A viewpoint from photonics on bio-inspired camouflage

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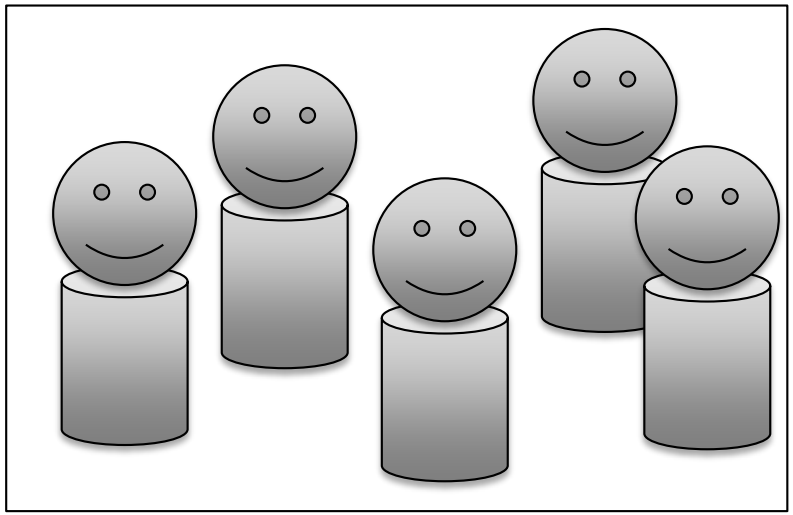
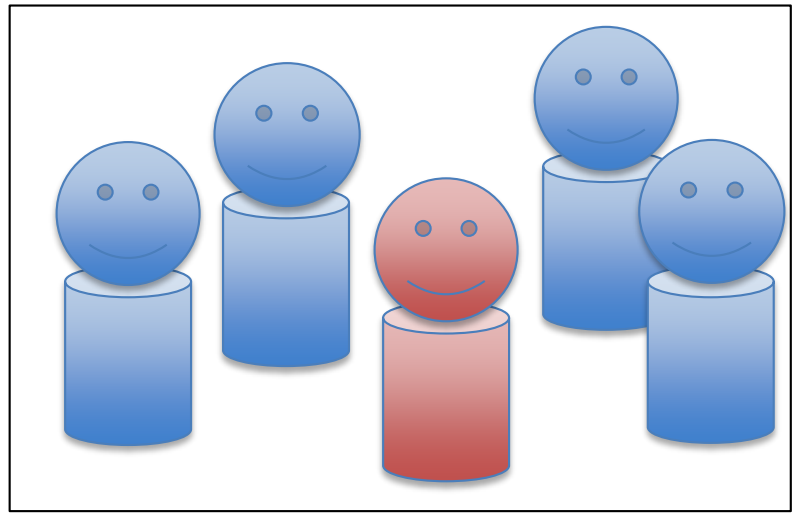
What are you trying to hide from?



Single-channel intensity detection
(black and white)



3-channel intensity detection
(RGB)

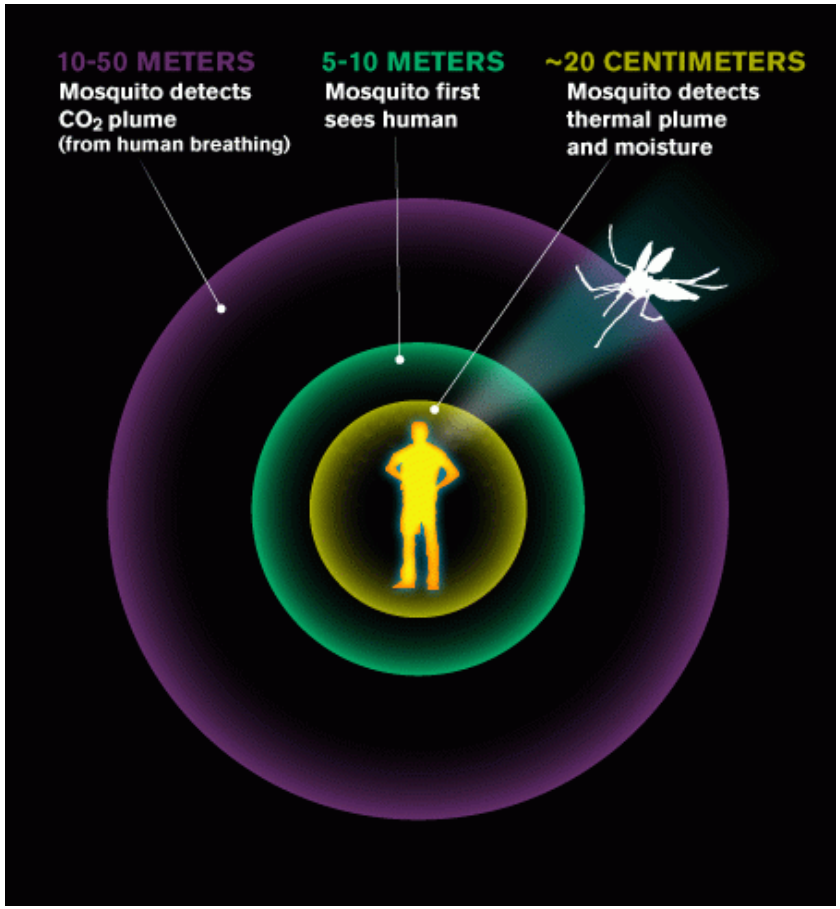
Generalization: Multi-spectral / hyper-spectral VIS/IR detectors

As detector complexity increases, so does the required number of matching attributes

a.k.a. "better detector needs better camouflage"

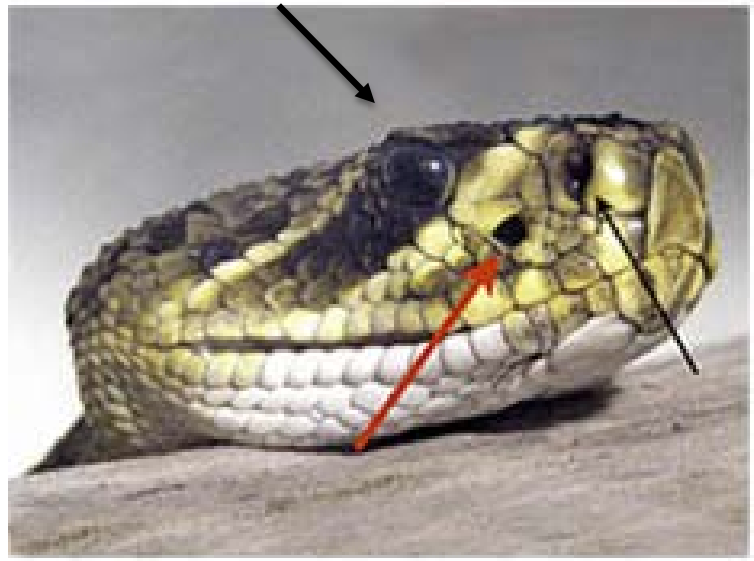
Animals as generalized multi-channel detectors

Driven by predator-prey relationships



https://earthsky.org/earth/how-mosquitoes-find-you-to-bite-you

eyes
(visible)



nostril

pit organ
(infrared)

https://www.nature.com/articles/nature08943

Are there animals that have developed multi-channel evasion mechanisms?

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Where are you trying to hide?

Low spatial-variation scene

✓ 

✗ 

Small number of effective strategies:
e.g. “be sand colored”

High spatial-variation scene

✓ 

✓ 

Greater number of effective strategies:
many different colors will blend in

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Increased scene complexity → increased solution space

Is anything moving?

Low temporal-variation scene

To stay hidden, don't move.

High temporal-variation scene

Works great, until there is a wind storm.

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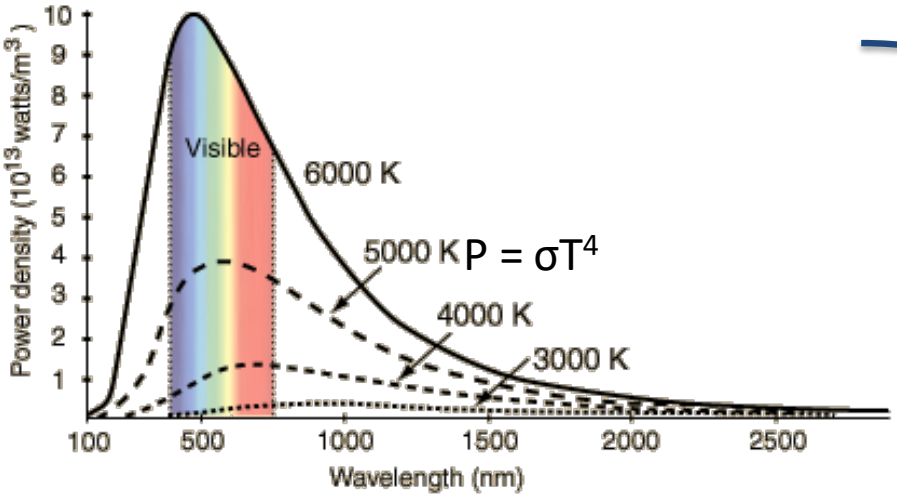
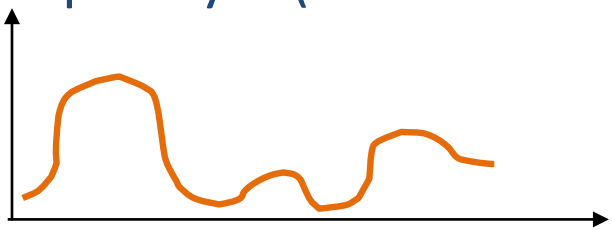
Matching is required in both space and time

Basics of thermal emission

T-dependent
blackbody distribution

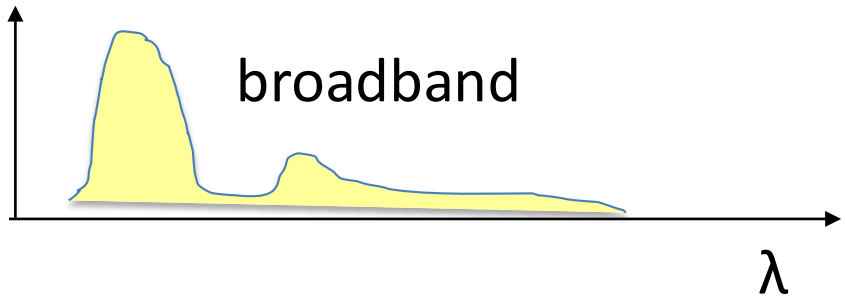


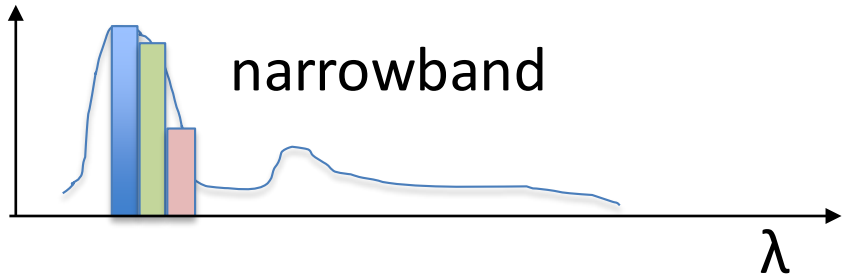
Absorptivity α (or emissivity ε)



λ

(1) Multiply, and
(2) Integrate over detector response





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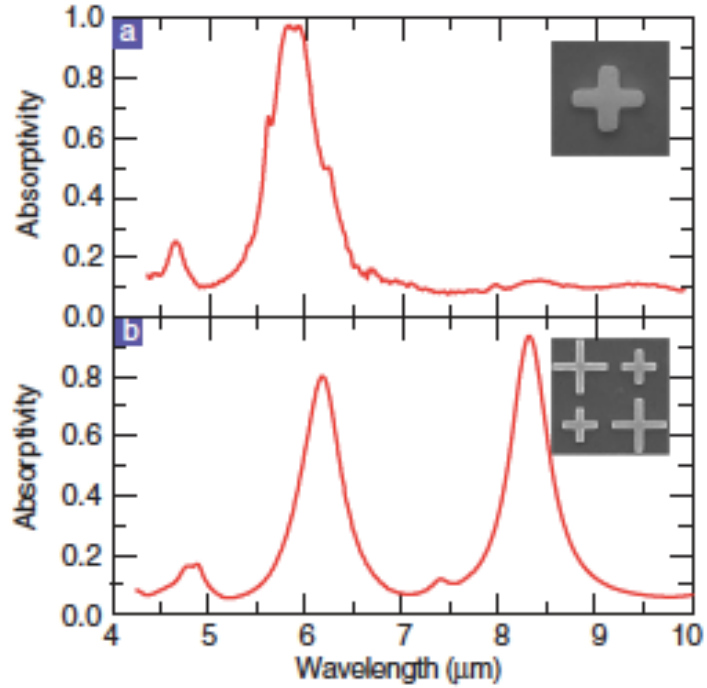
Emission spectrum can be engineered using microstructure

Static: Creation of spectral peaks



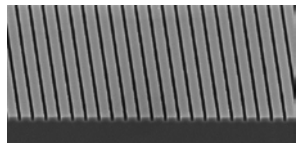
Padilla et al, PRL 2011

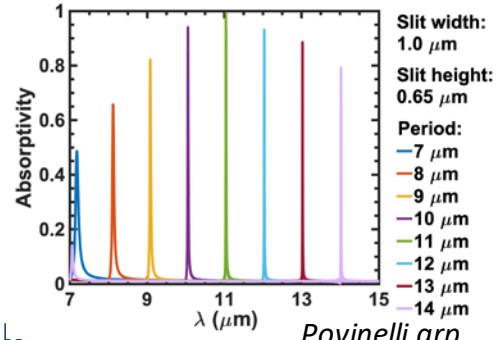
Taxonomy of engineered materials

(a partial list of a much wider body of work)

metals

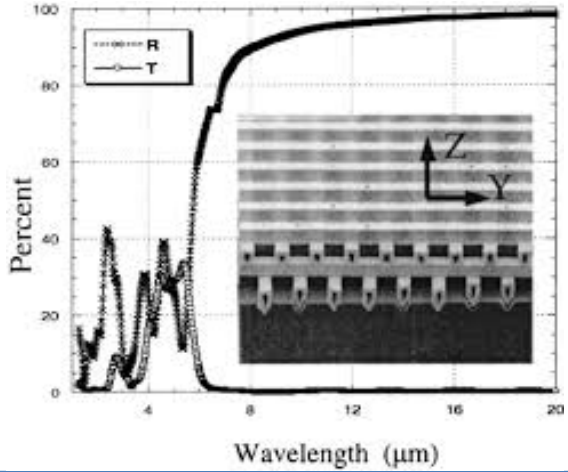
- **surface plasmons**





Povinelli grp

- **photonic crystals**

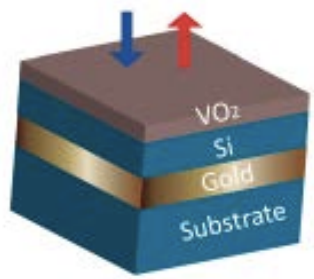


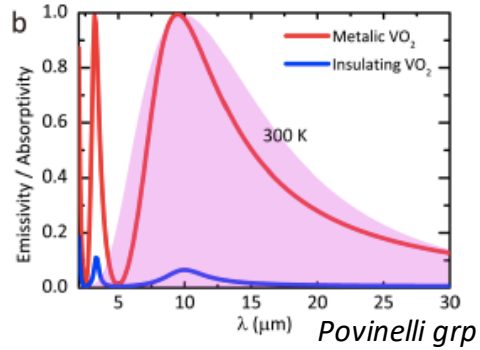
El-Kady et al

dielectrics

(often high-refractive index *n*)

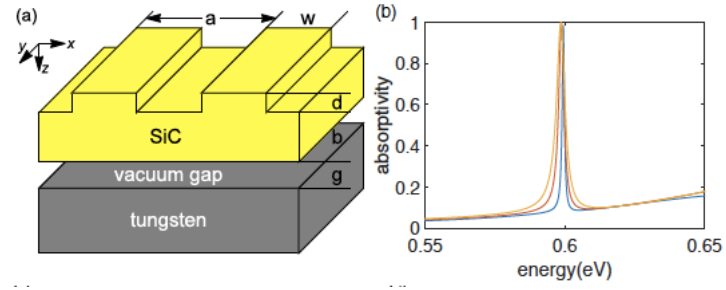
- **Fabry-Perot cavities**





Povinelli grp

- **guided-resonance modes**



- *Are engineers missing mechanisms that biology has found?*

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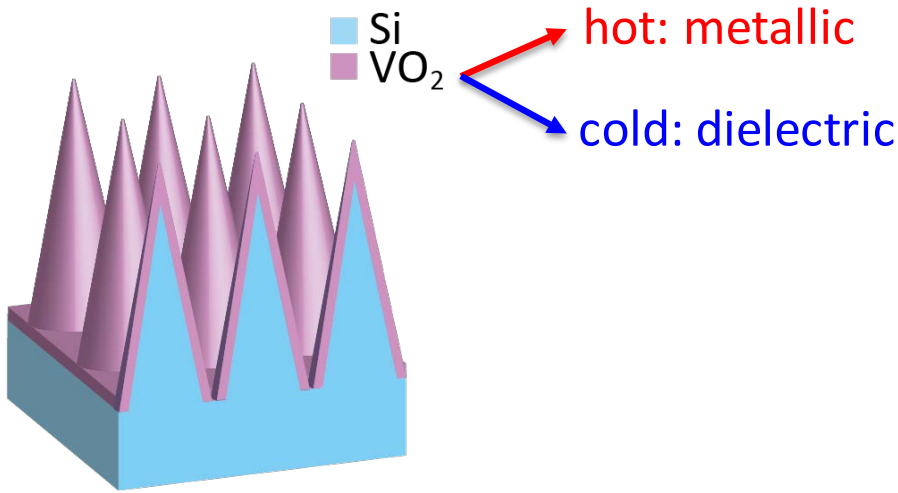
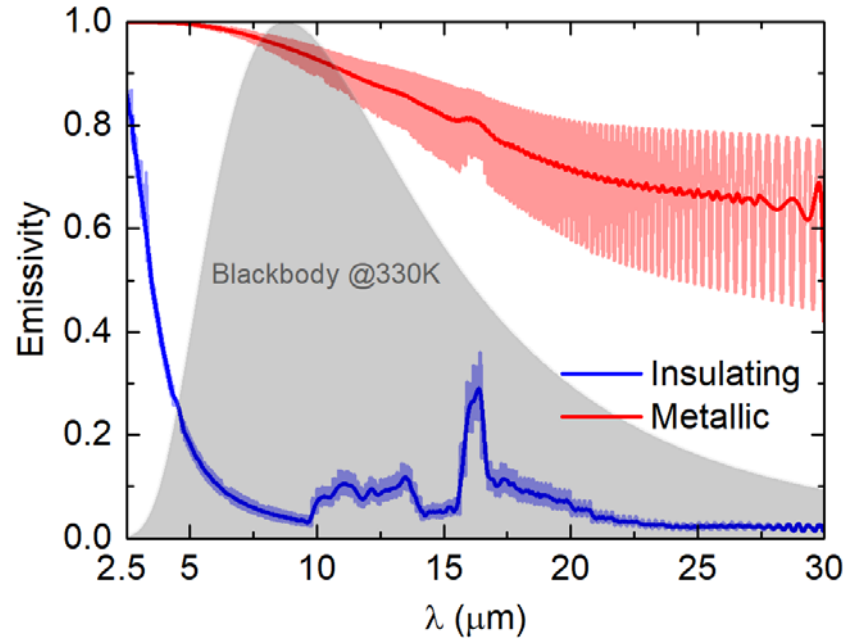
Adaptive responses are of increasing interest

Homeostasis: self-regulation of biological processes, e.g. temperature

Synthetic materials for thermal homeostasis





Povinelli Group / NG-NEXT, *Optica*

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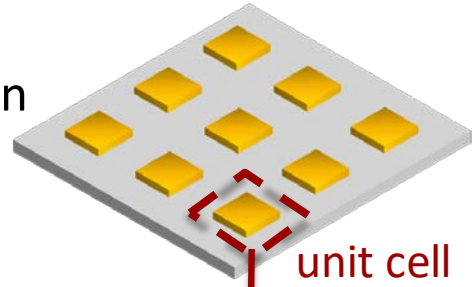
Enabling Optimization via Parametric Design

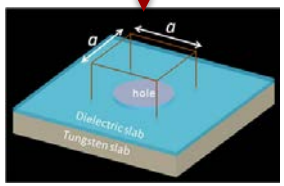
Collaboration w/ Zongfu Yu, U. Wisconsin

Optimizing microstructures is computationally expensive

(1) Choose physical design



(2) Input unit cell to numerical solver



lumerical

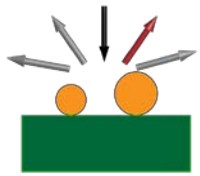
(3) Calculate absorption

(4) Iterate under optimization function

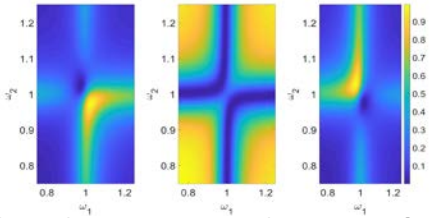
– costly

Parametric models for fast optimization

(1) Look at class of designs described by spectral resonances



(2) Optimize over reduced parameter space **– orders of magnitude speed-up**



(3) Use look-up catalog to find real, physical structure

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Faster calculation lets you tackle more-complicated optimization functions, e.g. optimization <u>in presence of variability; bio-inspired</u>