Finger revival and reconnections near breakthrough in unstable growth processes

Stanisław Żukowski[1,2], Annemiek Johanna Maria Cornelissen[2], Stéphane Douady[2], Piotr Szymczak[1]

[1] Institute of Theoretical Physics, Faculty of Physics, University of Warsaw, Warsaw, Poland
[2] Laboratoire Matière et Systèmes Complexes (MSC), UMR 7057, CNRS & Université Paris Cité, Paris, France
s.zukowski@uw.edu.pl

Transport networks, such as vasculature or river networks, provide key functions in organisms and the environment. They often emerge as a result of unstable growth processes, in which growing branches compete for the available flux. This leads to effective repulsion between the branches and screening of the shorter ones. We show that a striking transition in growth dynamics takes place as the leading branch reaches the boundary of the system. The shorter branches revive then and grow toward the leading one forming loops. These effects are found in a large variety of systems (Fig. 1b-d): dissolving fractures, viscous fingering, discharge patterns, and even growth of a gastrovascular canal network of the jellyfish *Aurelia* (Fig. 1e). The ubiquity of this process suggests the existence of a shared underlying mechanism, which we elucidate.

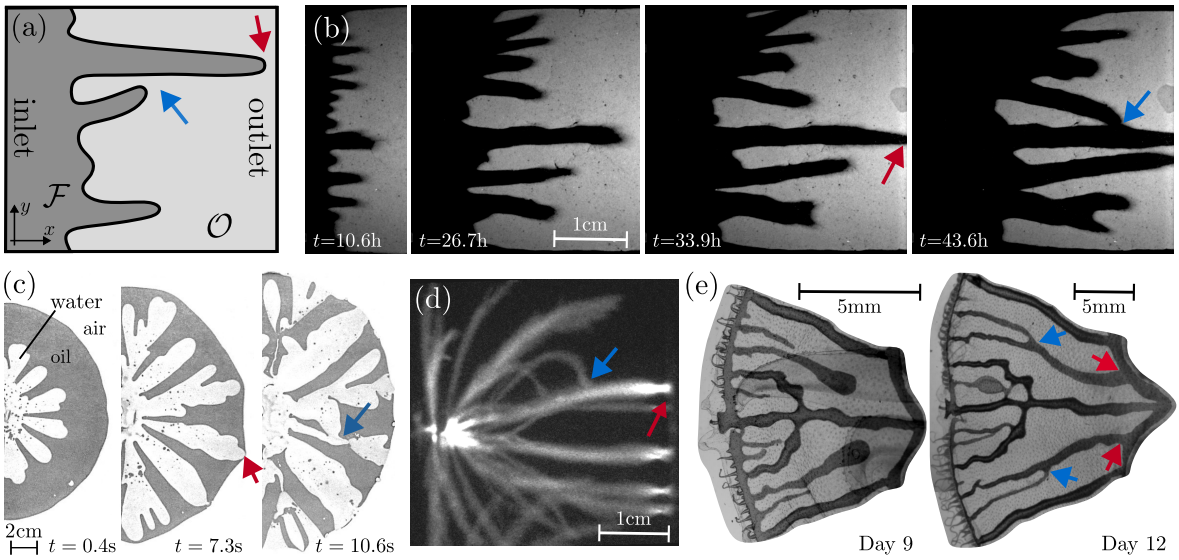

Figure 1. Systems near breakthrough in nature. (a) Each system consists of two phases: an invading phase with mobility λ_1 ($\mathcal{F}$), and a displaced phase with mobility λ_2 ($\mathcal{O}$), separated by an interface. Growth direction is from left to right. Red arrows mark places where the fingers are near breakthrough or already broke through, and blue arrows mark associated breakthrough reconnections. (b-e) Examples of breakthrough reconnection in various systems: (b) a fracture dissolution experiment in a Hele-Shaw cell, (c) viscous fingers in the Saffman-Taylor experiment, (d) streamer channels in air (photo: Sander Nijdam, Eindhoven University of Technology, by permission), (e) an octant of the jellyfish *Aurelia*, showing the gastrovascular canal network in dark gray.)

References

1. S. Żukowski, A. J. M. Cornelissen, S. Douady, P. Szymczak, Finger revival and reconnections near breakthrough in unstable growth processes, https://doi.org/10.48550/arXiv.2212.08878 (2022)