1. INTRODUCTION

What is active matter?
Agents that convert energy from their environment into autonomous motion.

Why is active matter important?
Active matter defies the laws of thermodynamics by being able to spontaneously produce useful work [1].

Passive matter cannot turn a ratchet.
E. coli can turn a ratchet, producing useful work [2].

How can active matter be used?
Active matter could be used to self-power machines. The most promising candidate for these ‘active matter engines’ is E. coli.

Designing active matter engines requires a better understanding of how heat is transported in an active matter system.

2. RUN-AND-TUMBLE E. COLI

How do E. coli move?
E. coli perform ‘run-and-tumble’ motion, consisting of straight-line motion interspersed with random changes in direction. E. coli move in this way to search for food (move up a concentration gradient).

Run-and-tumble heat transport is captured by a 1D model composed of different physical processes.

3. MODEL

Each process is a term in a governing equation for the model.

Run and tumble:
- Rate of change of particle’s probability to be at a particular position.

\[
\frac{\partial P}{\partial t} = \begin{cases} \text{Collisions} & \text{Collisions slow the rate of heat transfer.} \\
\text{Tumbling} & \text{Particles transfer heat from a hot object to a cold object.} \\
\text{Heat transfer} & \text{In 1D, tumbling switches between leftwards and rightwards motion.} \\
\text{Diffusion} & \text{Random Brownian motion of particles.} \end{cases}
\]

4. FIELD THEORY

Why field theory?
Field theory is used to build a solution to our model from successively adding each layer. The long-winded mathematical equations for each process are then ‘disguised’ by intuitive diagrams. Working with these diagrams simplifies the required calculations.

Solving the layer cake using field theory

The known solution of the base layer is represented with a line.

The physical process of the next layer is introduced and its mathematics is replaced with a more intuitive diagram.

The full solution is obtained simply from drawing all possible diagrams!

5. CONCLUSION

We developed a model which ‘reinvents thermodynamics’ for active matter and, through a novel field-theoretic reimagining of heat transport, solved part of the formidable equation that governs the model. Future work is aimed at solving the entire model to provide the theoretical foundation for the design of active matter engines.

REFERENCES