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Reading 6: Self-Assembly - Thermoregulation

Paper 1: Coordinated Movements Prevent Jamming in an Emperor Penguin Huddle, PLOS One, 2011

Paragraph or two on any/some of the following points:
What do you feel the main contribution of this paper is? What's the essential principle that the paper exploits? What did you find most interesting about this work?

While humans have developed technologies of various kinds to face harsh winters, the Emperor penguins use their bodies themselves to create a collective heating system for winters that are as cold as it gets. Researchers have probably observed the penguin huddles since a long time ago, but with this paper, we now know that penguins do the wave to keep warm. As penguins move in from the rear, the penguins in the huddle take small steps en masse to keep the tightly formed group stay together. The continuous large-scale reorganization of the huddle is important to give individual penguins a chance to spend time in the huddle center where it's warmest before they have to be peripheral penguins. Interestingly, the authors liken these small steps (5-10cm every 30-60s) to temporary fluidization and the propagation of the penguin waves to that of sound waves in gas or fluid. These waves made of small, regular steps of individual penguins seem to serve three purposes: to keep the pack as dense as possible, to allow forward motion of the whole group and allow small huddles to merge like magnetic domains, and to give rise to macroscopic reorganization. I'm fascinated that individual penguins don't force their way in or out of the huddle, but by just contributing to the collective waves, they harmoniously balance their time spending inside or on the periphery of the huddle. The author raise the point that I am much curious about: whether crowds of humans also display similar undulations, and whether our human waves are as peaceful and united as the penguin waves. We have something to learn from Emperor penguins!

Short answers to the questions below
One major strength of the paper

The authors look at the penguin huddles from a physics perspective and can see striking analogous physical phenomena in this Emperor penguin behavior. As the authors stated, these observations are an unexpected intersection of physics and biology. I think this gives a great start to modelling this phenomenon as an emergent property of individual agents who follow a set of rules and don't necessarily have information about the collective formation but effectively contribute to it.

One weakness of this paper

Something only briefly mentioned but very interesting is the hexagonal packing arrangement of neighboring penguins inside the huddle and how this configuration is an equilibrium. I'd like to know about this! Because I am thinking about honey bees, I wonder if hexagon is the shape of choice for similar reasons between these two animals. If I think like a honey bee (who seems to be an excellent geometer), I'd wonder what shape gives me the most space to store my honey, but requires the least amount of wax. A circle would leave gaps between cells: wasted space! Then I'd calculate areas of some other shapes: squares, triangles, and hexagons. I'd find that hexagons give the most storage space without gaps in between the cells. I'd love to know more how the penguins inside the huddle form this hexagonal arrangement, what that arrangement actually looks like, and perhaps also conjectures on why they opt for this shape.

Short discussion of
One question or future work direction you think should be followed. Or some insight/connection you think is interesting to pursue.

Now that the authors have these observations of the penguins and ideas on how condensed matter physics concepts may be conceptual/computational models of this huddling behavior, I think the next step could to be develop a model for this collective behavior, in the similar fashion as other papers we have read so far: A set of rules that the individual agents follow and the characteristics of the emergent collective.

Like the authors, I would like to study the trigger of the traveling waves: whether they're initialized by one or a few penguins and whether that indicate a hierarchy of some kind in Emperor penguin society.

Paper 2: Collective thermoregulation in bee clusters, R. Soc. Inter., 2013

Paragraph or two on any/some of the following points:
What do you feel the main contribution of this paper is? What's the essential principle that the paper exploits? What did you find most interesting about this work?

Like the Emperor penguins, honey bees also collectively use their bodies as an air conditioning system. For the bees, huddling together is not only to keep warm but to keep the swarm together as they leave a hive to create their own. In this paper, the authors present observations and a model of how a honey bee cluster maintains its core temperature in response to changes in ambient temperature. The authors mention previous models of this collective behavior and how these models, like the authors', treat the bee clusters as a mantle-core structure. But these models cannot explain several aspects of the experimental observations: high core temperature persists at low ambient temperatures, cluster don't break up at moderate to high temperatures. Thus, the authors refine previous models and present one that is consistent with observations, showing how swarm cluster thermoregulation forms from the collective behavior of bees that only have local info but can propagate info about the environmental temperature throughout the swarm.

The model have the following features: 1) the cluster behavior results from collective behavior of the bees who individually act on local info, 2) the cluster forms a stable mantle-core structure, 3) the cluster expands at high ambient temperature and contracts at low to maintain the core temperature.

Short answers to the questions below
One major strength of the paper

I appreciate that the authors clearly state their model features and assumptions to allow for model assessment and future directions: 1) packing fraction of bees and air temperature are the only 2 independent fields and they determine the bee body temperature and metabolism (which the authors define as a function of local air temperature), 2) the cluster is an active porous structure, 3) cold bees want to huddle densely while hot bees don't want to, 4) fixed number of bees in cluster and cluster is axisymmetrical with spherical boundaries.

One weakness of this paper

While reading, I only had many questions regarding the assumptions of the authors' models, but they've addressed them very well and are conscious of their model's assumptions that may not match reality., such as those about the bees' metabolism or finite and constant size of the bee cluster. Overall, I cannot have actual criticisms for this paper! One thing extraneous that I'd love to know though is whether there's a difference in the bees that form the cluster versus the bees that go scout for new hive sites, and of course, where the queen is in this cluster and whether she might regulate it at all (would it be a centralized system at the point?).

Short discussion of

One question or future work direction you think should be followed. Or some insight/connection you think is interesting to pursue.

How is the total radius (R) of the mantle-core structure measured?

Does the model assume that the cluster is a circular shape? How well does this match observations?

In reality, is the number of bees in the cluster constant as the model assumes?

I love the authors' idea that we can apply different temperatures to the surface and the interior of the cluster to see if the cluster can be tricked into overpacking and overheating its core. This should definitely be a follow-up study!