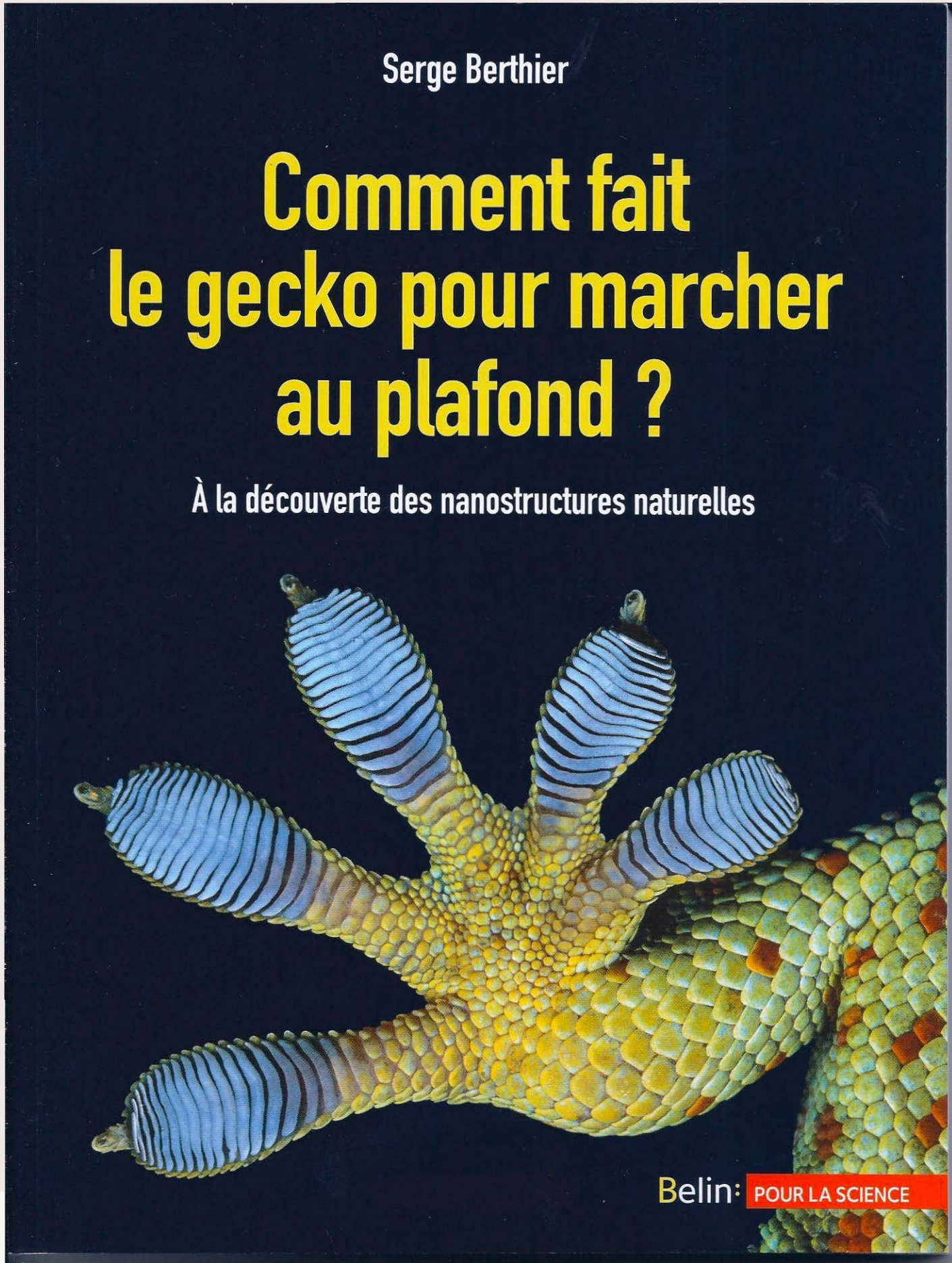


IDEA INCUBATOR 1

Painless drug delivery by injection.

Lumière

nanosstructures et création de lumière



Sommaire

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L'air : lumière, couleurs et odeurs

[Rappels : la lumière, l'optique et la photonique] 22

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Son

le boom actuel de la bioacoustique

- Bioacoustique des loups
- Bioacoustique du sifflement

Chez les oiseaux et les mammifères, les signaux de communication acoustique (comme les cris ou les chants) jouent un rôle particulièrement important dans le transfert et l'échange d'informations telles que l'appartenance à l'espèce, à une population, l'identification d'un voisin ou d'un partenaire. De là, l'analyse et l'utilisation des signaux acoustiques peuvent rendre de nombreux services dans la détermination des espèces et l'identification des individus, l'étude des dynamiques de population et la gestion et la conservation de nombreuses espèces gibiers et/ou d'intérêt patrimonial.

En brament, le cerf donne des informations sur sa condition physique qui pourraient être exploitées dans le cadre des études démographiques.
© B. Hamann.



FRÉDÉRIC SÈBE

Équipe Communications Acoustiques,
Centre de Neurosciences Paris-Sud, UMR 8195,
CNRS – Université Paris Sud, Orsay.

L'inventaire et le suivi des espèces sont la base de tout plan de gestion et de sauvegarde de la biodiversité. L'accroissement des surfaces à couvrir et l'accélération de l'évolution des habitats et des modifications climatiques requièrent des méthodes rapides et fiables d'évaluation. Actuellement, cette évaluation est basée sur l'analyse et l'interprétation d'indices de présence tels que les traces, les fèces, les observations visuelles et les indices acoustiques. D'un point de vue biologique, on retrouve des signaux acoustiques dans la plupart des comportements des oiseaux et des mammifères : appartenance spécifique, recherche du partenaire sexuel, du jeune ou du parent, territorialité, localisation des individus et indication d'états émotionnels. L'avantage de la communication acoustique est qu'elle est rapide, ne laisse pas de trace, et que l'intégralité des informations contenues dans un signal est facile à enregistrer, à analyser et à diffuser (**encadré 1**). Ainsi, en s'immiscant dans les réseaux de communication acoustique d'une espèce, soit en tant que récepteur, soit en tant qu'émetteur, on peut obtenir des informations capitales sur l'animal mais aussi influencer son comportement.

Recensement des individus par l'utilisation des signatures vocales individuelles

Le comptage des individus constitue généralement une étape incontournable à tout plan de gestion et de conservation des espèces. L'identification des individus est souvent lourde et difficile à mettre en place (captures laborieuses et non exhaustives, observations *de visu* difficiles, doubles comptages). On fait alors de plus en plus appel à d'autres outils de discrimination, comme l'identification acoustique. En effet, chez plusieurs espèces territoriales, le contenu informatif du signal répond aux contraintes d'ordre comportemental (discrimination des voisins) imposées par la

Le hurlement comme outil de suivi des populations de loup

Le hurlement est un extraordinaire moyen de communication pour le loup et, bien qu'il soit encore plein de mystères, il apporte des informations capitales pour sa conservation et sa réhabilitation. L'objectif des travaux menés en partenariat entre l'Université de Paris-Sud et l'ONCFS (CNERA Prédateurs - animaux déprédateurs) a consisté à obtenir des informations relatives à la présence de meutes et au nombre d'individus et de jeunes qui les composent.

Les expériences de diffusion de hurlements permettent de déceler la présence et d'estimer l'abondance relative de canidés sauvages, comme les lycaons, les coyotes, et bien sûr les loups. Le *wolf howling*, ou repasse, consiste ainsi à diffuser des hurlements de loups pour stimuler des réponses vocales. Ces premiers travaux ont permis de mettre en évidence l'intérêt mais également les limites du *wolf howling* dans le suivi et le recensement des individus. L'utilisation des hurlements pour la conservation du loup est un procédé adapté et intéressant qui a encore de nombreuses informations à nous apporter.

Loups adultes et jeunes (Hautes-Alpes, automne 2010).

© R. Roy.



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- Sèbe, F., Heitz, N., Latini, R. & Aubin, T. 2005. Wolf howling, a tool for the conservation of wolves: possibilities and limits. *Recherche naturaliste en région Centre* 14 : 53-60

Julien Meyer, *Whistled Languages : A Worldwide Inquiry on Human Whistled Speech*, Springer, 2015



<https://youtu.be/k6iesNH-s0k>

https://fr.wikipedia.org/wiki/Langage_sifflé

Le Ceebios



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en biomimétisme

Le Ceebios accélère la transition sociétale par le biomimétisme en fédérant un réseau d'experts et en développant les ressources indispensables à l'appropriation de la démarche par les secteurs académiques, institutionnels et privés.



FÉDÉRER LE RÉSEAU DE COMPÉTENCES
EN BIOMIMÉTISME



ACCOMPAGNER LES PROJETS INNOVANTS,
DE L'IDÉE AU DÉMONSTRATEUR



CONTRIBUER AU DÉVELOPPEMENT
DE DÉMONSTRATEURS ET PLATEFORMES



DÉVELOPPER LES OUTILS
D'ACCOMPAGNEMENT

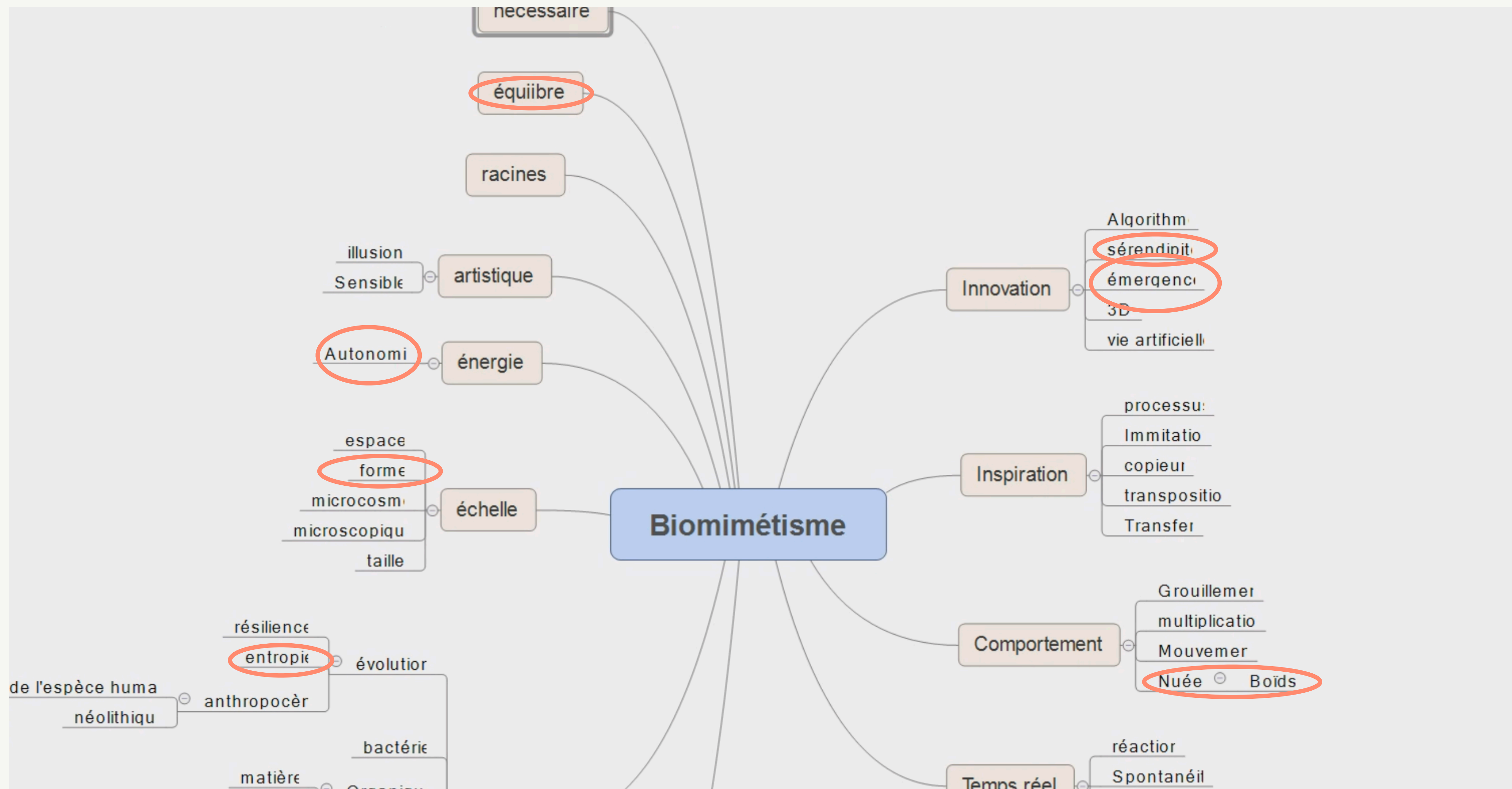


CONTRIBUER AU DÉVELOPPEMENT
DE LA FORMATION



COMMUNIQUER, INFLUENCER





A l'instar de la grammaire française, la biologie
est la science des exceptions, c'est l'art de
s'engouffrer dans les failles improbables

inspired by Terrence Malik

l'Art est le moyen le plus élégant
pour sortir du sujet

inspiré par Magritte


B612

S'il te plait, dessine moi un mouton

(2578) Saint-Exupéry est un petit astéroïde de la ceinture principale, qui a été découvert par Tamara M. Smirnova le 2 novembre 1975

Antoine de St Exupéry





lecture de l'eau dans la pierre

La lecture des pierres, Roger Caillois

**Evolution
Taille
Néolithique**

Yvan Rahbé

**Agronome
Biochimiste
Santé des Plantes**



INRAE



functionalized protein binders have been used in *Drosophila* will be discussed, and a look into the promising future of research with *Drosophila* will end the presentation.

Disclosure of interest The author declares that he has no competing interest.

References

- [1] S. Harmansa, M. Affolter, Protein binders and their applications in developmental biology, *Development* 145 (2) (2018), <http://dx.doi.org/10.1242/dev.148874> [Review, pii: dev148874].
- [2] D. Bieli, I. Alborelli, S. Harmansa, S. Matsuda, E. Caussinus, M. Affolter, Development and Application of Functionalized Protein Binders in Multicellular Organisms, *Int. Rev. Cell. Mol. Biol.* 325 (2016) 181–213, <http://dx.doi.org/10.1016/bs.ircmb.2016.02.006> [Epub 2016 Mar 19, Review].

Further reading

E. Caussinus, O. Kanca, M. Affolter, Fluorescent fusion protein knockout mediated by anti-GFP nanobody, *Nat. Struct. Mol. Biol.* (1) (2011) 117–121, doi: 10.1038/nsmb.2180.
S. Harmansa, F. Hamaratoglu, M. Affolter, E. Caussinus, Dpp spreading is required for medial but not for lateral wing disc growth, *Nature* 527(7578) (2015) 317–322, doi: 10.1038/nature15712. Epub 2015 Nov 9.

<https://doi.org/10.1016/j.crv.2019.09.003>

3

Insects as interactants in artists minds: Symbols and anti-symbols

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Insects, as small animals of frequent and easy access to humans, at least under their non-flying larval stages, have always been of interest to our species. The interest has probably been nutritional, but also naturalistic and symbolic. Many aspects of insects' biology are of high symbolic potential, among which biodiversity, metamorphosis or flight. These three creative attributes of the insect orders, over the mammalian order at least—the *self* or reference class of human life—, probably induced early interests in human societies. This interest is indicated by folk classification of insects in some indigene cultures of northern America or central Africa [1]. Representation of insects in paleolithic art is scarce but existing; one of the earliest attested records could be that of “the buprestid” of Arcy-sur-Cure, revised as a ground beetle–carabid–(Magdalenian III, ≈ 15000 years BP), or that of “the grasshopper” of Enlène [2]. The first is sculpted in lignite and could have served as a shamanic representation, while the latter is more obviously naturalistic in nature, and carved on bone. The more recently discovered Chauvet cave might contain insect representations (a “butterfly” or a many-legged animal), but no attested insects yet. Similarly, no insect mention come yet from Sulawesi caves (late Mousterian, < 30,000 years BP). Neolithic representations are much more numerous, as exemplified by bee hunting and bee rearing in Iberic or Egyptian parietal and monumental arts. This trend culminated in Egyptian jewellery and its quasi-industrial representations of scarab or dung beetles. Noteworthy, most prehistoric representation of insects lie on coleoptera and Hymenoptera, and associated with symbolic features linked to colour, strength (beetles), metamorphosis (all) or social and utility behaviours (bees, ants). Aristotle himself did not clearly recognize aphids as a group, as the ancient Greek word *ψυλλίδα* did not differentiate aphids and psyllids. Many mentions however, on the

reproduction of such insects, for example, show that he was talking of aphids. In line with these historical roots, insects have been associated with far eastern or Christian society arts [3]— in contrast, Islamic and Jewish imaging or alimentary taboos having banned them from visible representations in middle eastern societies. A previous review on the subject gives an excellent outline of our matter, restricted to European painting [4]. I will here sketch a variant perspective, trying to uncover a hitherto hidden monument of cultural entomology, with the case study of the representation of aphids (Hemiptera: Aphididae) in various arts and all periods of history. Our purpose is to draw a reflexive perspective on what such invisible insects, through their invisibility, tell us of their representation in artists' minds, and more generally in any human mind (being he a reader, a writer, a watcher, an actor, or in any position of the artistic universe). The first and archetypal position to be quoted in my survey of invisible insects is the *detail aphid*. This position of a subject, the detail, have been analysed thoroughly in the history of arts [5]. It reflects both scientific and artistic mastery end precision (it is painted because *it exists*), and a position of power of the painter who is freely choosing low signification or even forbidden or non-codified subjects due to the act of freedom of the artist (and art factories, often specialized in such very specific matters); I paint it because *I want/know* it. This is characteristic of the Flemish and Dutch renaissance, as visible in the *Bouquet of flowers in a vase* by Jan velvet Brueghel the Elder (Fig. 1). In contrast to many of its fellow insects, cricket, coleoptera, syrphid, the aphid is extremely difficult to localize (Fig. 1A), and needs an intensive focus on its lily host-plant to be seen (Fig. 1B). However, in spite of its minute size, it is precisely depicted, and the *crescent-marked lily aphid* was recognized by expert aphidologists (Colin Favret, pers. comm.). A non-expert comparison between object and subject (Fig. 1B,C,D), be it living (1 C) or mounted (1D) is edifying and informs us on the naturalistic and observational abilities of the painter(s). As one may imagine, such identification of aphids in European classical painting is extremely difficult and has been only found on three occasions and with the help of the G-art Gigapixel project, apart from Fig. 1: in another still life by velvet Brueghel, *Flowers in a Vase* displaying at the Antwerp museum of fine arts, and in a third *Chat renversant un vase de fleurs* by Abraham Mignon, Museum of Fine Arts, Lyon. All Dutch painters. One easy case of *naturalistic aphid* lie in the paintings of Maria Sibylla Meriam, a painter and entomologist of the seventieth century who has painted aphids



Fig. 1 *Bouquet of flowers in a vase*, by Jan Brueghel the Elder (1608, oil on copper 65 × 45 cm); original (A) in the Pinacoteca Ambrosiana (Milan, Italy), © with permission. Detail with an aphid on a lily leaf (B) situated at the bottom-left corner of the bouquet. Inferred species, with the help of Dr C. Favret: *Neomyzus circumflexus*, quoted from Encyclop'aphid (C) with its typical darkish crescent on the back (D).

in numerous works, and both entitled some of her paintings with the word, and depicted the whole aphid ecosystem including all trophic levels in the global picture (*Rode akelei met bladwesp en bladluis*, 1684). One important item in our quest is the topos of the *female aphid* (and eventually *superfemale aphid*). It probably did not start with Charles Bonnet, but at least has fully expanded after him. This talented Swiss student of Réaumur discovered, described, and demonstrated parthenogenesis in what could be called one of the first modern scientific papers in biology, its *Traité d'entomologie* (1745). This signed a series of quasi-quotes all over the following centuries, exemplifying the importance of this reproductive trait in biology, as well as the importance of aphids as a model for this trait: this started by a pejorative citation of Eugène Delacroix in a letter to a friend in 1830 (“*What a pity that such brilliant mind and man has lost his time and eyes for understanding the venial sin of such hideous animals*”), followed by a real tribute to parthenogenesis in the masterpiece of Simone de Beauvoir, *Le deuxième sexe* (Volume 1, Chapter 1, “The data of Biology”). One may also quote in this very context the interesting parallel, made by the contemporary art blog Quadriaviva, between parthenogenesis and the codified representation of “*Sainte Anne trinitaire*” in the European religious sculpture of the late Middle Ages (<https://quadriv.wordpress.com/2011/06/10/jesus-aphids-and-parthenogenesis/>). The sculptural code of Ste Anne consisted in a triptychal representation of Virgin Mary, her mother Anne, and child Jesus in a strange character proportionality of adult (Anne), child-adult (Mary) and child-child (Jesus). This invasion of the female-only character over the Holy Trinity was increasingly popular in central Europe from the fortieth to the sixtieth century (https://fr.wikipedia.org/wiki/Sainte_Anne_trinitaire), and was only stopped by a specific canonical law codifying the Marial cult, or hyperdulia, within the Council of Trento (1542–1563). Although no aphid is represented in such topoi, of course, the parallel between parthenogenesis *and* viviparity, somehow unique to aphids, and the mystery of immaculate conception ought to be underlined. Already exemplified by Eugene Delacroix, cited above, the recurrent and frequent topos of the *evil aphid* has been used many times in French literature. Victor Hugo listed the vile aphid among a list of biological fearsome fellows (*Les Contemplations*, T3 L6 26, p. 467 as appears in the Frantext database). However, the complimentary figure of the *humble aphid* is also present in post-nineteenth-century occurrences, typically shown in Maurice Carême's poem entitled *Le Puceron*. Coming to modern art, the appearance of aphids tends to explode, and I will only quote two examples. One is what could be called the *surrealistic oulipian aphid* by Boris Vian (Fig. 2), the other being the *situationist aphid* of the musical theme of the Polish artist Duy Gebord in the well-named *Mildew* album (<https://duygebord.bandcamp.com/album/mildew>). The former merits a short outline, as it is emblematic of the mosaic Carollian style of Boris Vian (*Les Fourmis*, Fig. 2A). The prose starts as a very standard description of a explicitly boring subject, to fall out into the final blackhole of Oulipian fantasy (which translates as “The rearing of the Tyrolian 'gnatlet' or the milking of woolly aphids”). The induced image explicitly (again) looks as Fig. 2A, driving the reader in a universe of gentle and poetic madness typical of Vian's prose. It should be noted that the French mouchetis tyrolien (translated as Tyrolian gnatlet) does not refer, as it seems through subtle juxtaposition, to an insect: instead it refers to an industrial painting technique, also typical of the universe of *engineer* Boris Vian, who started as *fonctionnaire* of the French normalization agency AFNOR (as did Albert Einstein with the Swiss patent agency). . . We hope that our short survey of a hitherto boring subject has driven the reader on the wild side of the history of arts and sciences, and that the final references will allow him to escape even more, at night, from its truly exciting daytime highways of insect science. This compendium and conference is part of an ongoing project, involving the aphid BAPOA community for data collection, and partially published by Encyclopaphid [6]. The full corpus contains more than 100 entries and the present outline is thus only the hidden part of the iceberg, to be fully published soon. This conference is quoted

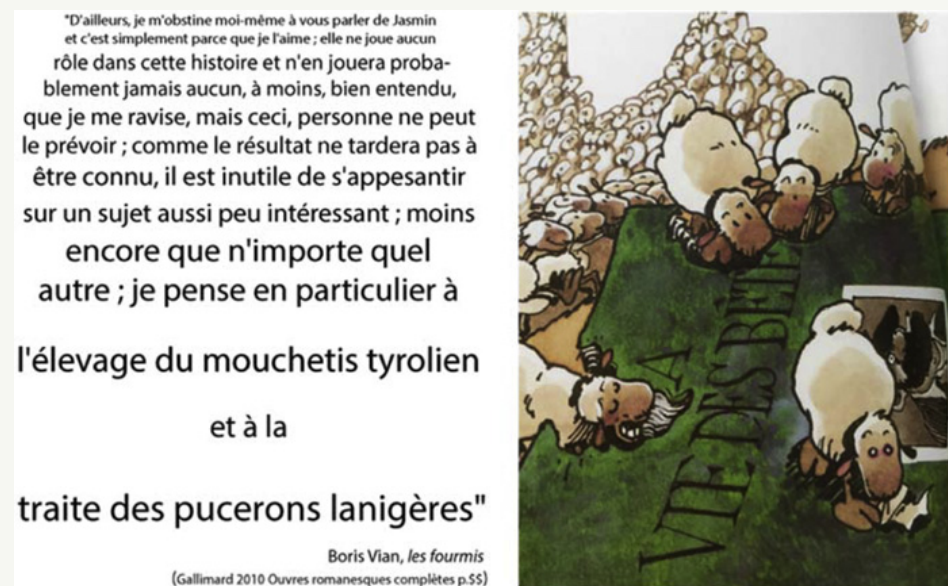


Fig. 2 The milking of woolly aphids, as cited by Boris Vian in *Les Fourmis* (Gallimard, La Pléiade) and reported on the left, with a possible representation on the right: *Le Génie des alpages*, F'Murr, Casterman.

in the CNRS repository HAL as: <https://hal.archives-ouvertes.fr/hal-02069668>.

Disclosure of interest The authors declare that they have no conflict of interest.

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The shining world of beetles

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Twisted liquid-crystalline organizations are ubiquitous in living matter [1,2]. Many insects own a tessellated carapace with bumps, pits, indentations, stripes or spots (Fig. 1). These geometric variation often exhibit iridescent colors, which are the consequence of a complex twist of chitin macromolecules. Such optical information with vivid structural colors might be of paramount importance in the life and the evolution of most day-living insects. Many biological functions are yet debated. They are related to conspecific or intra-species communication, thermoregulation, camouflage, survival or navigation [1,3]. For example, the cuticle of the scarab beetle *Chrysina gloriosa* exhibits two bands (Fig. 2). The green band serves as a wavelength-selective (green) diffuser due to the set of polygons arranged on a curved surface and, at the mesoscopic scale, it behaves as an array of wavelength-selective micromirrors [4]. The silver stripe plays the role of a flat metallic reflector operating over the visible spectrum and into the infrared spectrum [4]. The orientation of the helicoidal structure varies in green stripes

Aux États-Unis, Caillois a récemment été réhabilité par l'anthropologue Hugh Raffles, qui propose d'étudier les formes de la culture à partir de l'observation des insectes et des pierres: Raffles montre la fécondité d'une interrogation sur le merveilleux qui ne se coupe pas d'un intérêt pour la science, mais redécouvre dans la culture humaine un trouble ressenti devant les insectes.

Frédéric Kerk, Le sacrifice des insectes. Caillois entre Lévi-Strauss et Bataille (2013) Littérature 2013/2 (n°170), 21-32