The ant colony:
A post transition society

Tzfat, 2019

Ofer Feinerman

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Our protagonist

Our protagonist: 150M years later

Changes to the individual
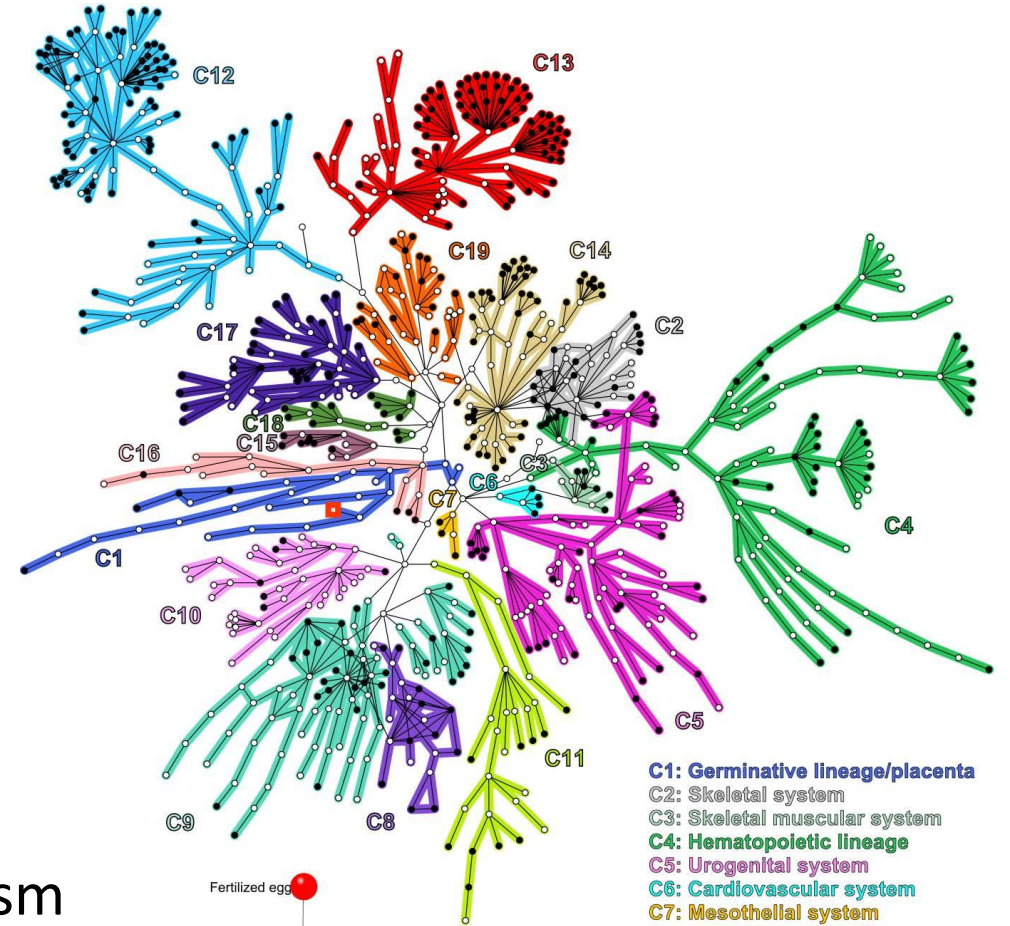
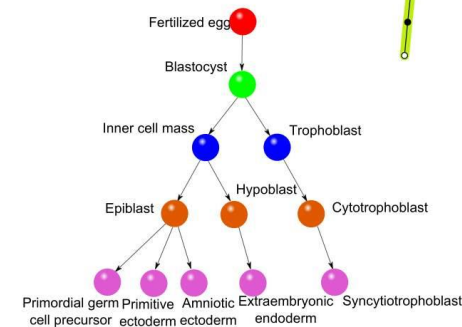# Reproductive division of labor (=post transition?)

Caste differentiation

Atta cephalotes leafcutter ants.
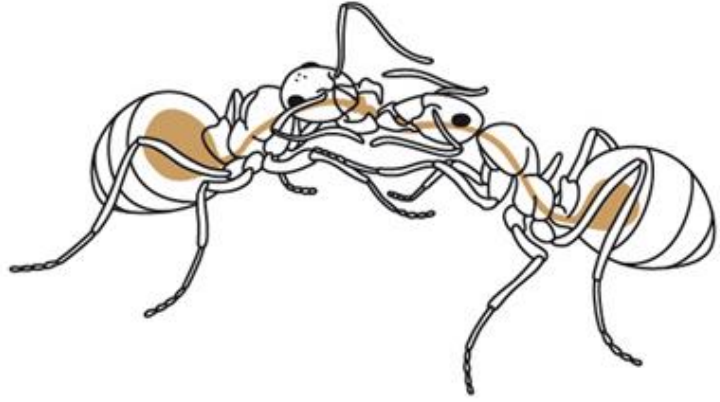
Caste differentiation

The superorganism resembles an organism

C1: Germinative lineage/placenta
C2: Skeletal system
C3: Skeletal muscular system
C4: Hematopoietic lineage
C5: Urogenital system
C6: Cardiovascular system
C7: Mesothelial system
C8: Respiratory system
C9: Digestive system
C10: Pharyngeal lineage
C11: Cloacal lineage
C12: Neural lineage
C13: Eye lineage
C14: Neural crest lineage
C15: Adenohypophysis
C16: Primitive oral cavity
C17: Ear
C18: Nose
C19: Integumentary system

The social stomach

The social stomach
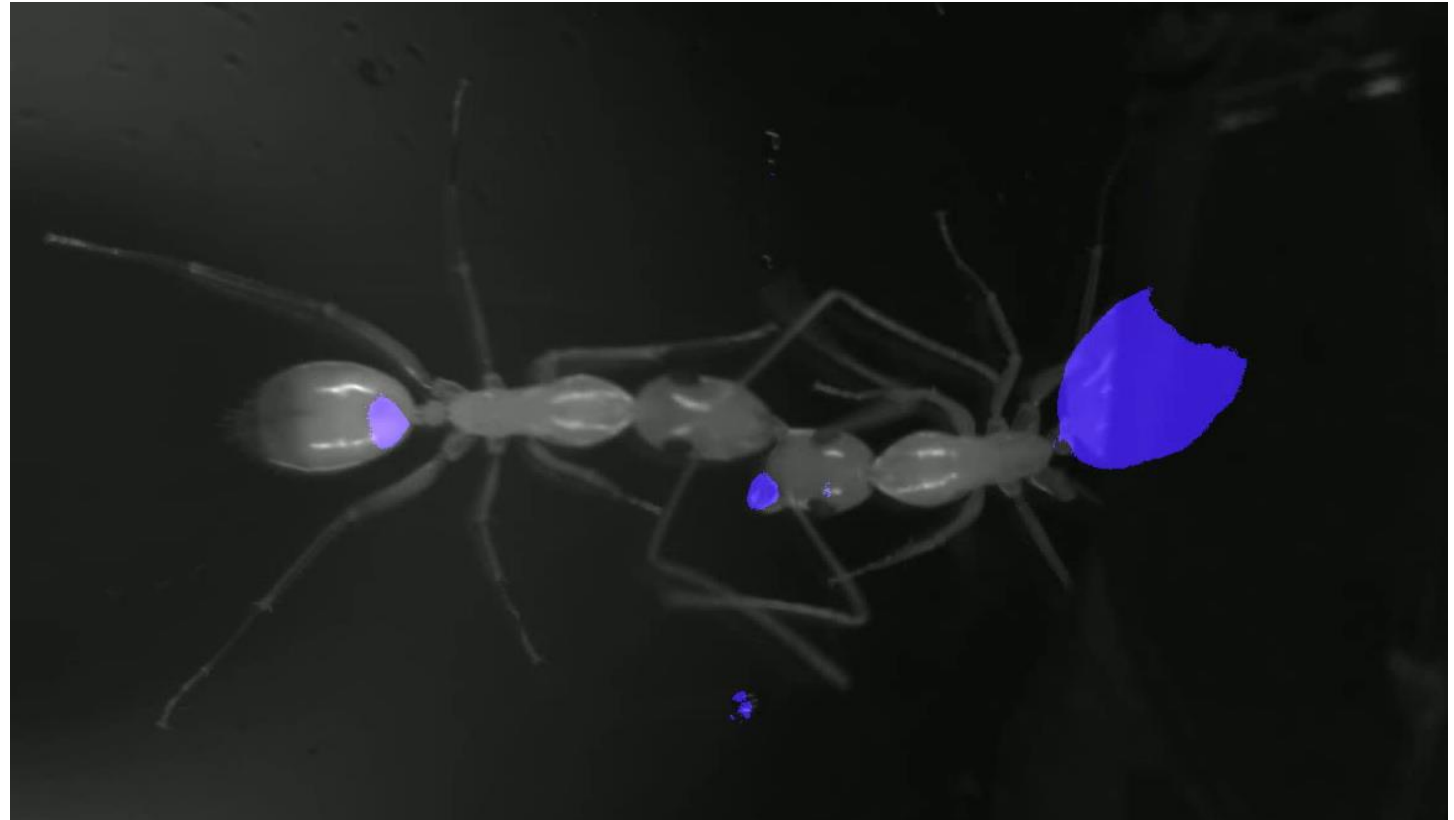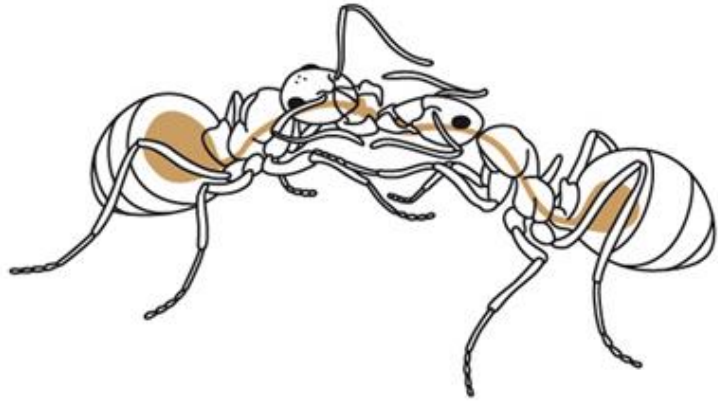
A social stomach caste

The Brain

What do expect?

Mushroom bodies

Antennal lobes

Antenna with
sensilla

Habituation and associative learning

Sensory adaptation
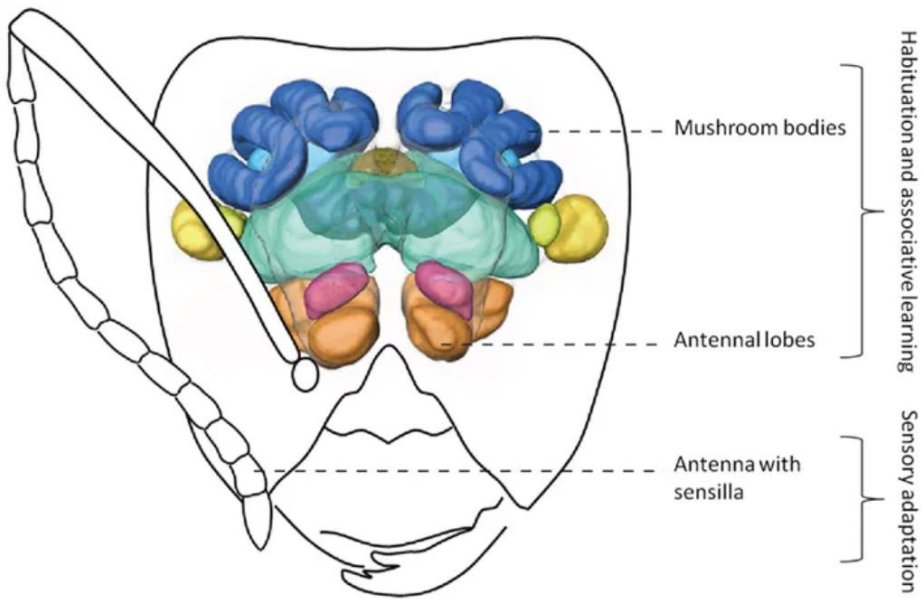
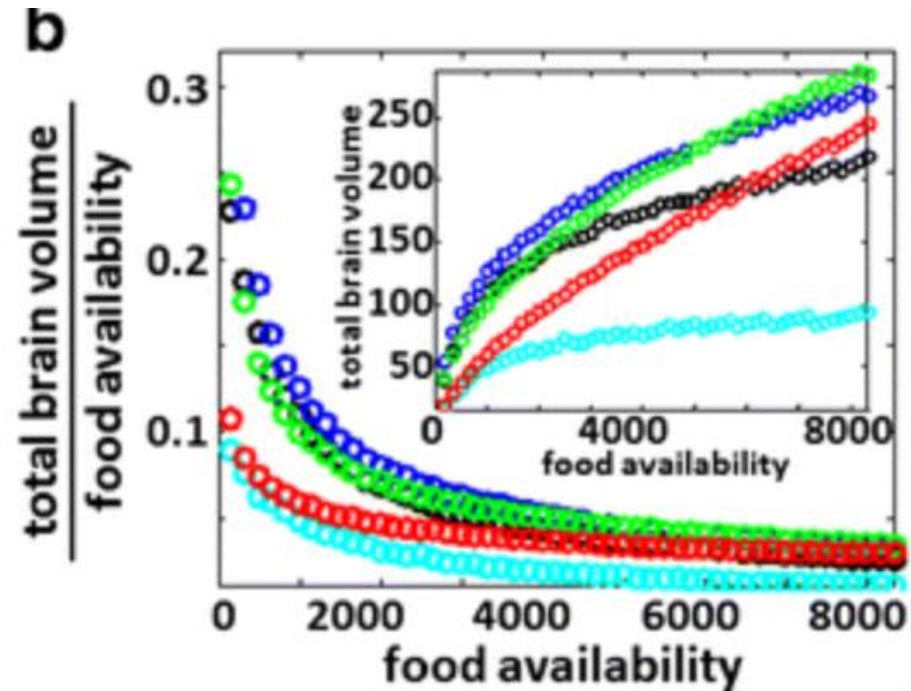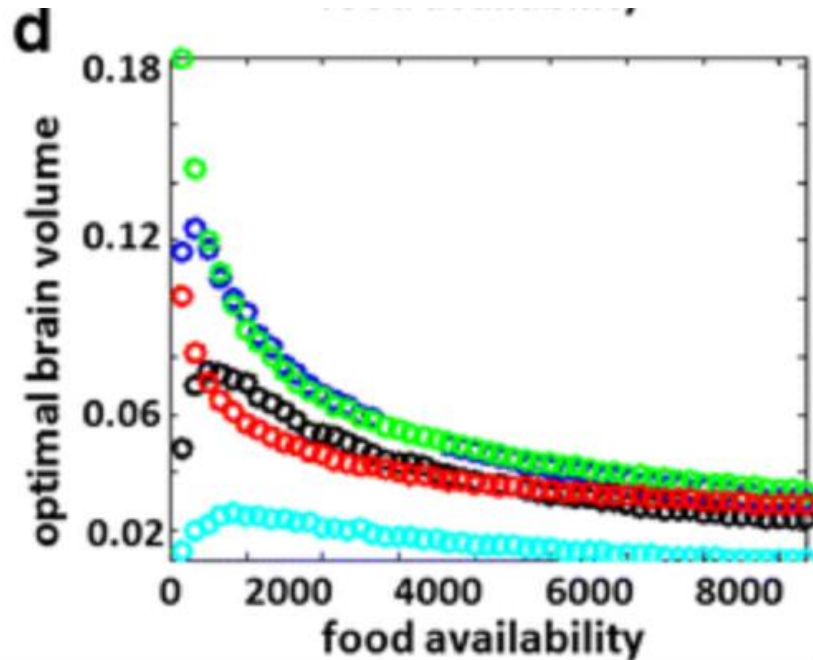# The Brain: Group living ➜ Larger brains

The social brain hypothesis

The Brain: : Group living ➜ smaller brains

Brains are energetically costly.

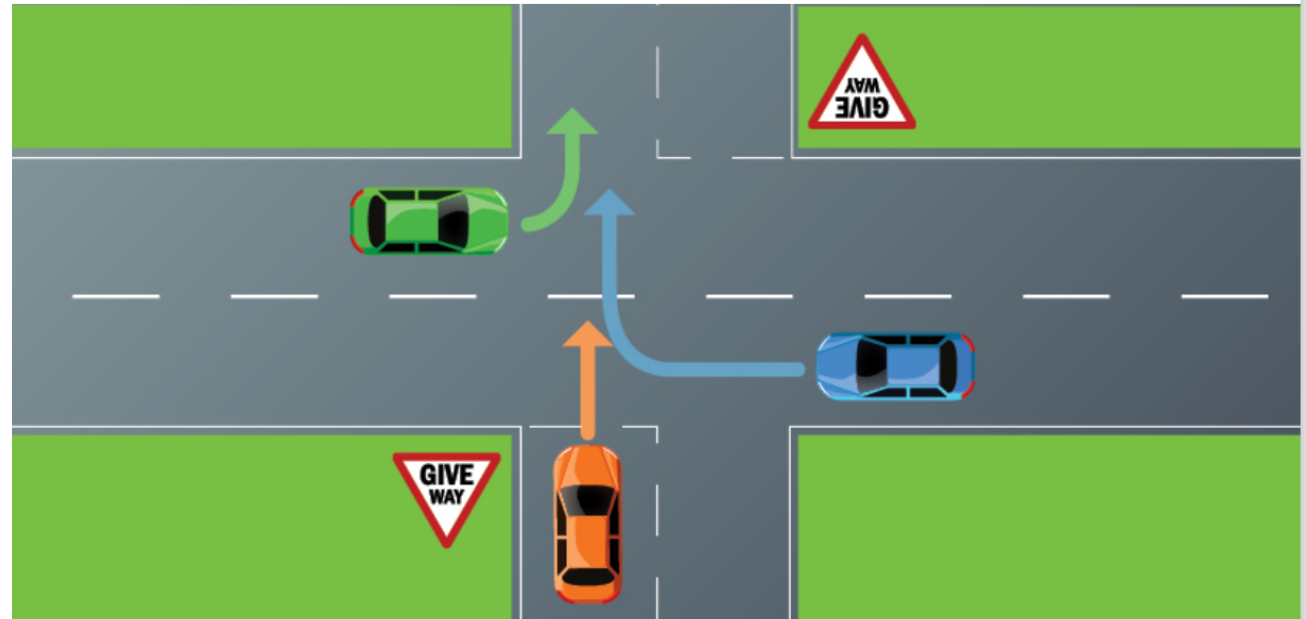Could "collective cognition" relax demands on individual brain size?

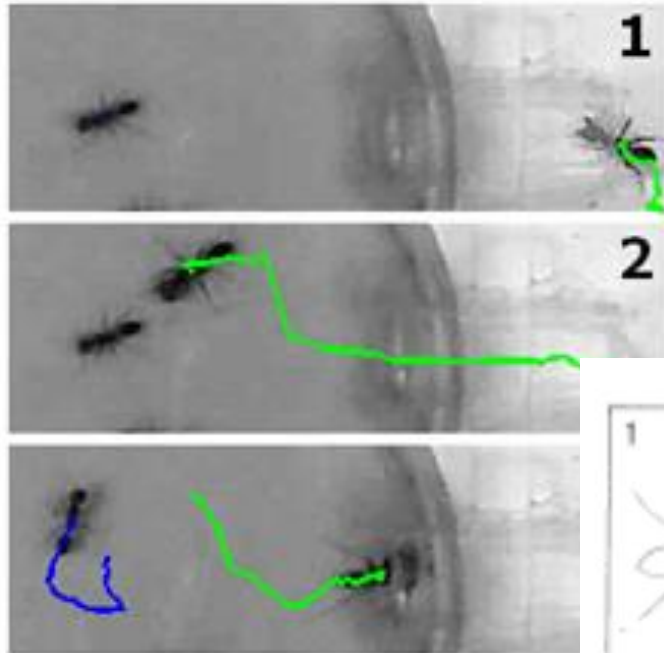# The Brain: : Group living ➔ smaller brains

Complex individuals are difficult to coordinate.

What order should these three cars go through the intersection?

Changes to the interaction

A rich vocabulary

Razin, Eckmann, Feinerman. Roy. Soc. I

Foraging place

39 faranal *Monomorium pharaonis*

40 (Z,Z,Z)-allofarnesene *Solenopsis invicta*

41-43 decyl, dodecyl and tetradecyl acetates n =0, 2 or 4

44 decyl butyrate

45 octadecyl butyrate

46 esterase

oxidase

47 n = 3,5 or 7   m = 3, 5, 7, 9 or 11 European *Crematogaster*

48 m = 2,4,6 or 8   n = 1,3 or 5 *Crematogaster nigriceps* (African) 8 compounds

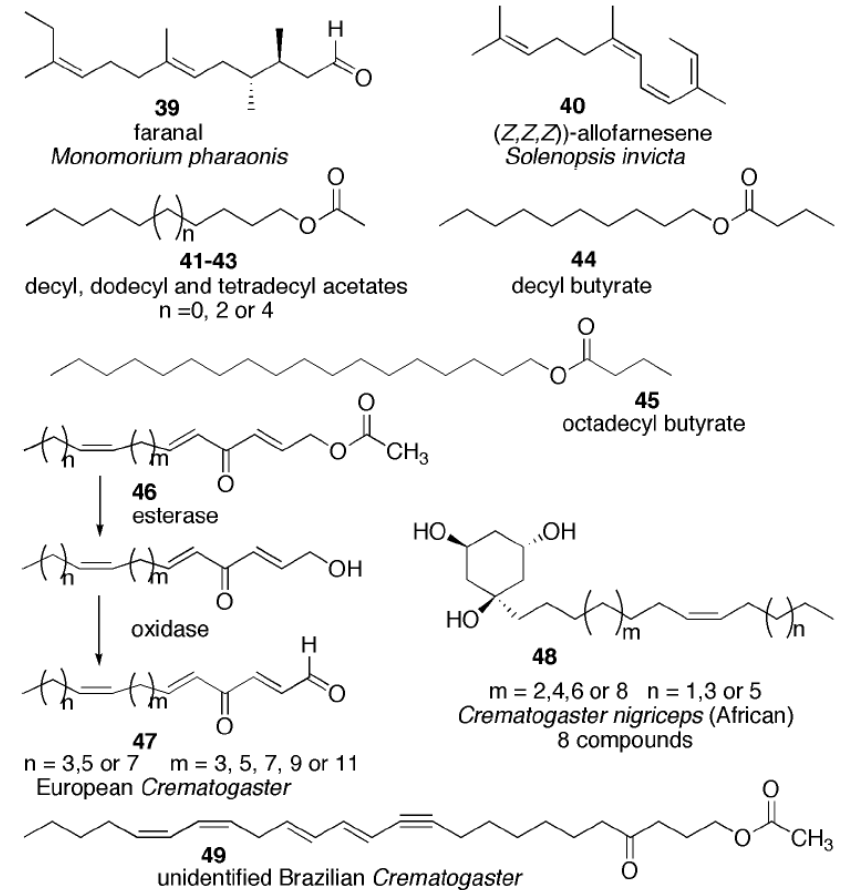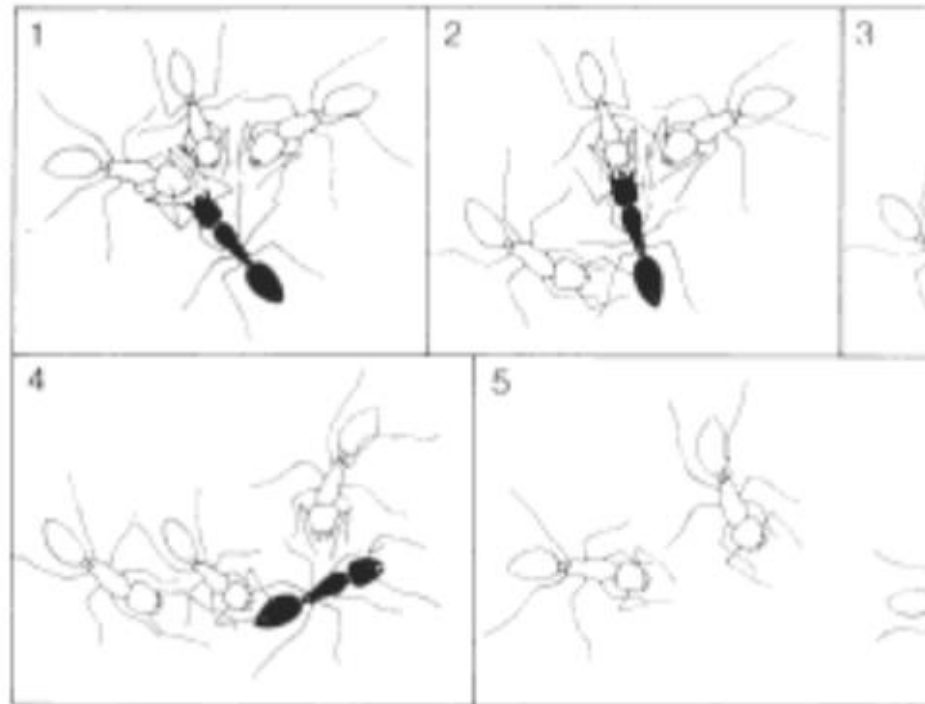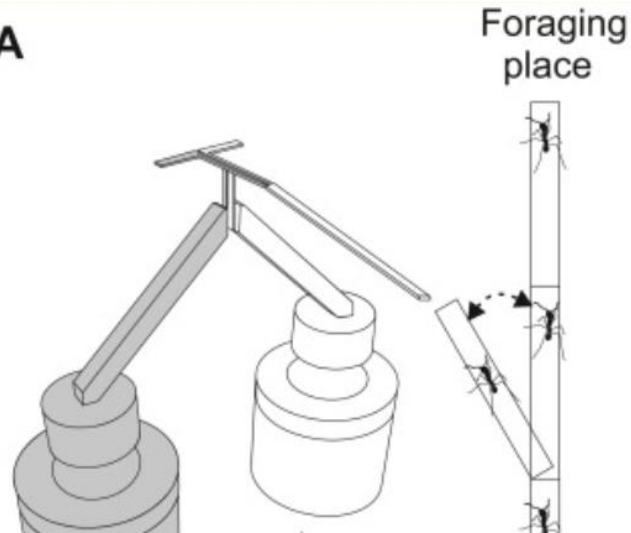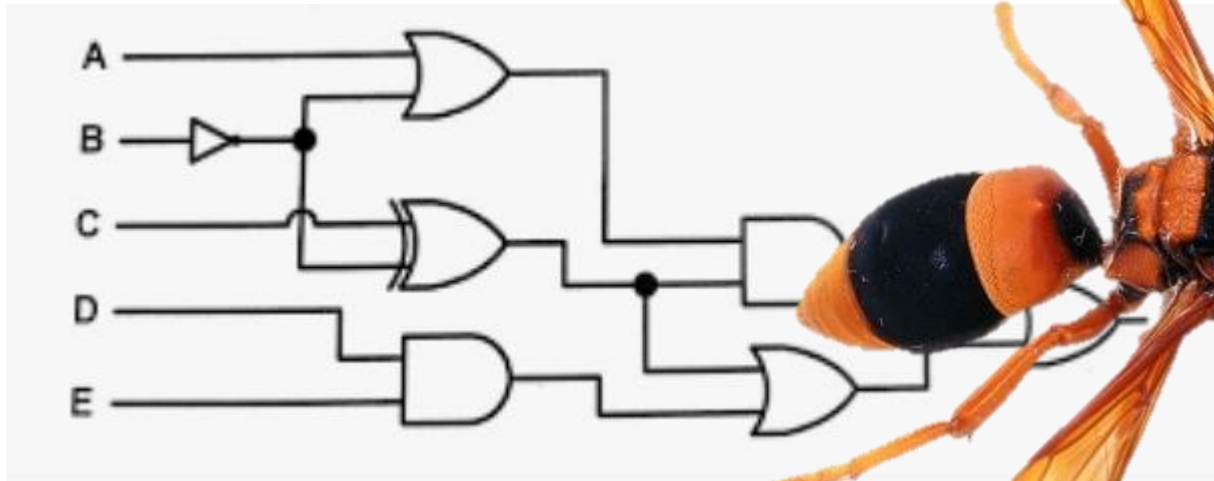**49** unidentified Brazilian *Crematogaster*

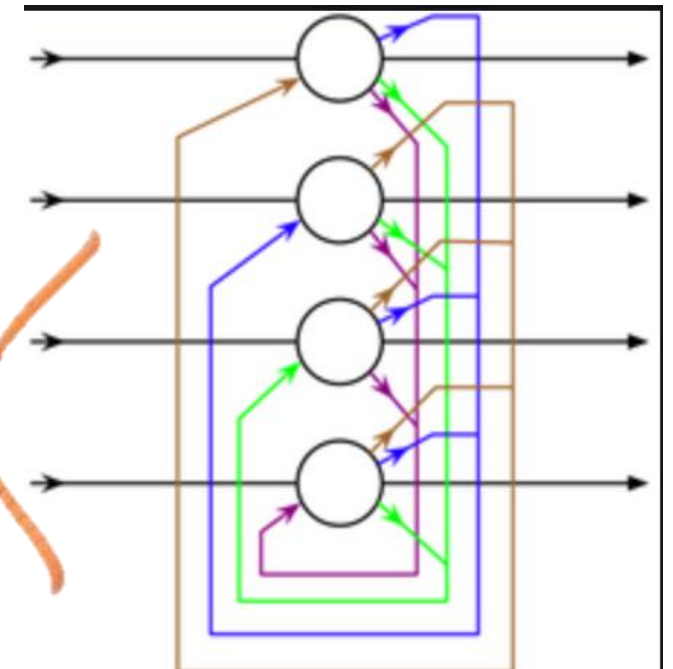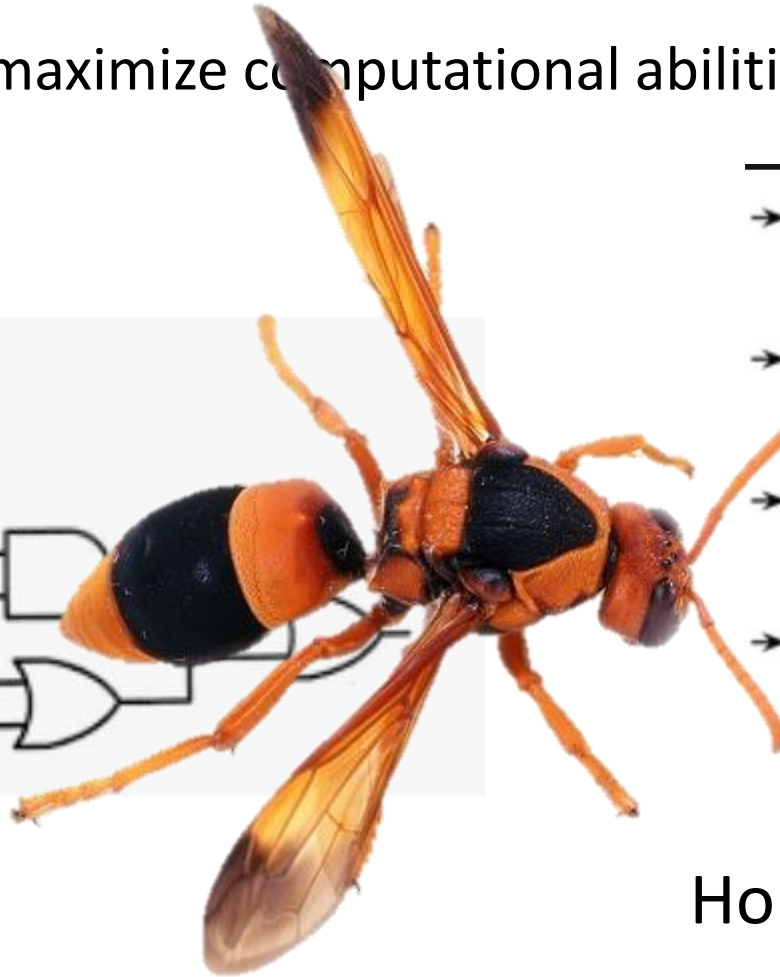Fig. 3: Trail pheromones found in Dufour glands, and Dufour gland substances peculiar to *Crematogaster*.

The interaction network

Smart connectivity can help maximize computational abilities.
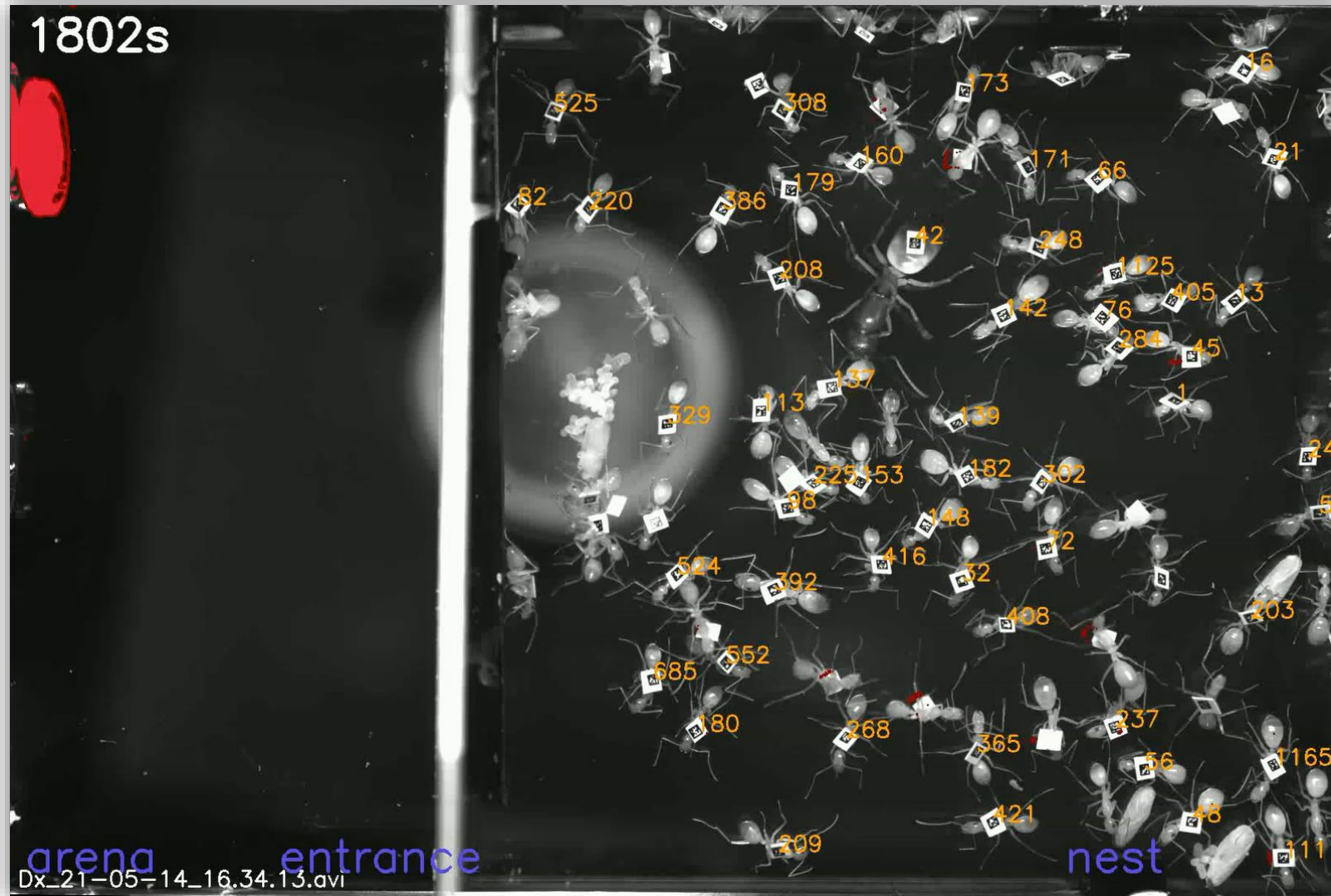

Logic gate network

Hopfield network

The interaction network

The interaction network

Rumor spread – without structure

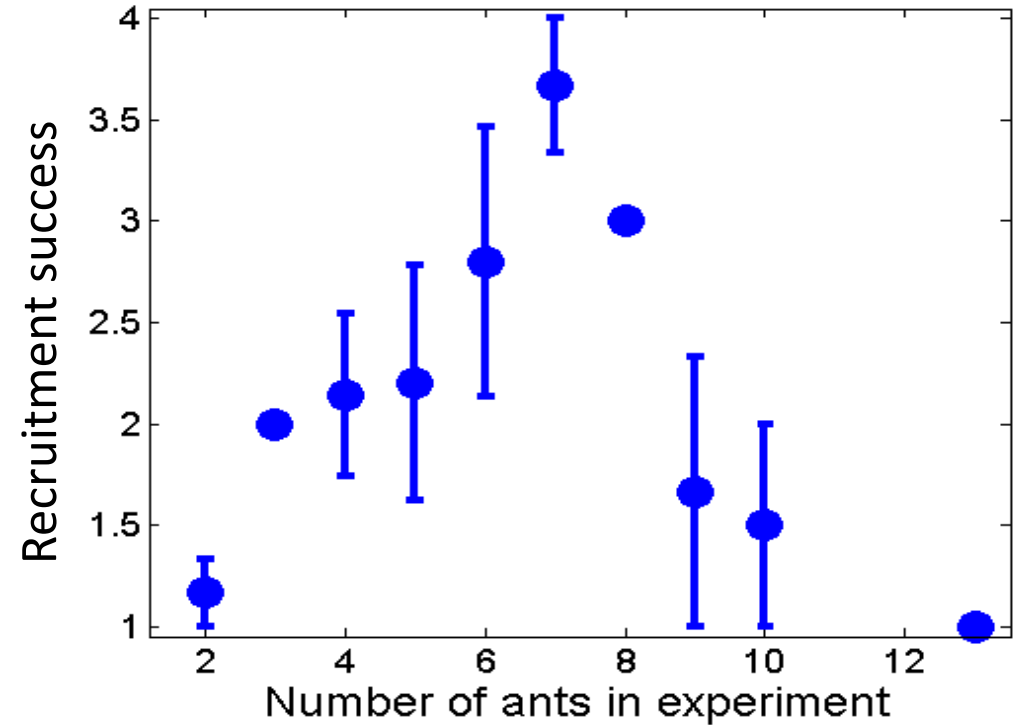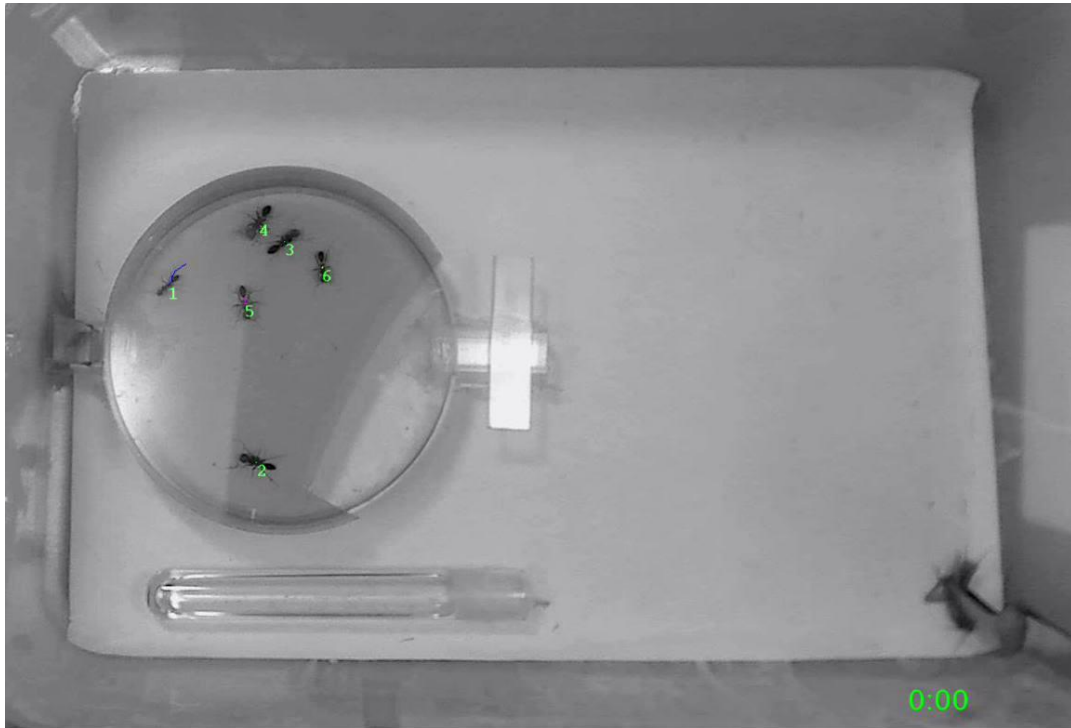With perfect communication:

Of course!

$T \sim \log(N)$.

Limited communication:

- Finite message repertoire S
- Passive communication (parallel PULL): $T \sim N$.
    =Choose other agent read its message.
- Noisy communication:
    Each message can be confused with
    any other with probability $\delta > 0$.

Boczkowski, Natale, Feinerman, Korman. PLoS Comp Biol, 2018.

The interaction network

Razin, Eckmann, Feinerman. Roy. Soc. Interface, 2013.
Boczkowski, Natale, Feinerman, Korman. PLoS Comp Biol, 2018.

Interacting individuals

Back to brain size

An ant colony with $3*10^5$ ants has $3*10^{10}$ neurons.
How best to deploy them?

Micro-wasp 7400 neurons

Ant 250,000

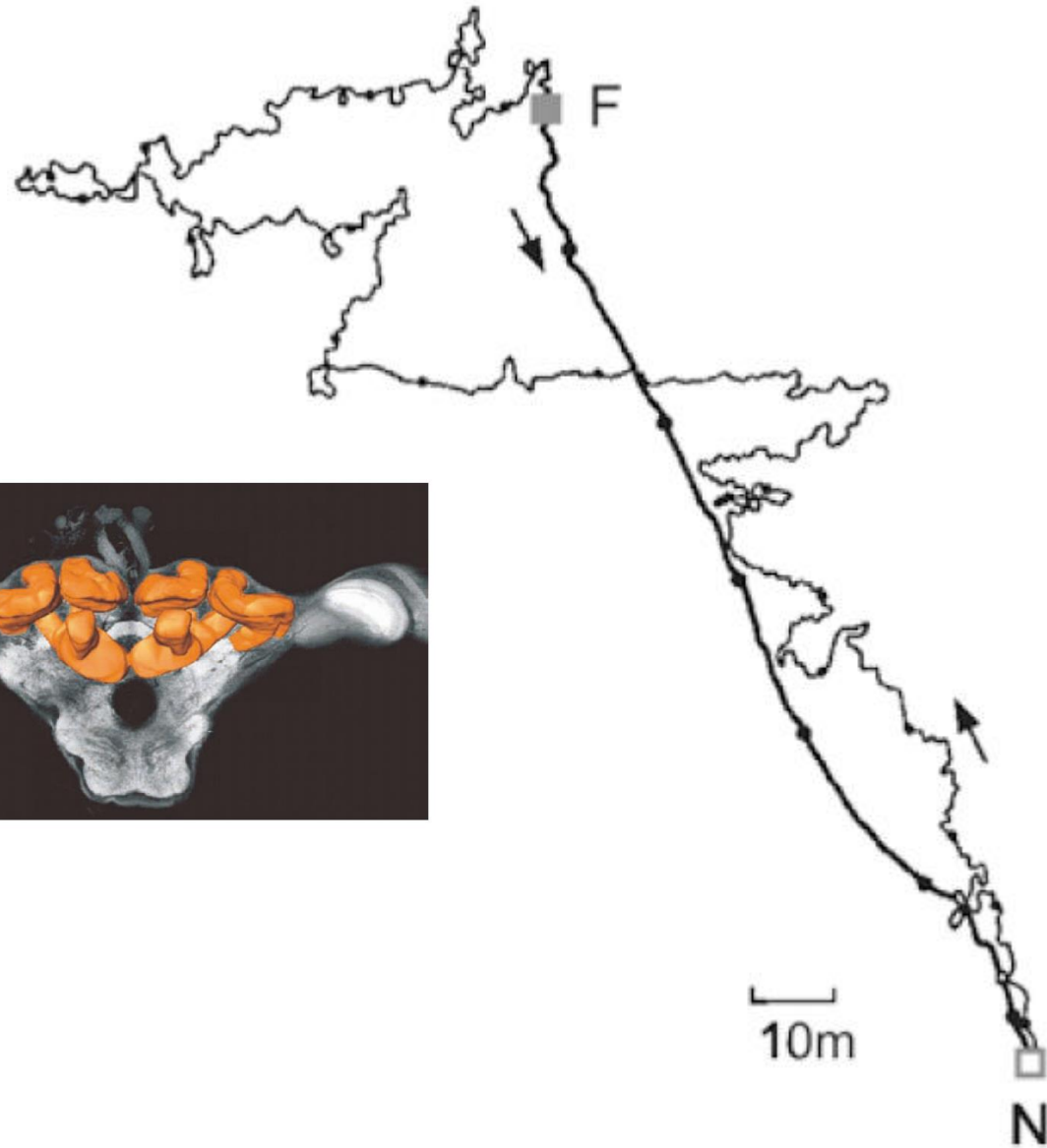Chimpanzee $3*10^{10}$

Back to brain size

Desert ant

F

10m

N

Tool use

Individuals and groups often face similar goals

Cooperative transport

to nest

0.5X

to nest

Longhorn crazy ants.

Feinerman, Pinkoviezky, Gelblum, Fonio, Ghosh, & Gov, Nat Comm 2015, PNAS 2016, *Nat Phys*, 2018.

Evolution of cooperative transport

- eagle spread

- leaders behave as solitary ants. **Capable navigators.**

- Followers need to evolve a capability for "letting go"

Does this work in more complex situations?

Umwelt (self centered world)

Jakob von Uexküll

FIG. 9a
A village street, photograph

A house fly

FIG. 9c
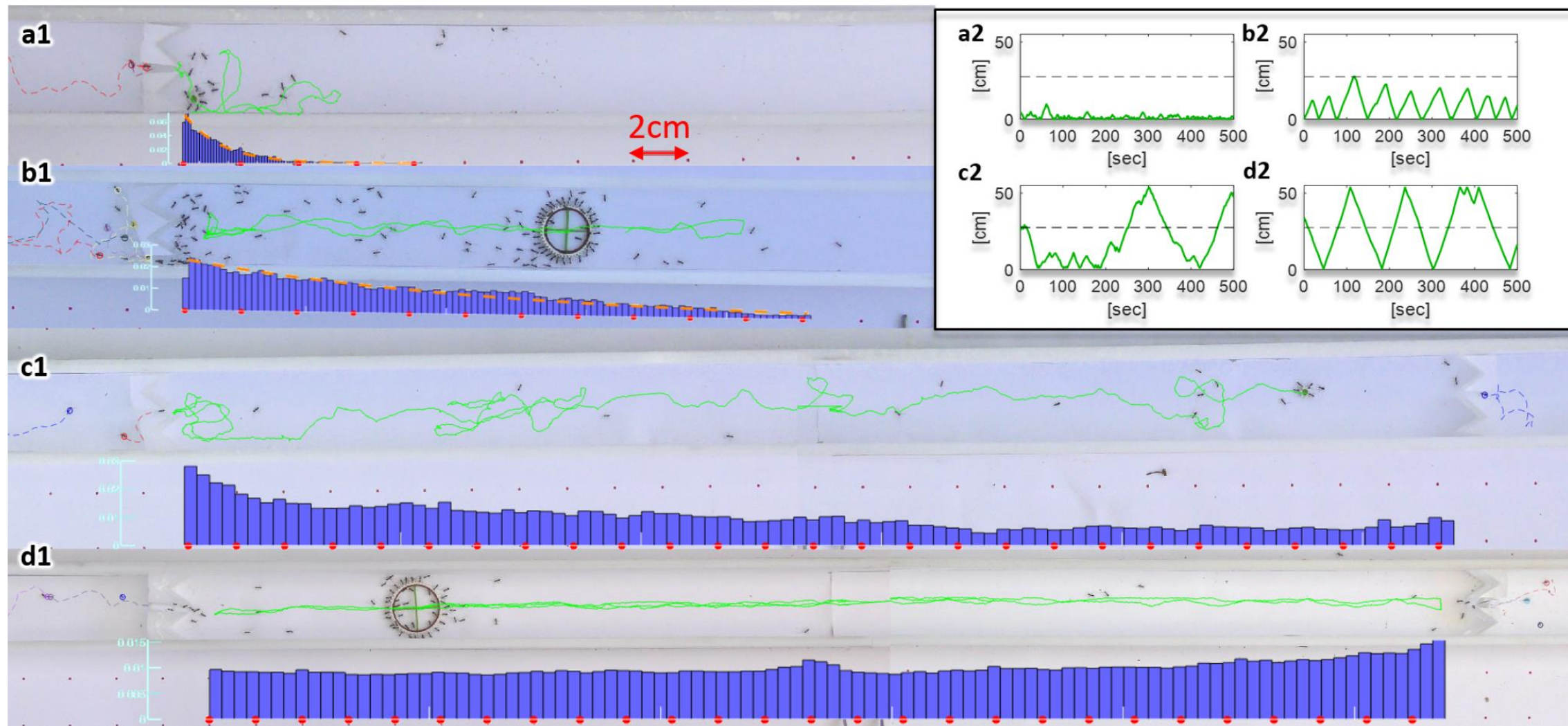The same village street as seen by a fly

How well does the *umwelt* of ant coincide with requirements of colony?

How well does the *umwelt* of ant coincide with requirements of colony?

To nest

Information conflict

Individual vs. group: a spectrum