Summary of talk at BDA 2014:
The ecology of collective behavior
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Ant colonies operate without central control, regulating their behavior using local interactions. Reviewed in:

> D M Gordon, 2010. Ant Encounters: Interaction Networks and Colony Behavior. Primers in Complex Systems. Princeton Univ Press.

Ant colonies use local interactions to solve many different kinds of environmental challenges.

Diverse ecological conditions give rise to diverse distributed algorithms. Are there trends in how interactions are used to solve particular environmental problems?

> Gordon, D.M. 2014 The ecology of collective behavior. **PloS Biology** DOI: 10.1371/journal.pbio.1001805 (http://www.plosbiology.org/article/info:doi/10.1371/journal.pbio.1001805)

For example, colonies use local interactions as a cue to density.

> Gordon, D. M., R. E. H. Paul, and K. Thorpe. 1993 What is the function of encounter patterns in ant colonies? **Animal Behaviour** 45:1083-1100. (http://web.stanford.edu/~dmgordon/old2/Gordon_etal1993.pdf)

which helps them solve the problem of collective search.

> Gordon, D. M. 1995. The expandable network of ant exploration. **Animal Behaviour** 50:995-1007 (http://web.stanford.edu/~dmgordon/old2/Gordon1995Network.pdf)

Local interactions also help regulate *task allocation*, adjusting colony effort in various tasks to current conditions. Interactions regulate which ant does which task, and also changes in activity level: whether ants are active performing a task right now.

> (e.g. Gordon, D. M. 1996. The organization of work in social insect colonies. **Nature** 380:121-124. http://web.stanford.edu/~dmgordon/old2/Gordon1996Organization.pdf)

Regulation of task allocation using interactions is a distributed process.

> Gordon, D. M. B. Goodwin, and L. E. H. Trainor. 1992 A parallel distributed model of ant colony behaviour. **Journal of Theoretical Biology** 156:293-307. (http://web.stanford.edu/~dmgordon/old2/GordonGoodwin1992.pdf)

An important form of interaction is antennal contact. In the course of an antennal contact, one ant can smell the cuticular hydrocarbon profile of another. In experiments with ant mimics, glass beads coated with hydrocarbons, we have learned that the crucial information is simply the rate of contact.

Greene, M.J. and D.M. Gordon. 2003.Cuticular hydrocarbons inform task decisions. **Nature** 423:32. (http://web.stanford.edu/~dmgordon/old2/greeneandgordon2003.pdf)

Greene, M.J. and D.M. Gordon. 2007 Interaction rate informs harvester ant task decisions. **Behavioral Ecology** 18:451-455. http://web.stanford.edu/~dmgordon/old2/Greene_Gordon2007.pdf)

Harvester ants use interaction rate to regulate foraging. Outgoing foragers do not leave the nest until they have sufficient contacts with returning foragers with food.

2011. Gordon, D.M., A. Guetz, M.J. Greene, and S. Holmes. Colony variation in the collective regulation of foraging by harvester ants. **Behavioral Ecology** 22(2): 429-435 (http://web.stanford.edu/~dmgordon/old2/Gordonetal2011.pdf)

2013. Pinter-Wollman, N., Bala A., Merrell A., Queirolo J., Stumpe M.C., Holmes S., D. M. Gordon. Harvester ants use interactions to regulate forager activation and availability. **Animal Behaviour** 86(1):197-20 (http://web.stanford.edu/~dmgordon/articles/other/animal-behaviour-86/Animal%20Behaviour%2086%20(2013)%201-11.pdf)

2013. Greene, M.J., Pinter-Wollman, N., and D.M. Gordon. Interactions with combined chemical cues inform harvester ant foragers' decisions to leave the nest in search of food. **PLoS ONE** 8(1):e52219. doi:10.1371/journal.pone.0052219 (http://www.plosone.org/article/info%3Adoi%2F10.1371%2Fjournal.pone.0052219)

Operating costs are high in the desert because water is scarce. The use of interactions as positive feedback helps colonies to manage the tradeoff between losing water while foraging and obtaining water from the seeds they collect.

We modelled the flow of outgoing foragers in response to the rate of forager return, and noticed the analogy with TCP/IP (Anternet).

2012. Prabhakar, B., Dektar, K.N., and D.M. Gordon. The regulation of ant colony foraging activity without spatial information. **PLoS Computational Biology** 8(8):e1002670. DOI:10.1371/journal.pcbi.1002670 (http://www.ploscompbiol.org/article/info:doi/10.1371/journal.pcbi.1002670)

We are currently developing integrate-and-fire models to model individual decisions.

Colonies differ in how they regulate foraging using interaction rate.

(Gordon et al 2011 Behav Ecol as above: http://web.stanford.edu/~dmgordon/old2/Gordonetal2011.pdf)

Using genetic variation to identify parent-offspring pairs, we were able to evaluate colony reproductive success.

> 2013. Ingram, K.K., Pilko A., Heer J., and D.M. Gordon. Colony life history and lifetime reproductive success of red harvester ant colonies. **Journal of Animal Ecology**. doi: 10.1111/1365-2656.12036 (http://web.stanford.edu/~dmgordon/articles/doi/10.1111-1365-2656.12036/IngramGordon2013.pdf)

Natural selection is shaping how colonies use local interactions to regulate foraging.

> Gordon, D.M. 2013 The rewards of restraint in the collective regulation of foraging by harvester ant colonies. **Nature**. DOI: 10.1038/nature12137 (http://web.stanford.edu/~dmgordon/articles/doi/10.1038-nature12137/nature12137.pdf)

In different environments, interaction networks are used to solve different ecological problems. For example, in the tropical forest, operating costs are low, and one arboreal species uses ongoing circuits that are limited by negative interactions.

> Gordon, D.M. 2012. The dynamics of foraging trails in the tropical arboreal ant *Cephalotes goniodontus*. **PLoS ONE** 7(11):e50472. doi:10.1371/journal.pone.0050472 (http://www.plosone.org/article/info%3Adoi%2F10.1371%2Fjournal.pone.0050472)