Oxford Mathematics Alphabet

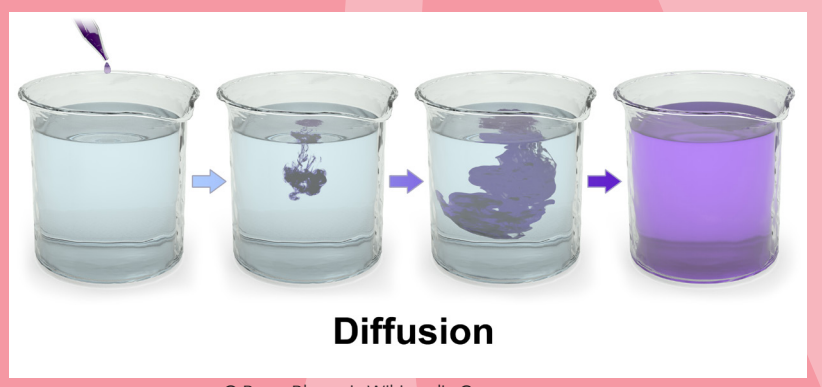
UNIVERSITY OF OXFORD
Mathematical Institute

M *is for* morphogenesis

How did the leopard get its spots? How did the zebra get its stripes?

One theory behind nature's beautiful patterns (known as morphogenesis, meaning "creation of form") stems from a highly counter-intuitive idea concocted in 1952 by Alan Turing.

Turing's theory depends on a couple of factors. Firstly, we need two interacting populations called morphogens. Critically, Turing assumed that the reactions are "stable", which simply means that the morphogens would settle into a fixed state if well-mixed. The second component of Turing's theory assumes that the morphogens are able to diffuse around their spatial domain. Diffusion is the random motion of particles as they bounce off one another. Over time, diffusion tends to homogenize everything - the opposite of forming patterns.



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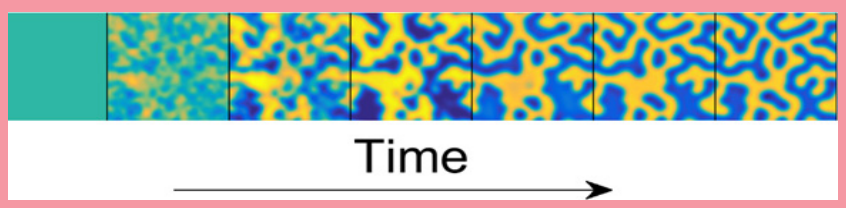
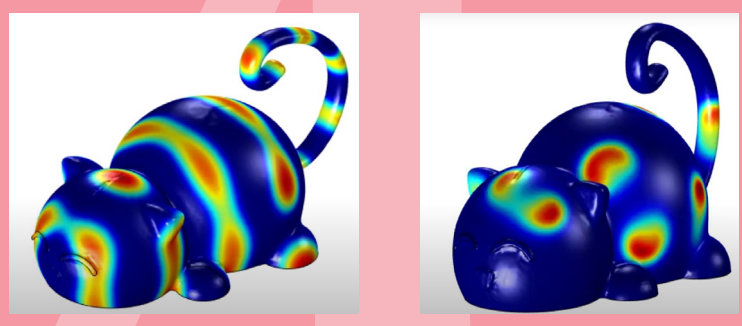
Neither of Turing's ingredients produces patterns alone. Moreover, one might think that they would actively work against pattern formation. However, Turing noticed that if you chose the right stable biochemical interactions and allowed them to diffuse at different rates, then patterns could not only be sustained, but appear spontaneously.



Turing's theory of morphogenesis is incredibly powerful, as it offers a whole range of different patterns. The labyrinthine patterns seen above, as well as the spots and stripes seen below, all arise from the same model, under small adjustments to the parameter values.



These ideas have the potential to explain mechanisms underlying human development. For example, you start out as a highly homogeneous spherical egg, yet once the egg is fertilised you develop into your highly heterogeneous body, with arms, legs, fingers and toes.

We aren't there yet, but as Turing once said,

"*We can only see a short distance ahead, but we can see plenty that needs to be done.*"

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