Rapid adaptive camouflage and signaling in cephalopods

Part 1: Concepts and questions

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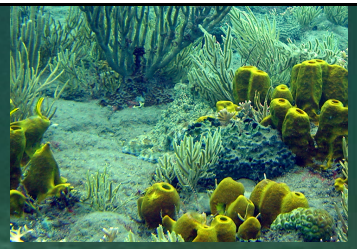
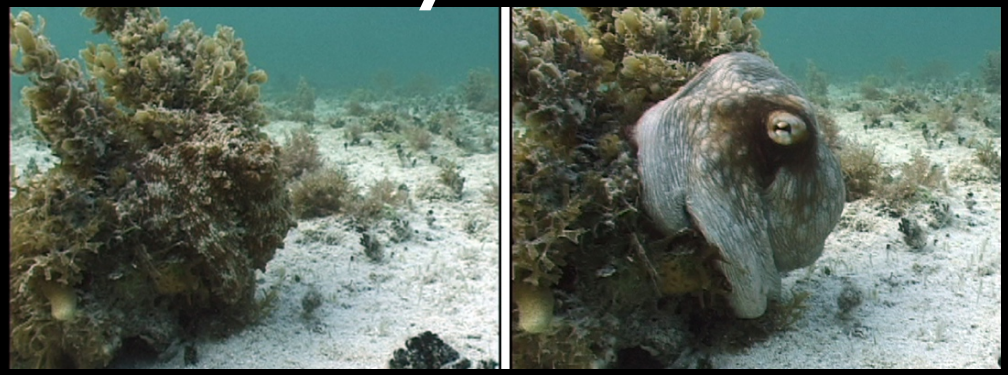


high-fidelity match:
-pattern
-posture
-intensity
-color
-3D texture

Camouflage is about VISUAL PERCEPTION
-How does the octopus view the background?
-How does the brain control the skin to produce such a diversity of visual illusions?
-What is the nature of the skin structures?

How and why do they do this?



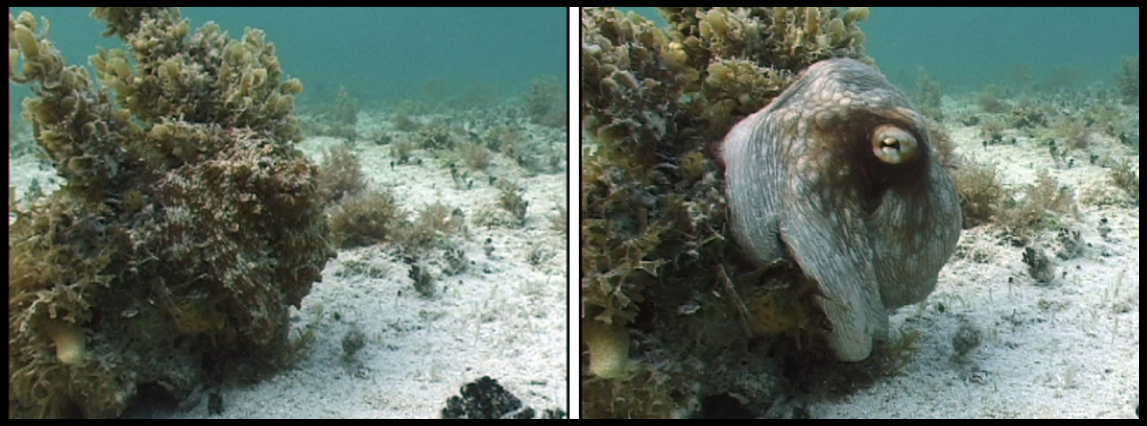
This system is

tuned to fish, bird and mammal vision

(**color,** polarization, night, UV, keen acuity, etc.)

"Global" look at a dynamic coloration & patterning system

behavioral ecology: pred/prey, communication, crypsis theory



vision: perception (2D, 3D, color, texture,night,motion)

neuroscience: neural control of motor output in skin

optical physics: quantify the light field & animal,
measure & model skin color and patterns

image analyses: quantitatively compare animal to background

nanotechnology & materials sci.: bio-inspired principles to engineer novel materials

art & science: art, architecture, fashion design, etc.

Rapid Adaptive Coloration

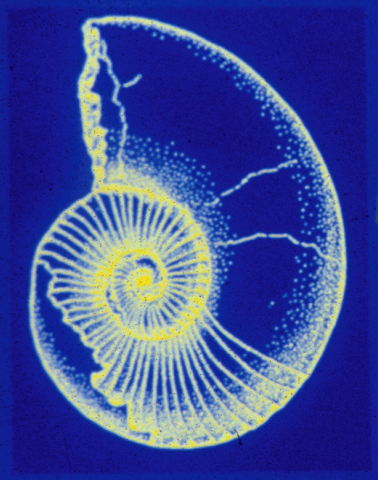
- Speed and diversity of cephalopods are unmatched on earth
- Rapid neural polyphenism
  - 30-50 patterns per animal
  - Direct neural control = change in <1 second
  - This system is **tuned to fish, bird and mammal color vision**

Static vs. Adaptive Camouflage in Nature

- Fixed pattern: take pattern to right place, implement it properly (=low versatility)
- Changeable patterns: go anywhere, match pattern to multiple backgrounds (=high versatility)

  - Slow change/ low diversity (amphibians & reptiles)
  - Fast change/ high diversity (some fish, all cephs)

Cephalopod evolution



shell loss

buoyancy

locomotion

brain

sense organs, effectors, memory/learning

skin

"live fast & die young"

Art and Science

- Camouflage ---------- Conspicuousness

- Shape, edges, contrast, color, texture, etc.
- These features are shared in:
- Art
- Photography
- Architecture
- Landscaping
- Marketing and advertising
- Biotechnology

How many camouflage patterns are there?

•Cephalopod analysis: 24 years / 22 species

•Short answer: THREE
•Uniform, Mottled, Disruptive
(counter-intuitive : Principle of Parsimony)

variations on each theme

Uniform

little to no contrast

Mottled

small-scale light and dark patches; moderate contrast, some repetition of general shapes

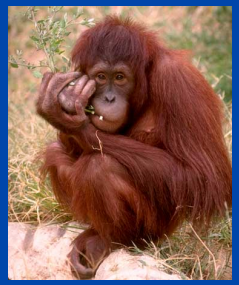
Disruptive

large-scale light and
dark shapes of multiple
contrast,
orientations and scales

If cephalopods can hide anywhere with only 3 pattern types .....

Is it possible that all animal camouflage patterns
can be grouped generally to UMD?

UNIFORM (general resemblance)



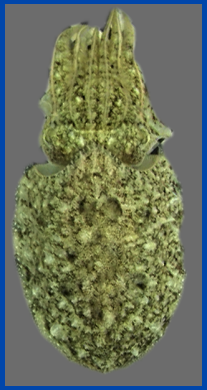
Amphibians

Reptiles

Fishes

Insects

MOTTLED (general resemblance)



©2000 Marc Kramer, courtesy of Lynda Horgan

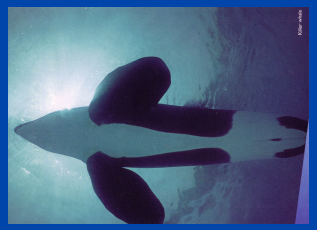
Female ©2000 Emerson Sy

Five-spotted hawkmoth Photo: Paul Opler

Insects

DISRUPTIVE (disrupts body outline)

Ar



Reptiles

Adult Male ©2000 Marc Kramer

Adult male, Ambilobe ©2003 Pam Reid

Male Ch. minor ©2000 C. Cattau Jr.

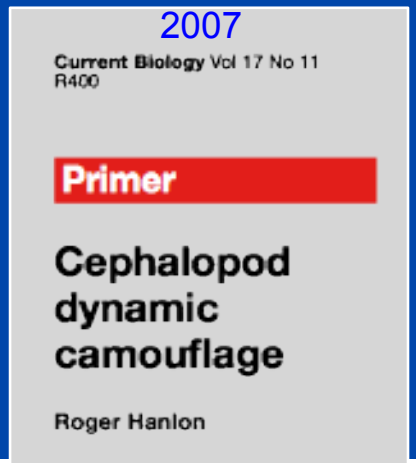
Fish

Insects

Significance

- If nature has honed only 3 camou pattern types in all habitats ....

- The implication is that all predator visual systems can be fooled by 3 basic tricks



-provocative
-controversial
-testable?

-pro
-pro
-co

What <u>is</u> camouflage?

The least-studied subject in biology that we think we know about

Camou isn't camou

-A generalist solution to a complex visual challenge
-Hundreds of background features
-What did the octopus cue on? What are salient features of pattern?

Camouflage entails:

- 1. Background matching
  - high fidelity vs generalist
  - (no perfect stat match)
- 2. Disruptive coloration
  - disrupt recognition/aid anti-detection
    - edge design, internal contrast
- 3. Masquerade
  - (or mimicry/deceptive resemblance)

Quantification of camouflage is a challenge

3 worthwhile books on camouflage

ADAPTIVE COLORATION IN ANIMALS

by

HUGH B. COTT

M.A., D.SC., F.R.P.S., F.Z.S.

LECTURER IN ZOOLOGY AND STRICKLAND CURATOR, CAMBRIDGE UNIVERSITY

with an Introduction by

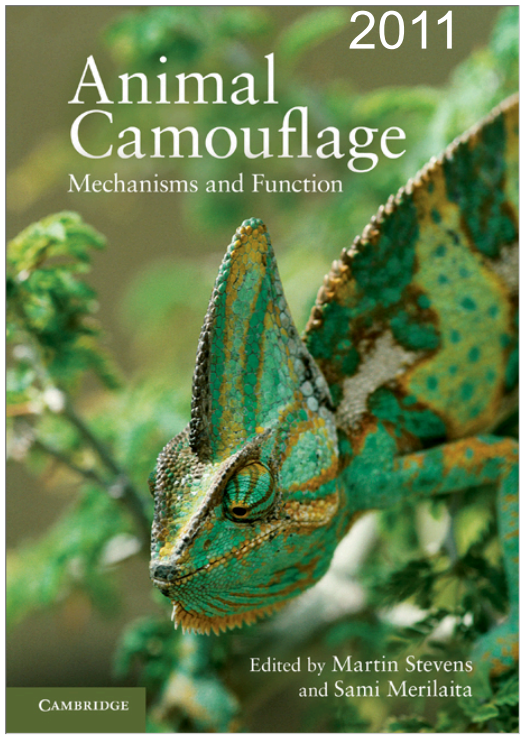
JULIAN S. HUXLEY

Illustrated by the Author with coloured frontispiece, 48 monotone plates and numerous illustrations in the text

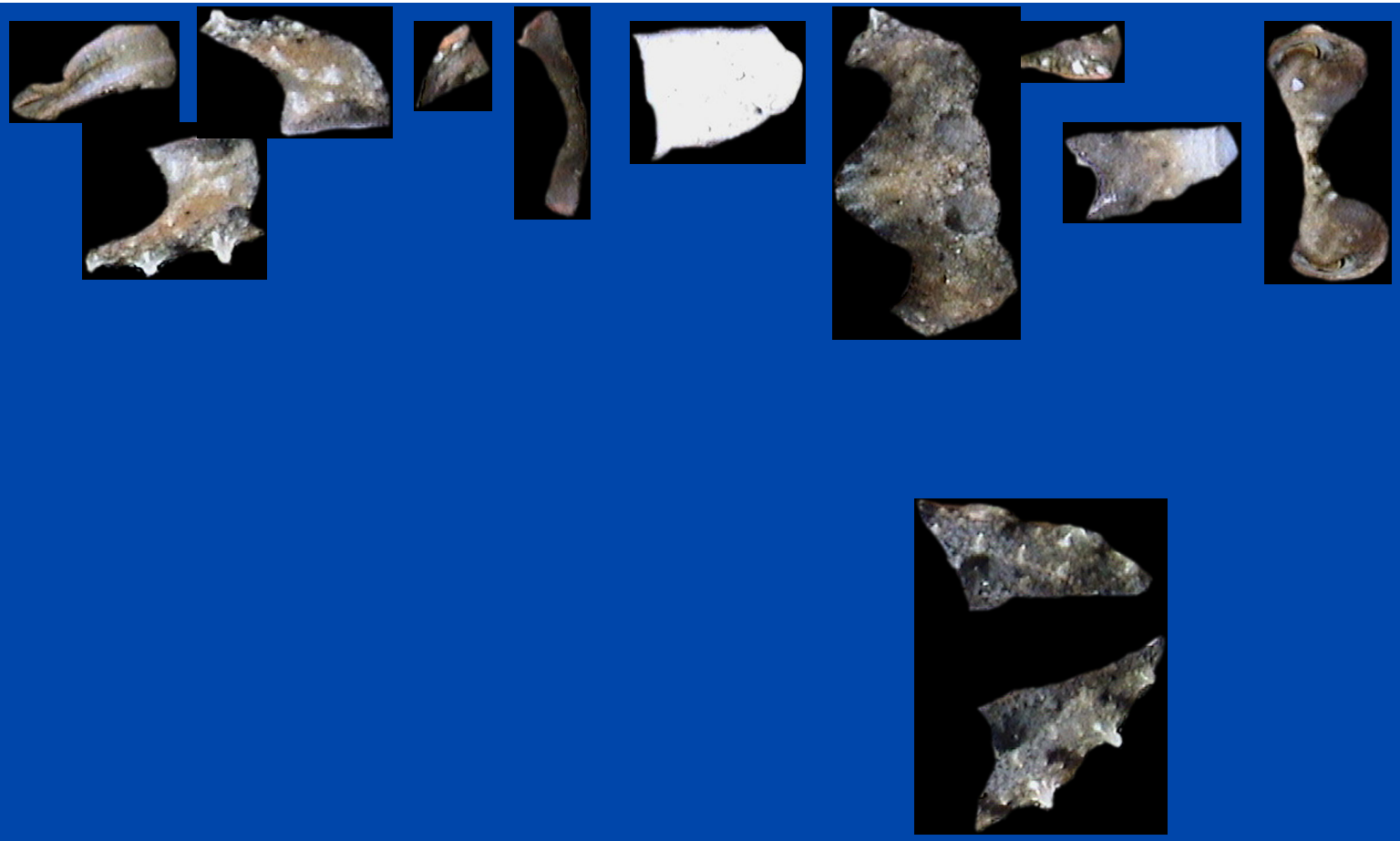
1940

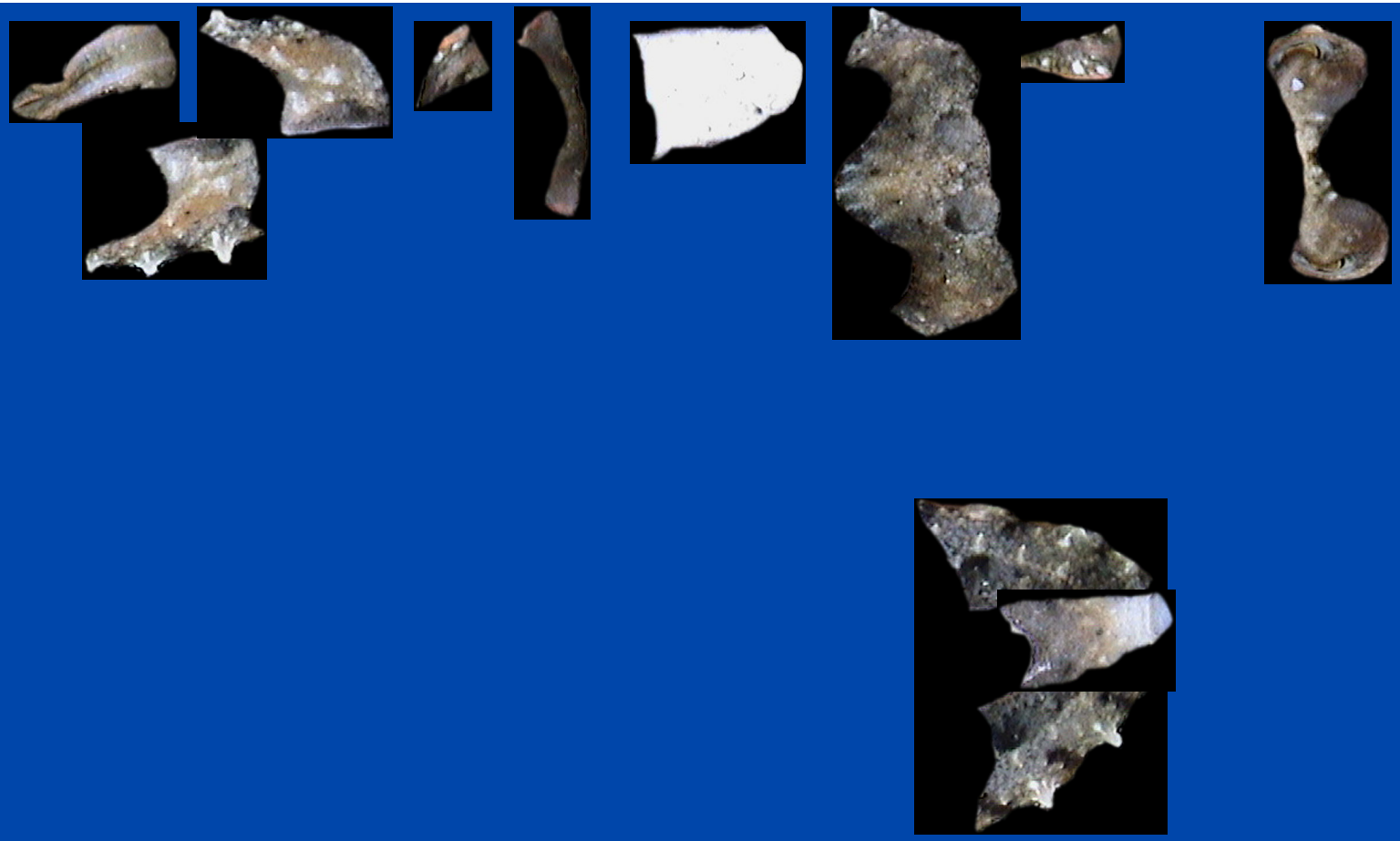
METHUEN & CO. LTD., LONDON

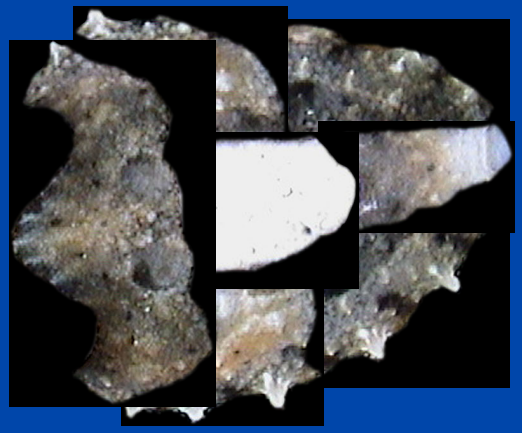
36 Essex Street, Strand, W.C.2

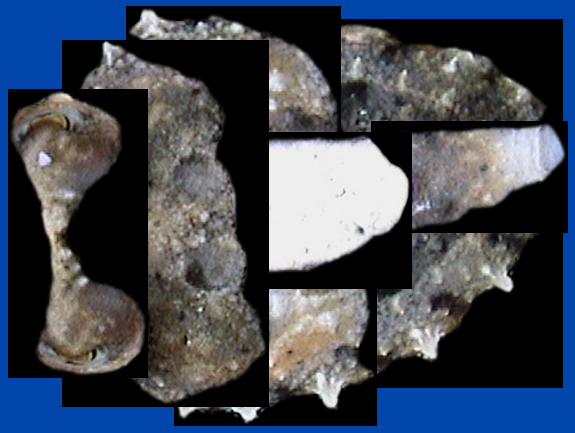


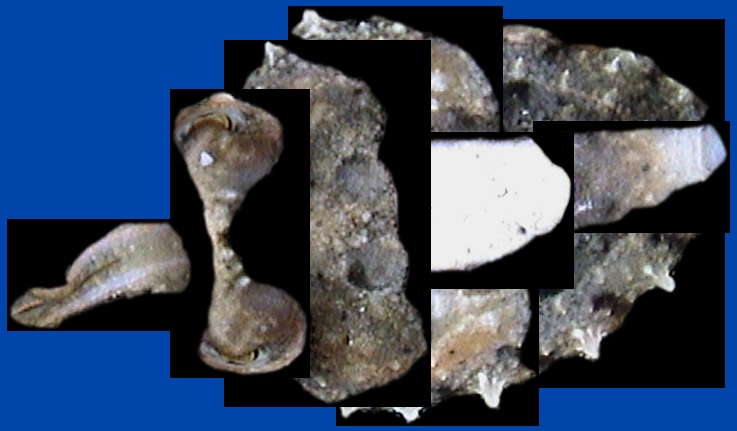
Disruptive coloration

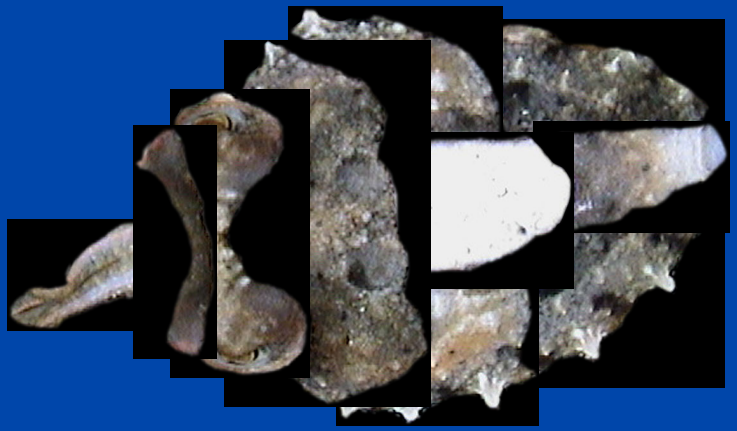


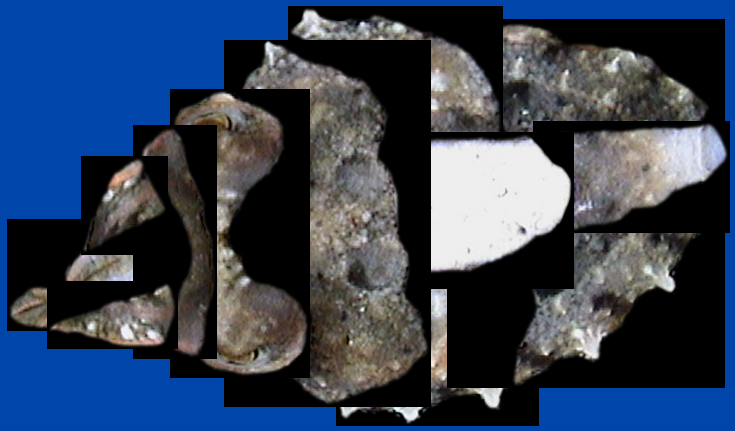












hide edges, create false edges, confuse figure/ground, distractive markings, etc.

ULTIMATE GOAL:

View a background and PREDICT the correct camouflage pattern for an animal of any shape and size

How is the background sensed to achieve adaptive coloration?

Key attribute:

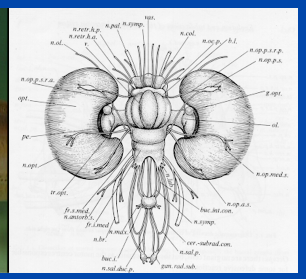
Cephalopods are genetically driven to camouflage themselves on any background - a primary defense that is visually guided

CONCEPT:

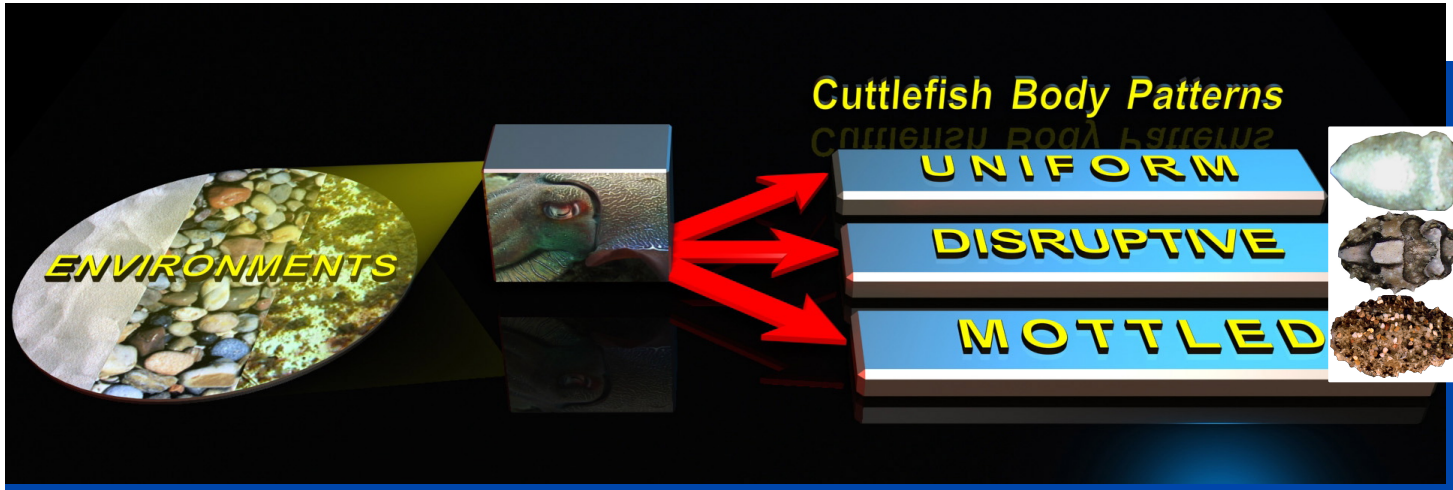
3 Pattern templates

3 Visual sampling rules

The animal's sensor:

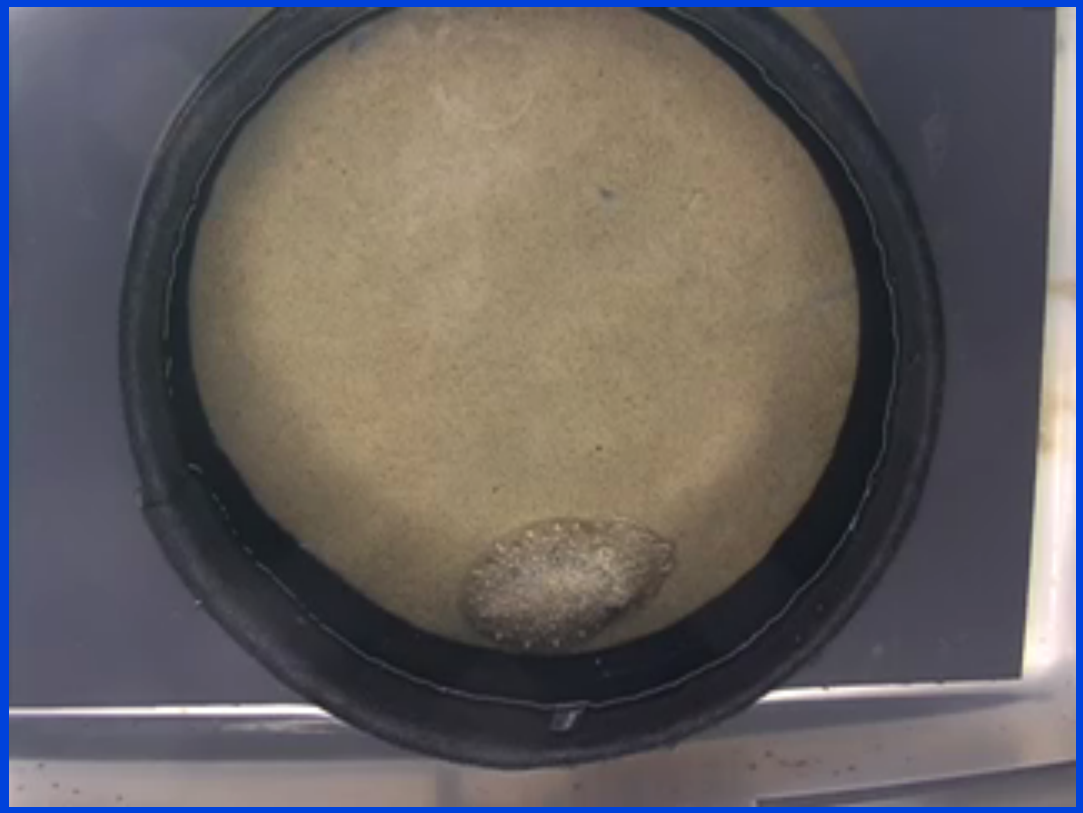


- Large, complex eye
- Huge optic lobes; a "visual animal"
- Keen visual acuity
- Polarization vision
- Excellent night vision
- Yet …… no color vision
- How do they achieve color-blind camouflage?



Basic experimental approach

Quick Change by Visual Assessment

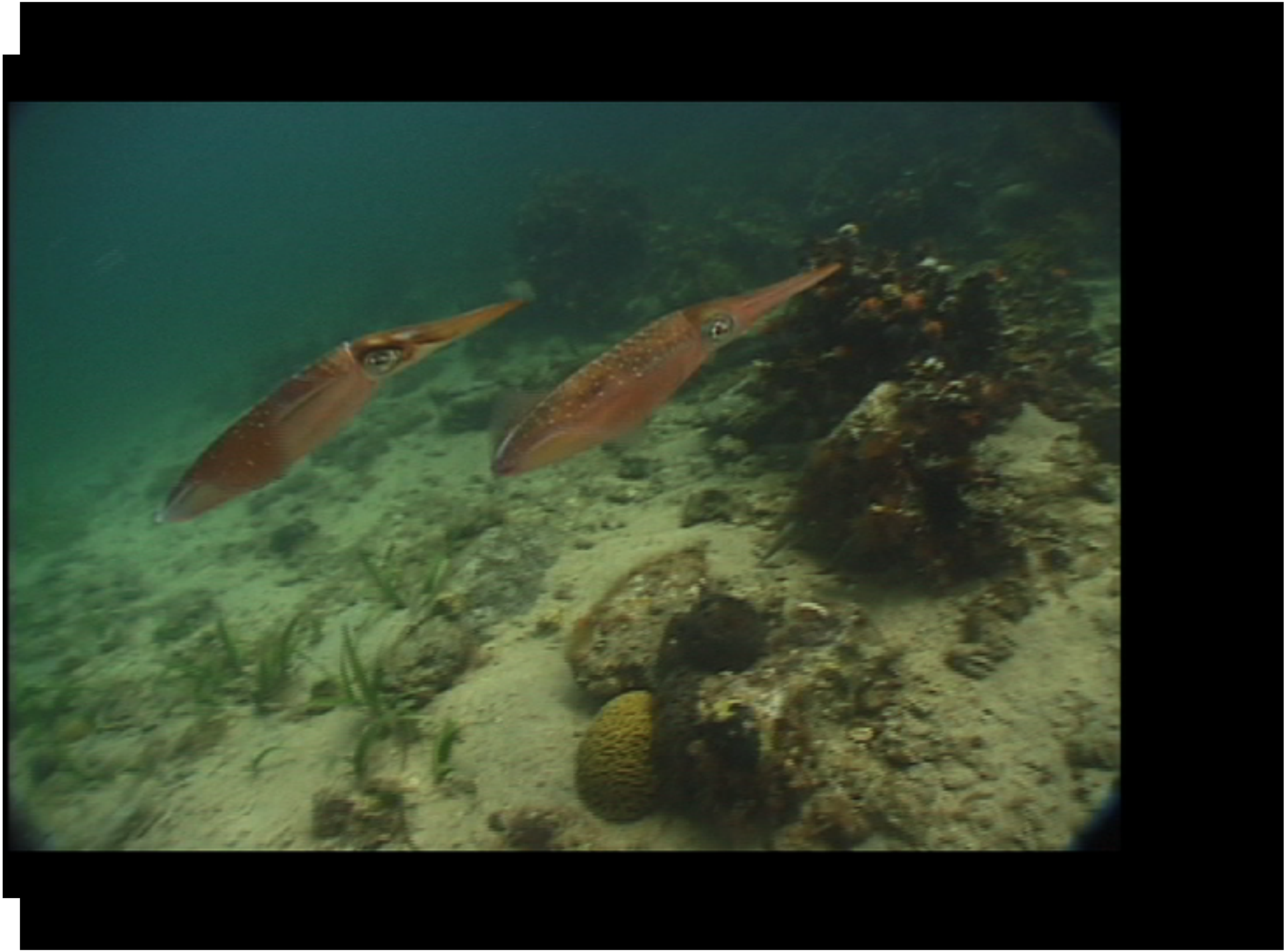


TRICK: they use simple cues to solve complex challenges

We will tease out the visual control in Part 2

Signaling

- Bright, unambiguous signals
- Sender → Receiver
- Visual deception
- Sexual signaling

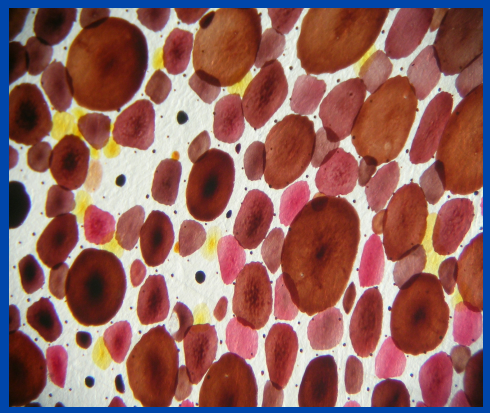


Key elements for adaptive coloration:

Keen (but strange) vision

Magical skin

(pigments and reflectors)



Dynamic, fine-tuned skin patterning

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Summary thoughts

-Coloration and patterning are widespread throughout nature

-Rapid adaptive coloration is evolved to the extreme in cephalopods

"Organisms that exhibit extreme of adaptation may reveal general principles not readily observable in less extreme species."

August Krogh (U Copenhagen, Denmark)
NOBEL Prize 1920 .. how capillaries regulate oxygen

-Camouflage is a key evolutionary mechanism both in predation and defense; it is poorly understood due to inappropriate assumptions

-Camouflage offers an unorthodox way to study visual perception (Part 2)

-Signaling is the opposite of camouflage although it exploits the same small number of variables

-Visual input guides both types of behaviors

-Skin is controlled directly by brain

-Skin pigments and reflectors combine in unique ways to achieve such diverse appearances (Part 3)

Study nature, not books

L. Agassiz ca. 1890

Thank you

Video:
Wow 1:08
GermanChan 0:36
Cuttle lab change 0:37
Squid cayman 0:56
Skin apama 0:46

TOTAL: 4.2 min

Some fundamental questions

Pattern: what elicits each of the 3 types?

Do they prefer certain substrates?

What about “conflicting” info for each eye?

Are 3D background objects more important than 2D?

Can they tailor camou at night?

How is the morphing 3D skin controlled?

How is posture controlled?

How do they achieve color-blind camou?

Is motion camouflage possible?