Nature's Aerosol Generators

Biomimicry and Aerosols

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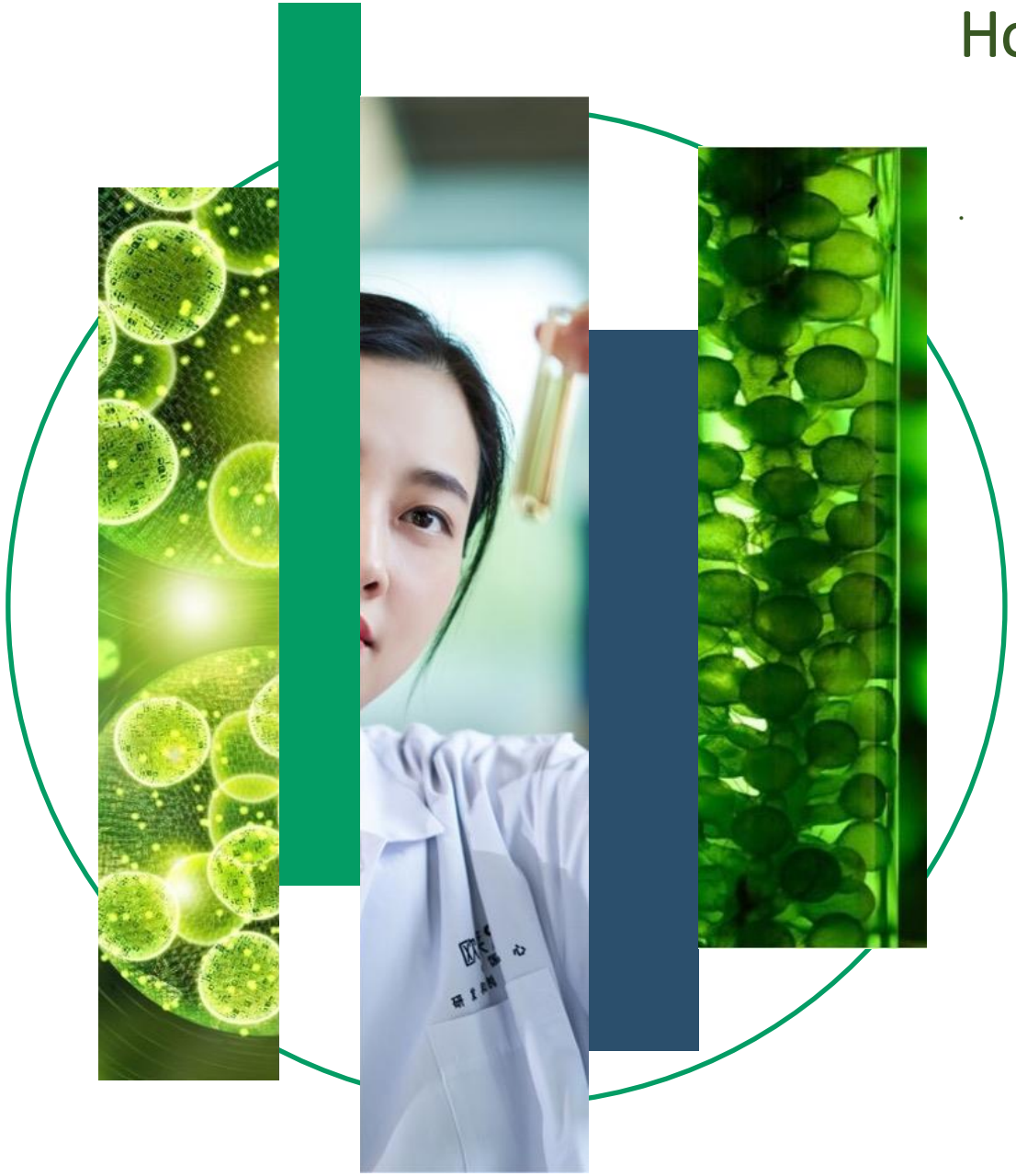


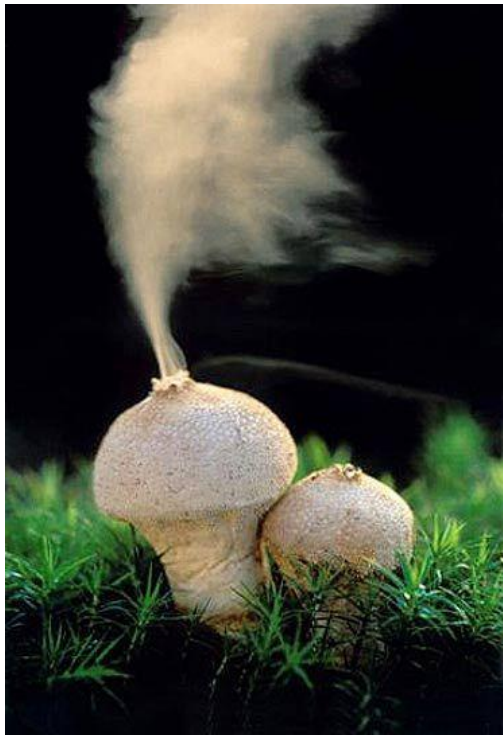
How does nature master droplet creation ?

- Formation of both liquid or solid dispersions in a gas within living organisms and biological contexts

Can this be a source of inspiration for droplet creation ?

Or is it already the case ?

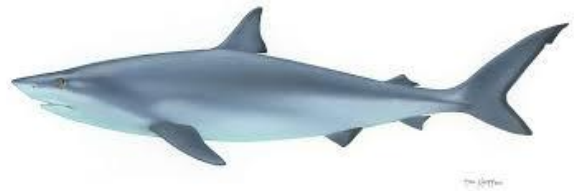
Could the Biomimicry approach inspire innovation for the aerosol format ?



Biomimicry

"To draw inspiration from the living to sustainably innovate"

Example: From biology to technology



Biological Functions

e.g.: Move

Limit drag (force that opposes movement)

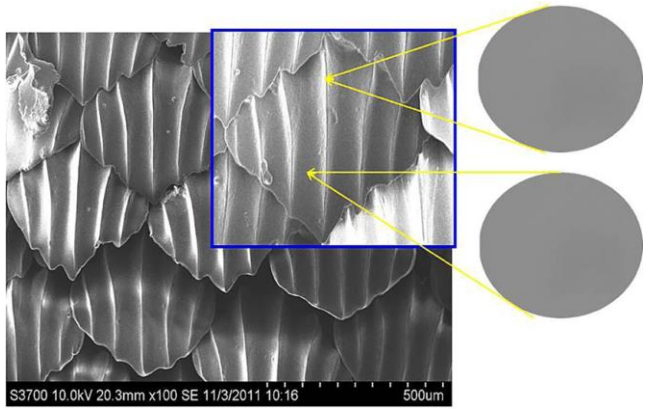
↓

Limit the adhesion of biological organisms

Operating Principle

e.g.: Size of the scales

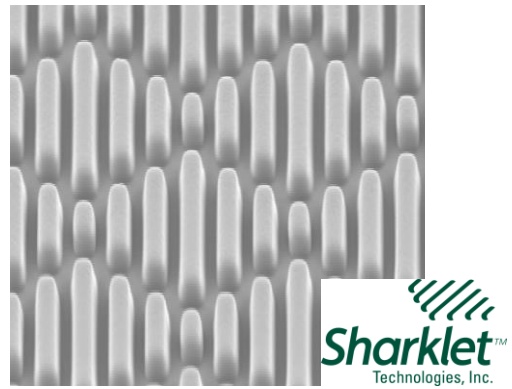
The spacing between the scales is less than the size of the bacteria, which prevents the bacteria from clinging to the shark's skin and forming a bacterial film.



Technological Function

Ex: Avoid contamination

A coating inspired by the non-stick properties of shark skin is developed for medical applications (door handles in hospitals).



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W.E.G. Müller et al., *Principles of biofouling protection in marine sponges : a model for the design of novel biomimetic and bio-inspired coatings in the marine environement ?*, Marine Biotechnology (2013)

W. Barthlott, C. Neinhuis., *Purity of the sacred lotus, or escape from contamination in biological surfaces,* Planta, 202: 1-8 (**1997**)

How does an aerosol technology translate into biology ?

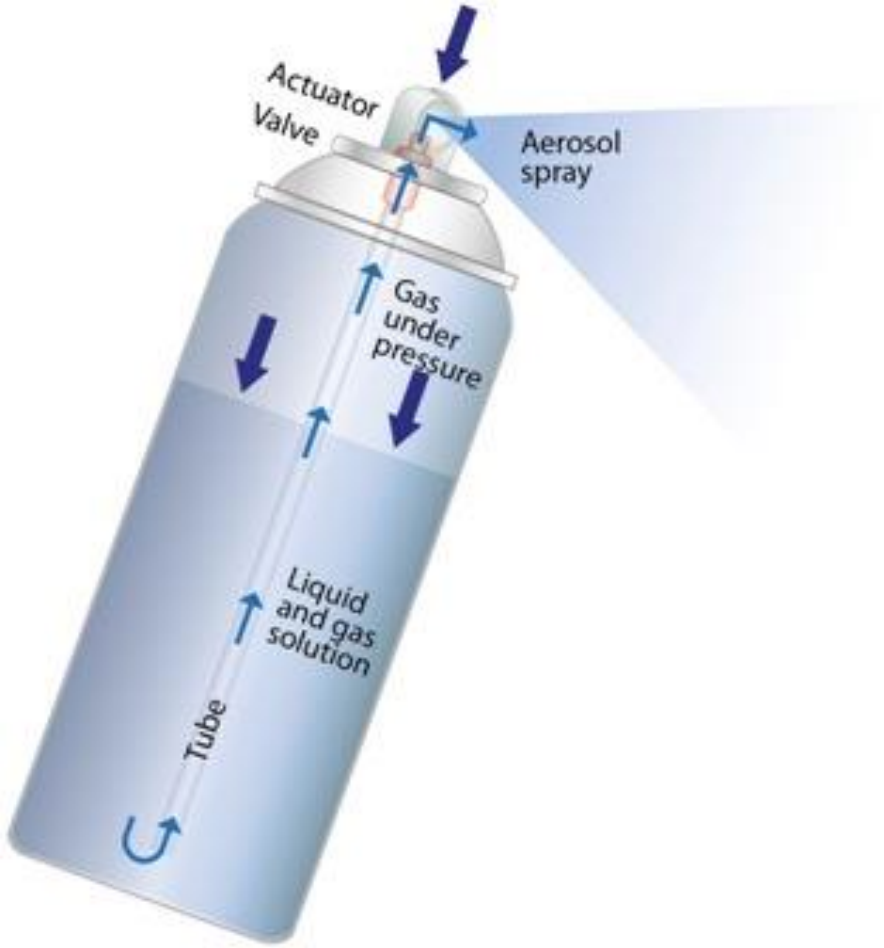
The Aerosol Generator

DEFINITION:

A device, that contains a substance that is often enclosed under pressure and that can be released as a fine spray from the device, generally by means of a propellant gas.

CHEMISTRY & PHYSICS :

a colloidal suspension of particles dispersed in air or gas.



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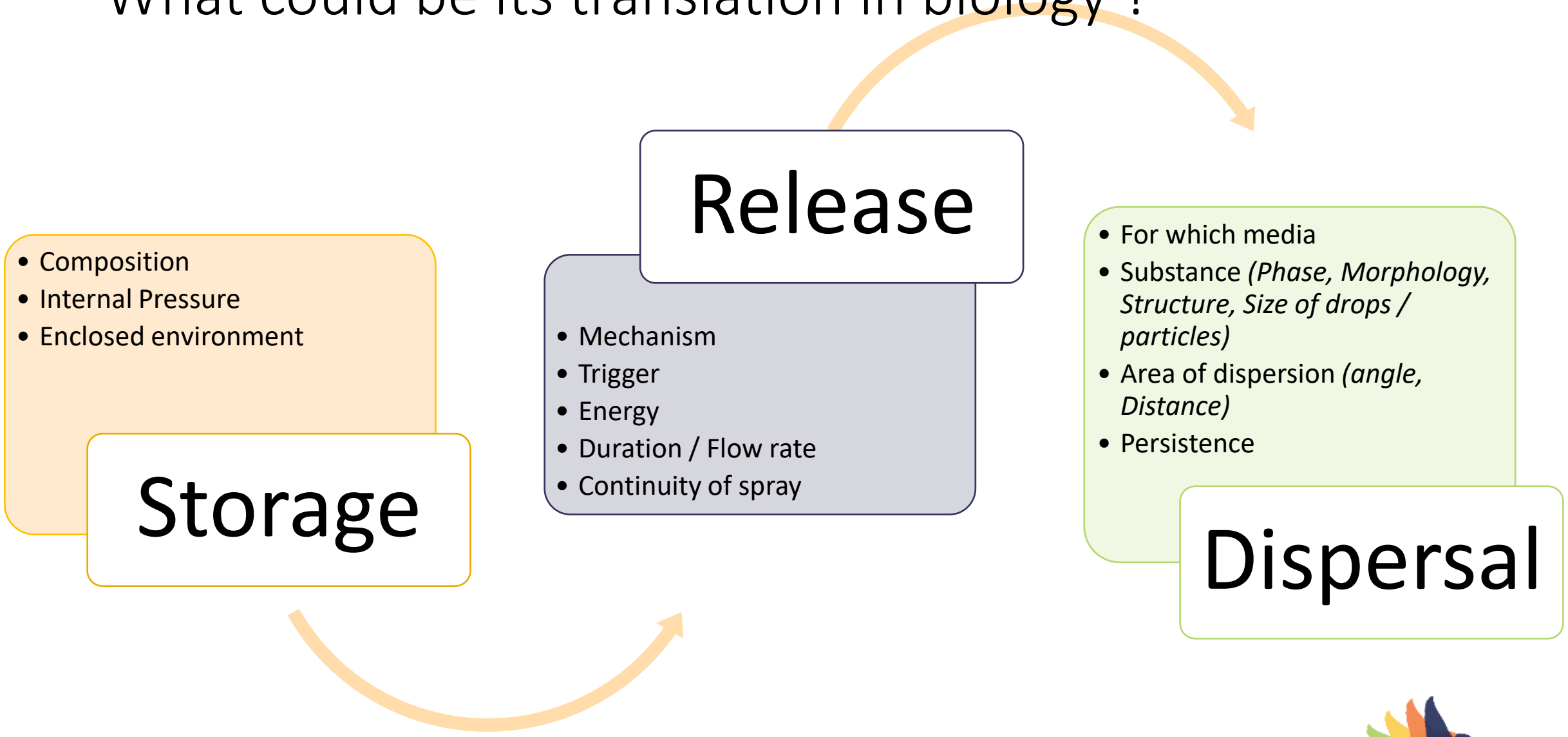
What could be its translation in biology ?



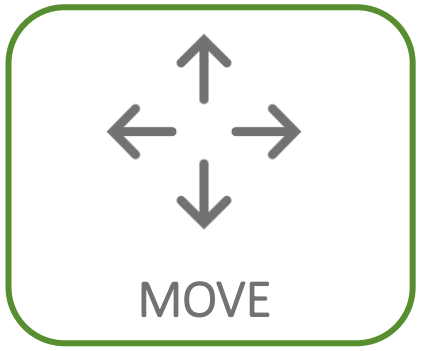
What could be its translation in biology ?

What is droplet generation, in a liquid or solid form used for ?

Intra / Inter species
Collective behaviour

Defence mechanism
Create diversion

Colonization
Seduction



Displacement

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Some Examples of Biological Models

Bombardier Beetle Defensive Spray

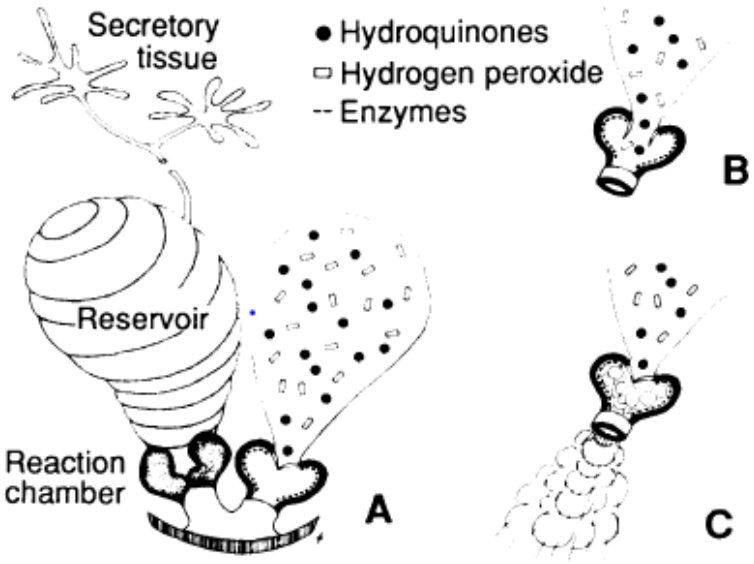
Stenaptinus insignis

Storage

Glands : 2 confluent chamber in which chemical reactants separately stored :

- Hydroquinones and hydrogen
- Oxidases (oxidative enzymes)

Quinones produced via the interaction of hydroquinones and hydrogen peroxide with the oxidative enzymes (acting as catalysts).



A discharge (A) (B) (C) is repeated several times

Storage Structure :

- **Reservoir**;
- **Reaction chamber**
- **Tight valve system**

Bombardier Beetle Defensive Spray

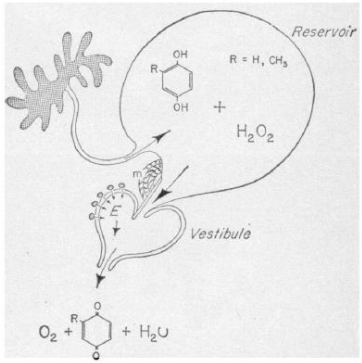
Stenaptinus insignis

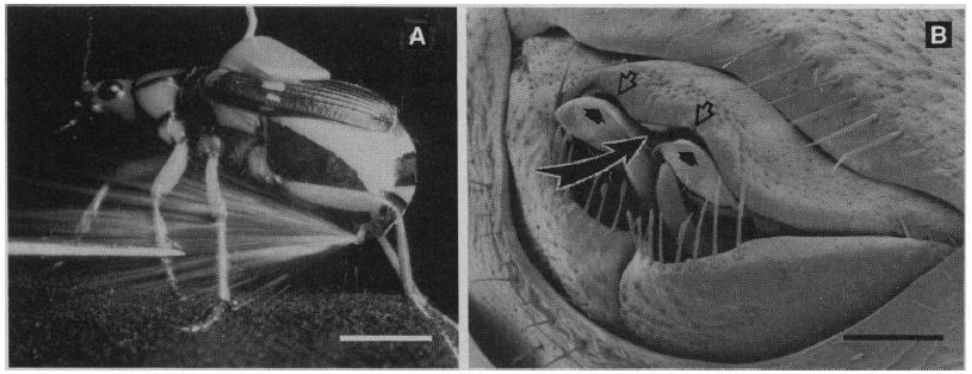
Release

Hydroquinone (aq) + H_20_2 (aq) --> quinone (aq) + $2H_20$ (l)

3 steps:

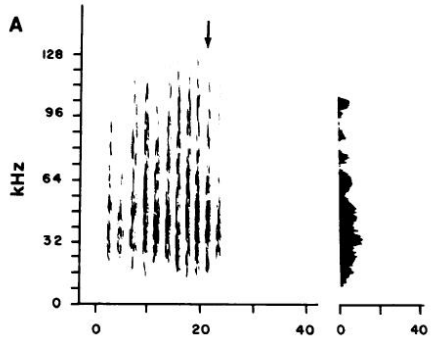
- hydroquinone (aq) --> quinone (aq) + H_2 (g)
- H_2O_2 (aq) --> H_20 (l) + ½ O_2 (g)
- H_2 (g) + ½ O2 (g) --> H_20 (l)

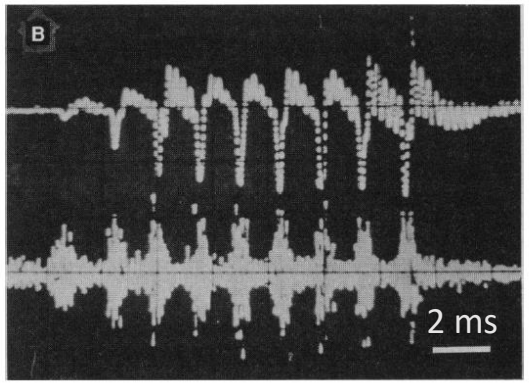




Ejected at near boiling point of water - 100°C

Discharge duration = approx. 12 milliseconds
Pulse rate = approx. 500 pulses per second





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Bombardier Beetle Defensive Spray

Stenaptinus insignis

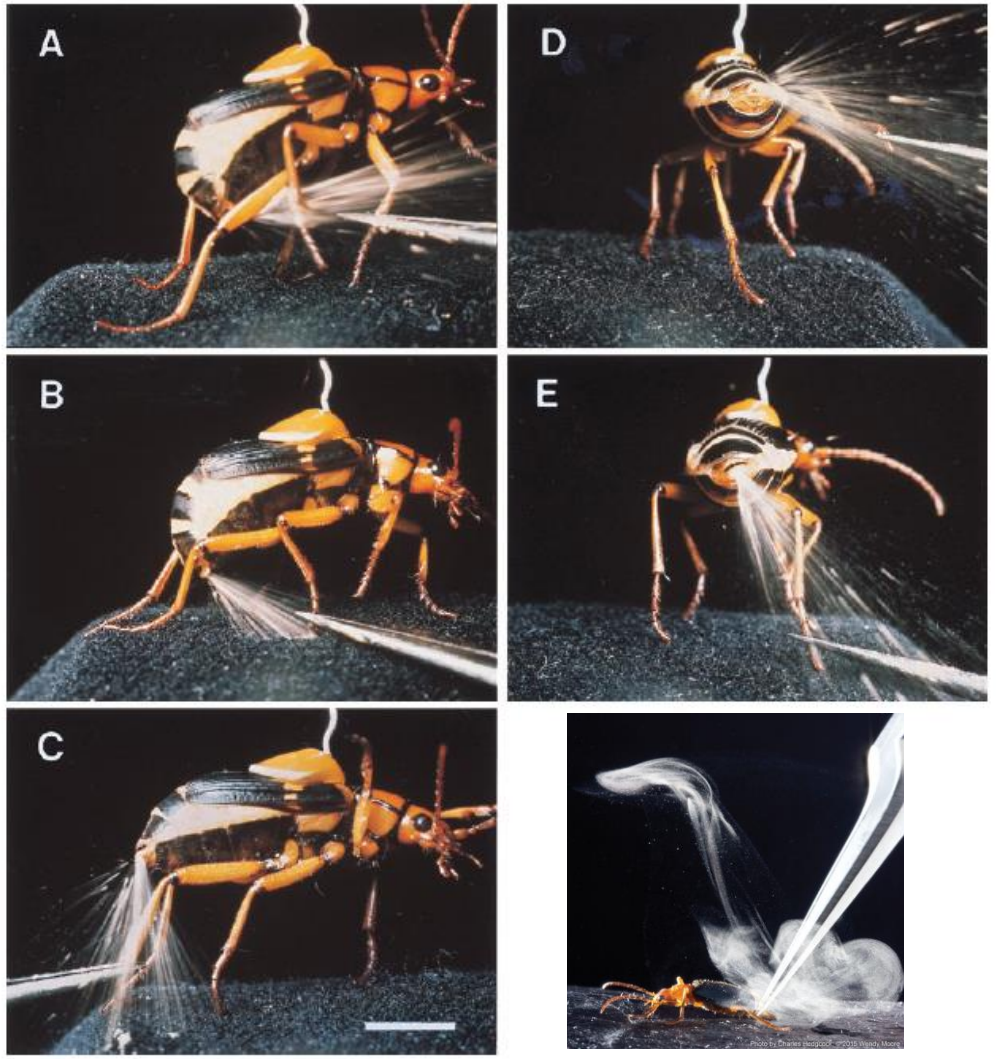
Dispersal

Pulsed Spray velocity: **1000 cm / s**

Abdominal tip acts as a turret enabling the beetle to aim the spray in all directions.

Spray deters vertebrate and invertebrate predators.

Reproducible / Rechargeable process



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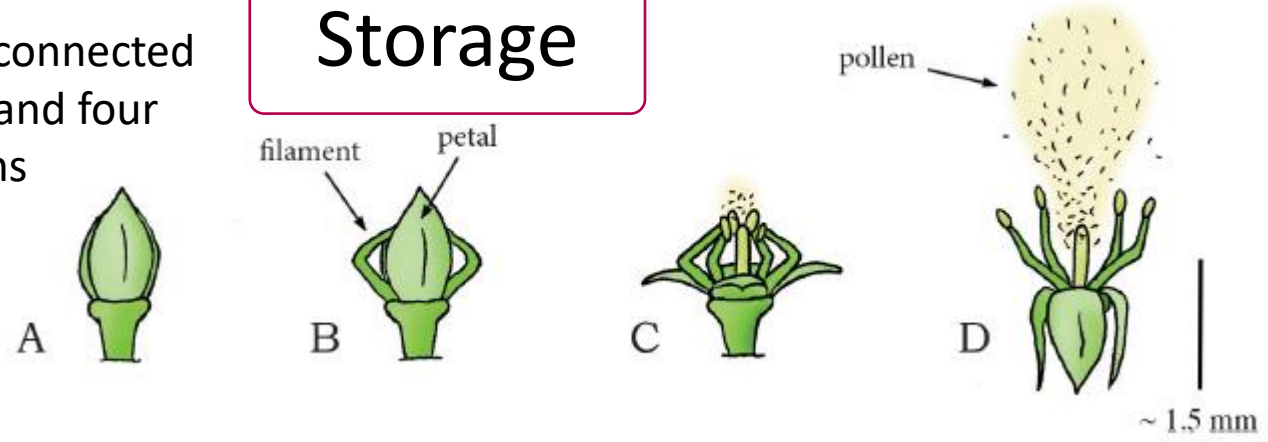
Plant Seeds & Pollen

Bunchberry dogwood – a record-breaking pollen catapult

4 interconnected petals and four stamens

Storage



Dispersal

Launch velocity of 7.5 m/s
Height of about 0.027 m (launch angle of 70–90° to the horizontal)

Release

(A) - (B) filaments grow and bend (storing elastic energy)
(C) - (D) fracture of the petal connection, allowing the filaments to unfold and accelerate vertically

Catapult System

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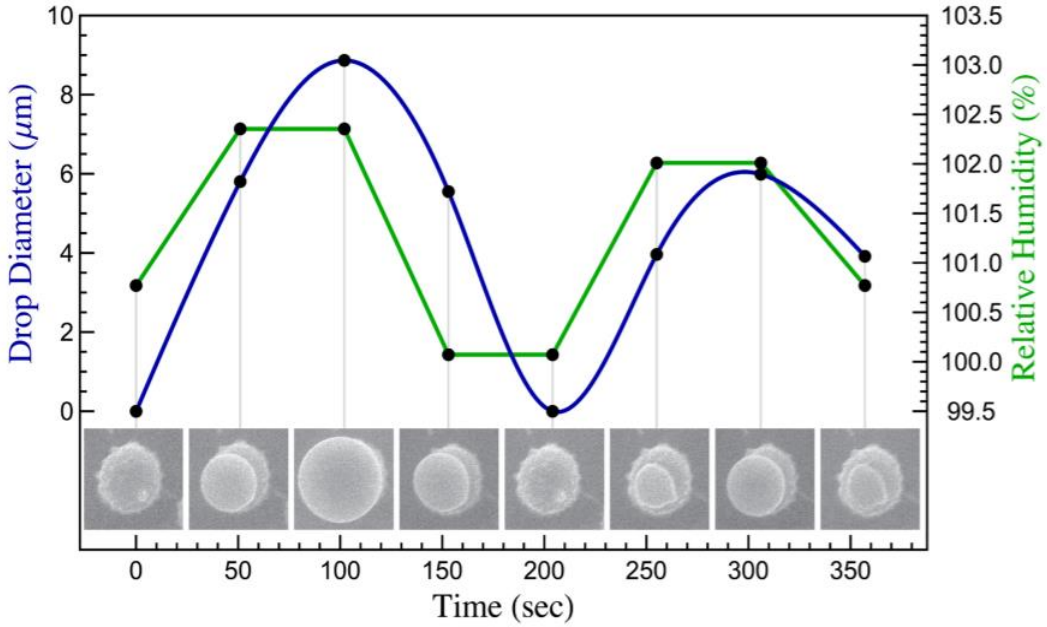
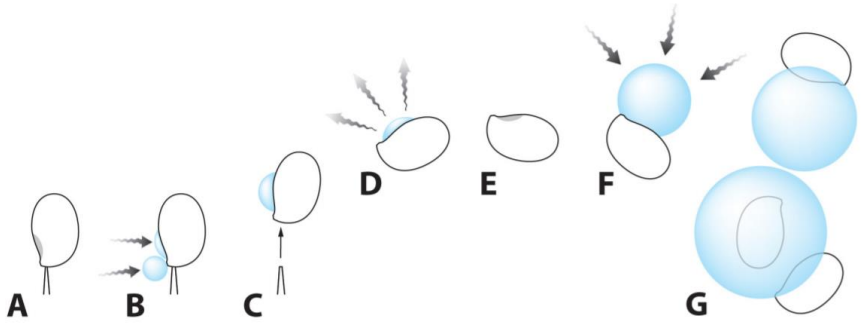
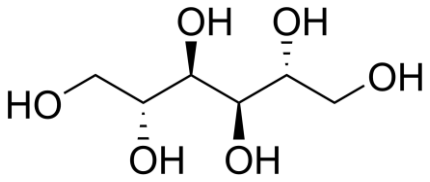
Spore of fungis



Release





Drops form via condensation of water on the spore surface and their coalescence causes a rapid shift in the center of mass of the spore that is responsible for the launch.

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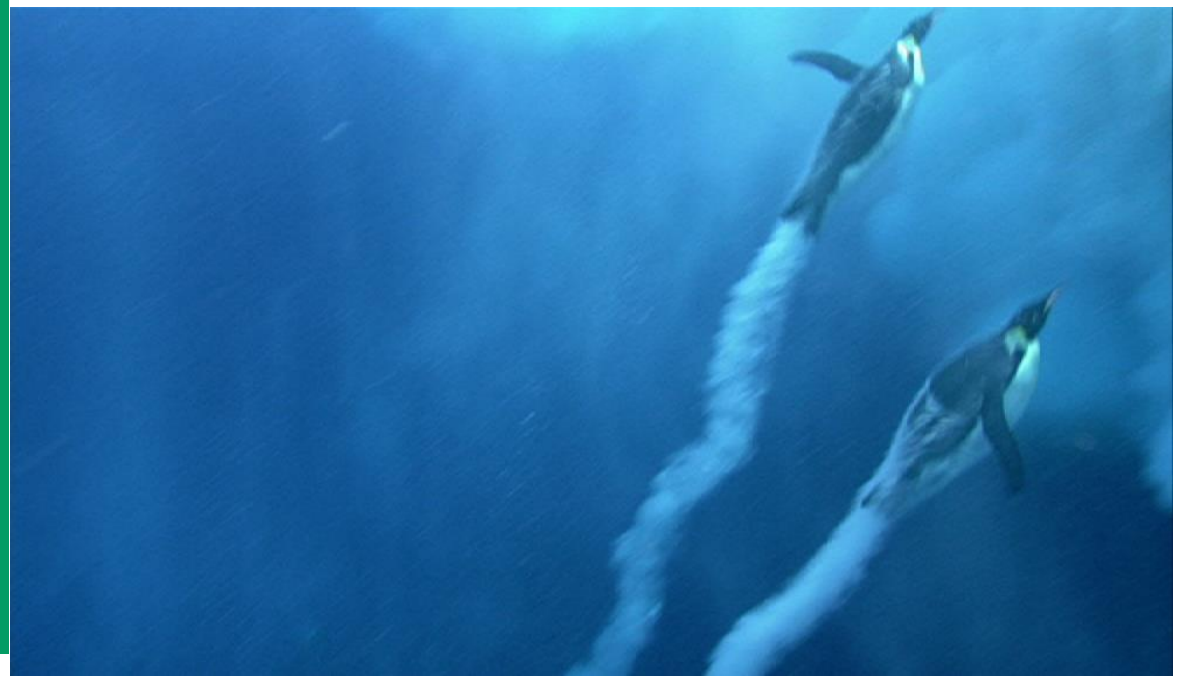
Penguins

Release

Composition : atmospheric air droplets
Droplet formation mechanism : compression of air
Droplet size : approx. 20 µm



Penguins dive to 15 to 20 m with air in their plumage and that this compressed air is released as the birds subsequently ascend whilst maintaining depressed feathers. Fine bubbles emerge continuously from the entire plumage, forming a smooth layer over the body and generating bubbly wakes behind the penguins

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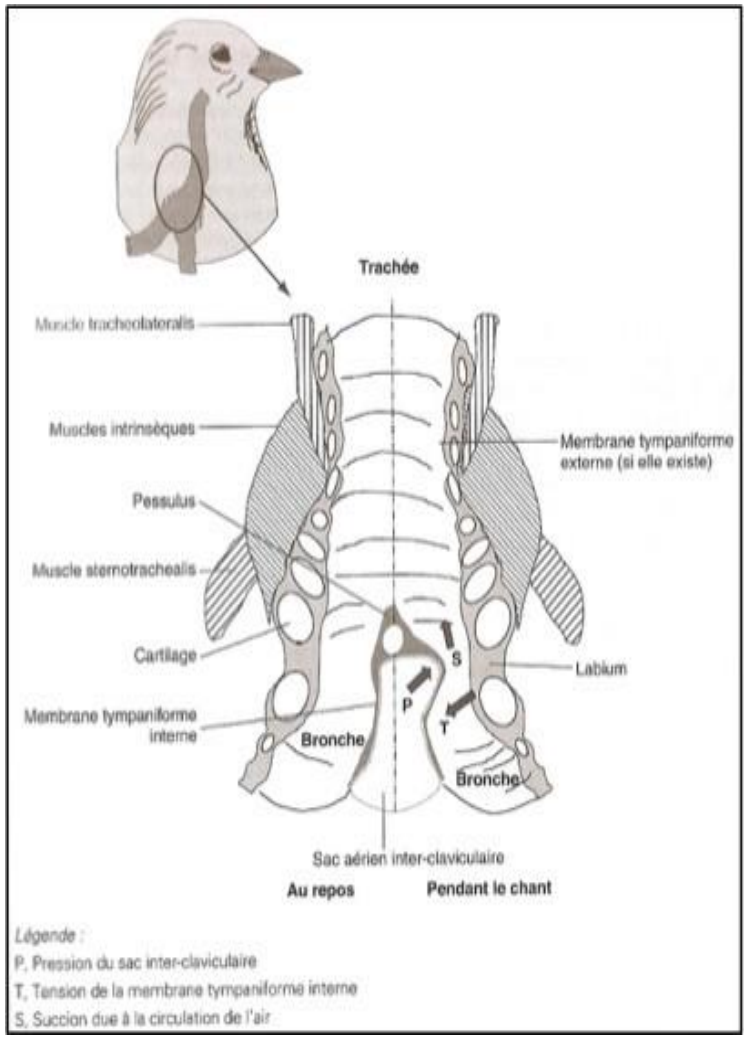
Birds

Release



Vibration of membranes within the syrinx

Air exhaled = 20°C condensation when in contact with cold air

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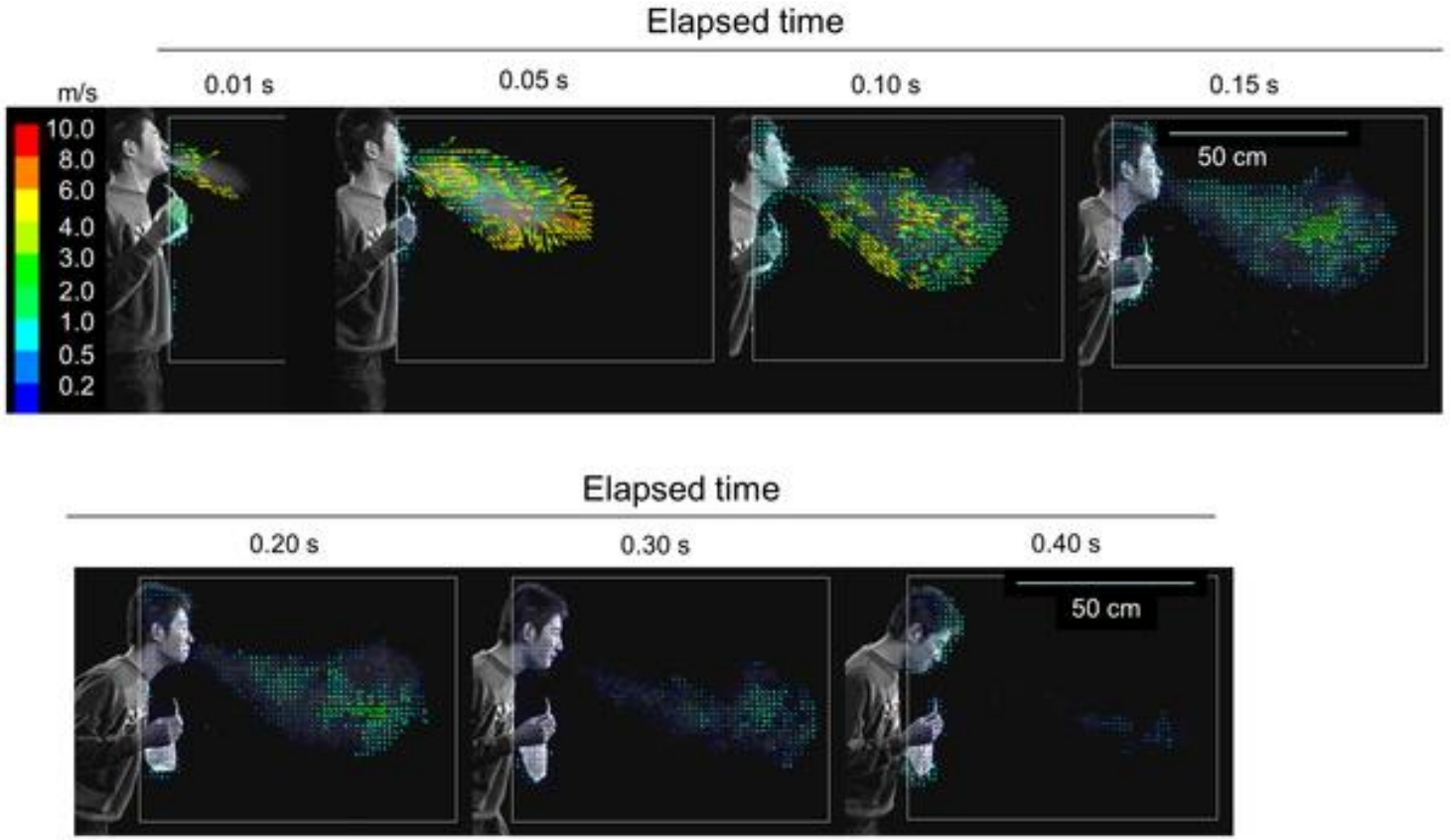
Sneeze

Release

Droplets 100 micrometers travel 50X less far than droplets of 10 micrometers in diameter. Droplets less than 50 micrometers in size can frequently remain airborne long enough to reach ceiling ventilation units (6 feets)

During ejection, droplet diameters vary between 1 and 2,000 µm of which 95% are in the range of 2 to 100 µm. However, they dry very quickly. The drying time for droplets of 100 µm and 50 µm in air at 50% relative humidity is 1.3 and 0.3 seconds respectively.



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Human sneeze

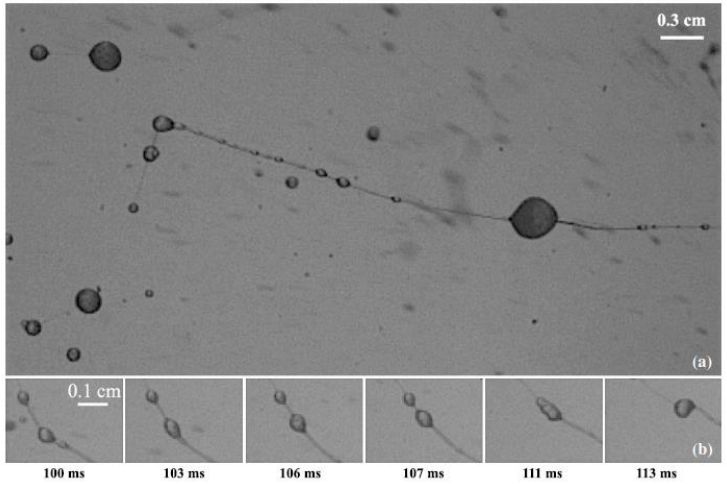
Release

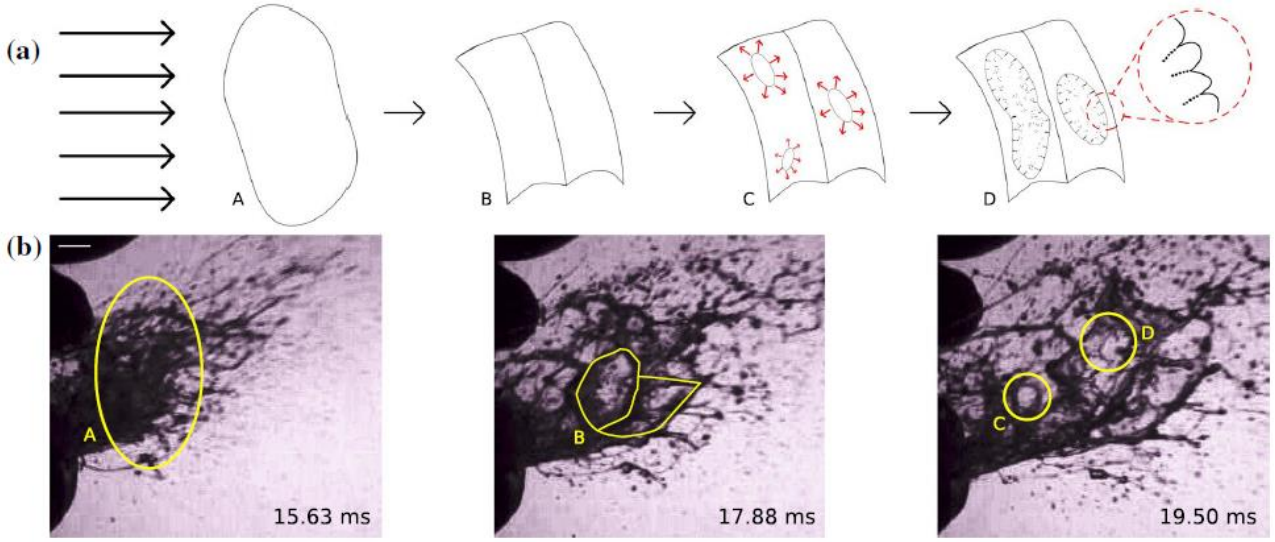
Final size of the droplet result of instabilities (Rayleigh–Taylor and Kelvin Helmholtz instabilities) :

Surface tension

Viscosity

Surface tension and fluid viscosity generally favor larger droplets, while higher air speeds tend to result in smaller droplets.





The initial liquid volume (A) is flattened into a sheet (B), followed by hole formation (C) and subsequent destabilization into ligaments, and, finally, droplets (D). Scale bar in (b) is 1 cm.

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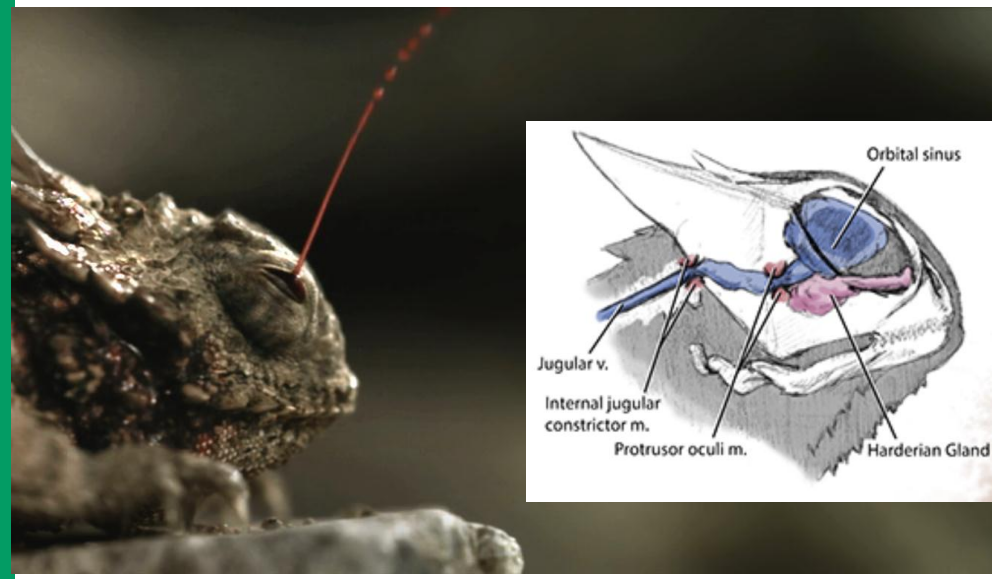
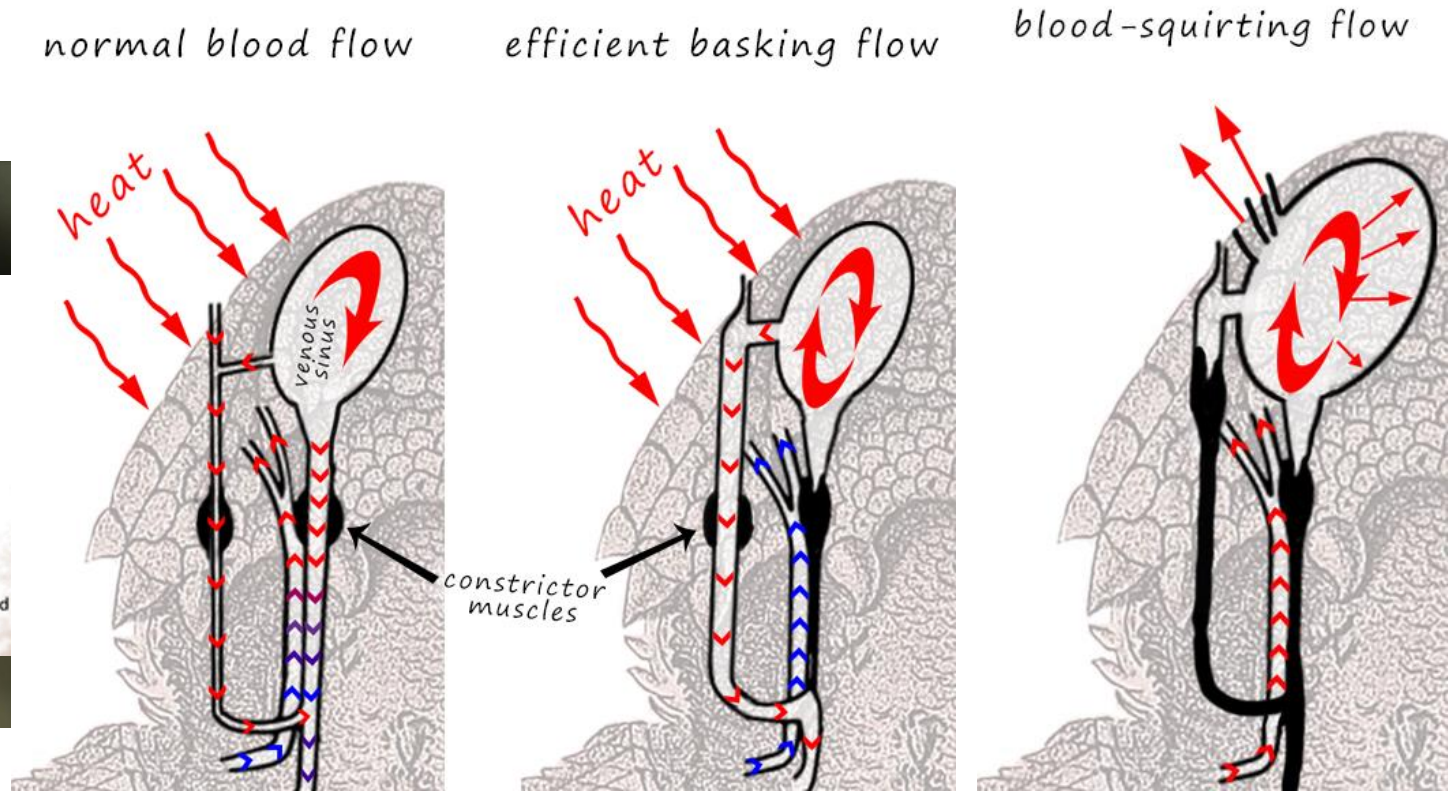
Horned lizard (*Phrynosoma cornutum*)

Release

Self-defence mechanism





- A 1,5 meter shoot
- 1/3 of its blood volume

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THANK YOU

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