Photonics for functional monitoring of ciliated airway epithelia

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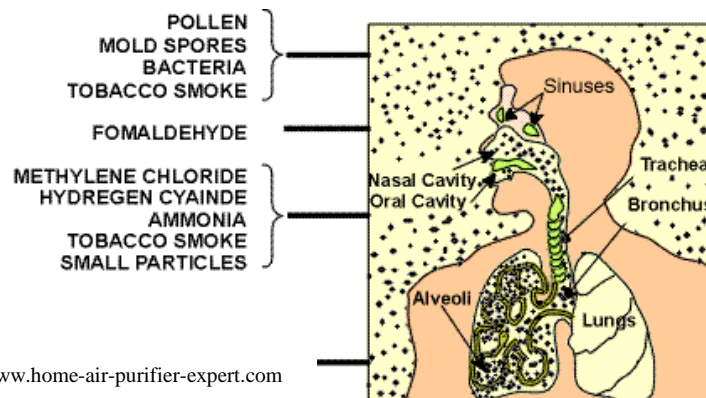
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UNIVERSITÄT
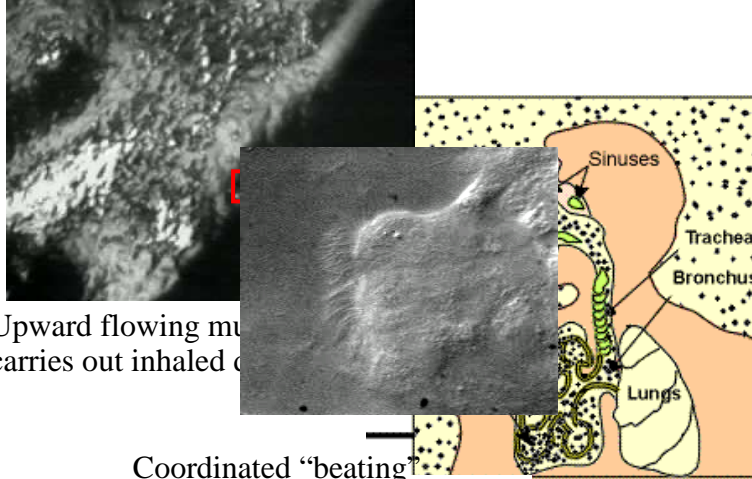BERN

Biomedical Photonics

IAP

Danger!!!
Internal area of 150m^2 exposed to hostile environment

POLLEN
MOLD SPORES
BACTERIA
TOBACCO SMOKE

FOMALDEHYDE

METHYLENE CHLORIDE
HYDREGEN CYAINDE
AMMONIA
TOBACCO SMOKE
SMALL PARTICLES

Sinuses

Nasal Cavity
Oral Cavity

Trachea
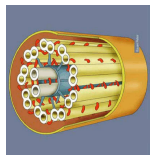
Bronchus

Alveoli

Lungs

www.home-air-purifier-expert.com

Primary defense: muco-ciliary transport system

Upward flowing mu...
carries out inhaled ...

Coordinated "beating"
of millions of cilia.
Supramolecular ATP fuelled motors
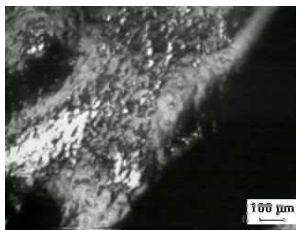

How and why does this work?

Structure

Activity and **coordination**

ATP supply

hydrodynamic **coupling**

Ca^{++} signaling,
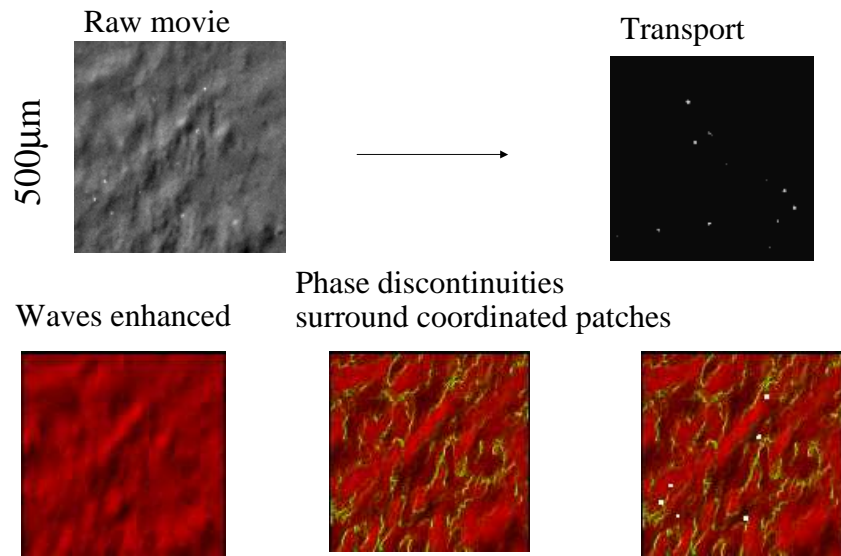
Mucus properties
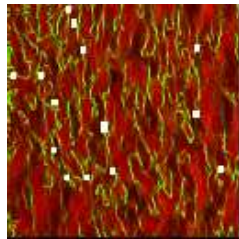
visco-elasticity

Regulation

mucus production

composition, structure

Observing muco-ciliary transport phenomena
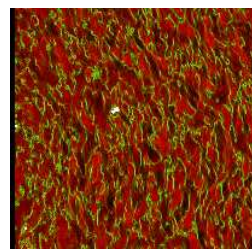
Particularly nice sample of bovine trachea

Raw movie

Transport
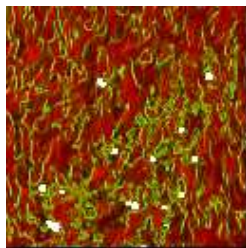
500μm

Waves enhanced

Phase discontinuities
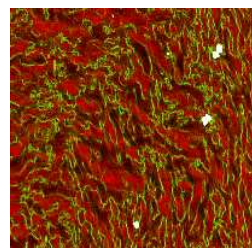surround coordinated patches
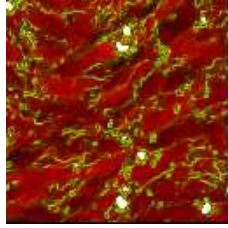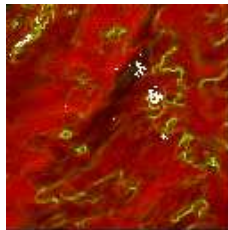
Cow

Rabbit

Pig

Turkey

Perfect sheep

Good coordination
is advantageous ...

... but one should not
overdo it!

Over-coordinated sheep

Certain degree of
self-organized
patchiness
may be required


Simple model of self-organized transport

Premises for success of self-organization

Internal communication, i.e., interaction between the
active elements of the system.

External feedback, i.e., interaction between the (partial)
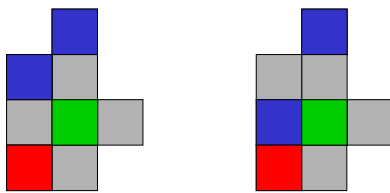system and its environment.

Ample of freedom, i.e., a sufficiently large number
of internal degrees of freedom.
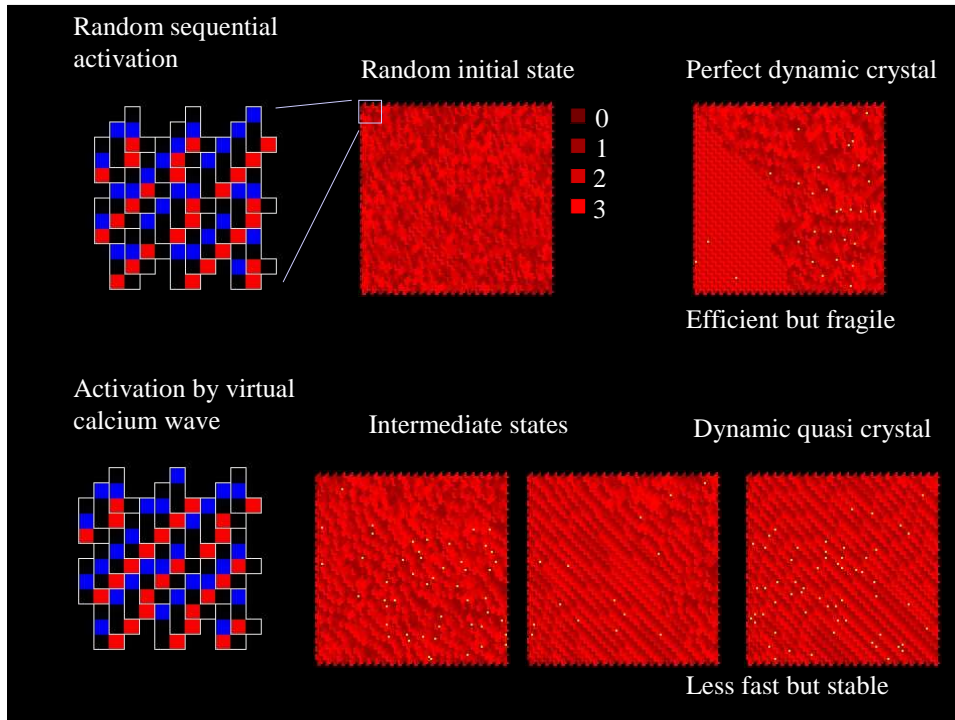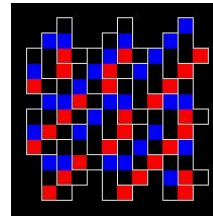
Simple model of self-organized transport
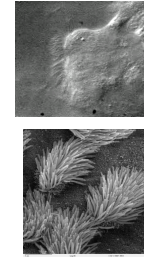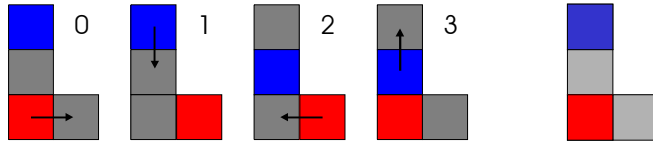
Two pre-coordinated
groups of ciliated cells

Internal and external interaction
mediated by "dust grains"

Ciliated epithel

Random sequential
activation

Random initial state

Perfect dynamic crystal

0
1
2
3

Efficient but fragile

Activation by virtual
calcium wave

Intermediate states

Dynamic quasi crystal

Less fast but stable

Moral of the story:

Amazingly simple interaction rules are sufficient
to turn randomness into self-organized action.

External coordination stimulus may be helpful.

Beware of over-coordination!
    Efficiency versus robustness

**I wish your networks
a pleasant and successful
self-organization!**