

# HELE-SHAW FLOW

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## Introduction

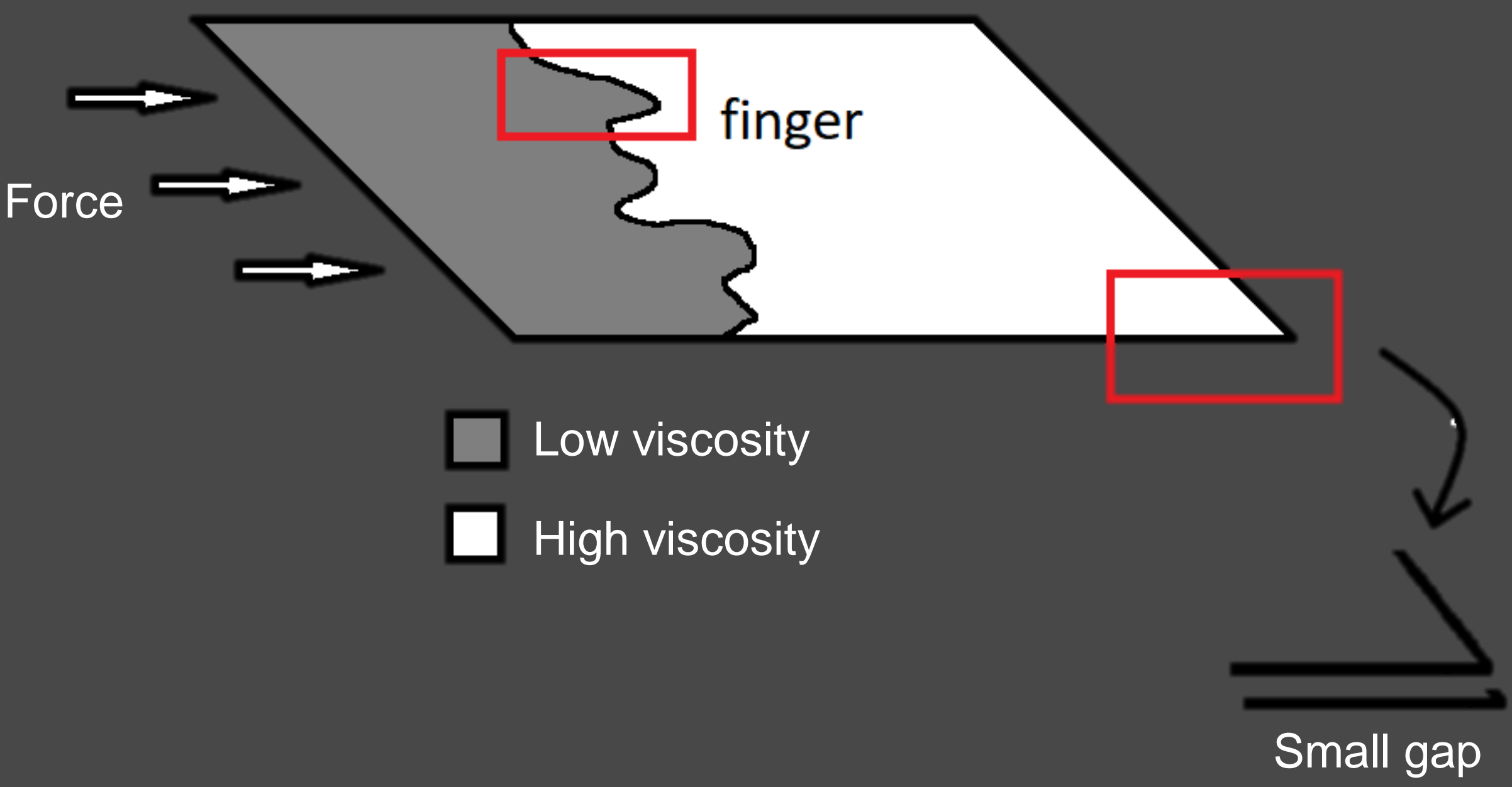


Fig. 1

## Setup

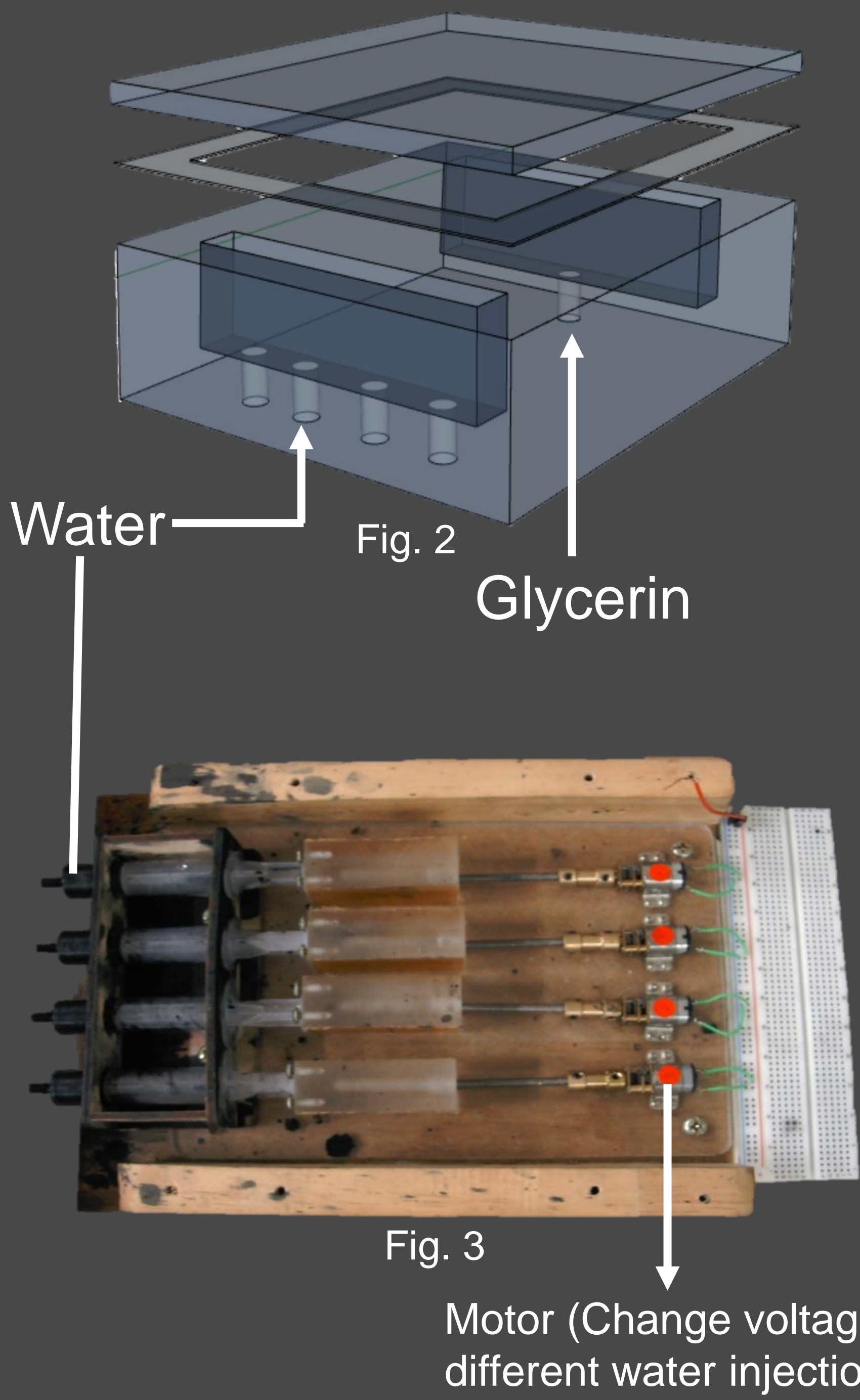


Fig. 3

## Simulation

- DLA (Diffusion-limited aggregation)

Diffusion-limited aggregation (DLA) is the process whereby particles undergoing a random walk due to Brownian motion cluster together to form aggregates of such particles. DLA can be observed in many systems such as electrodeposition, Hele-Shaw flow, mineral deposits, and dielectric breakdown.

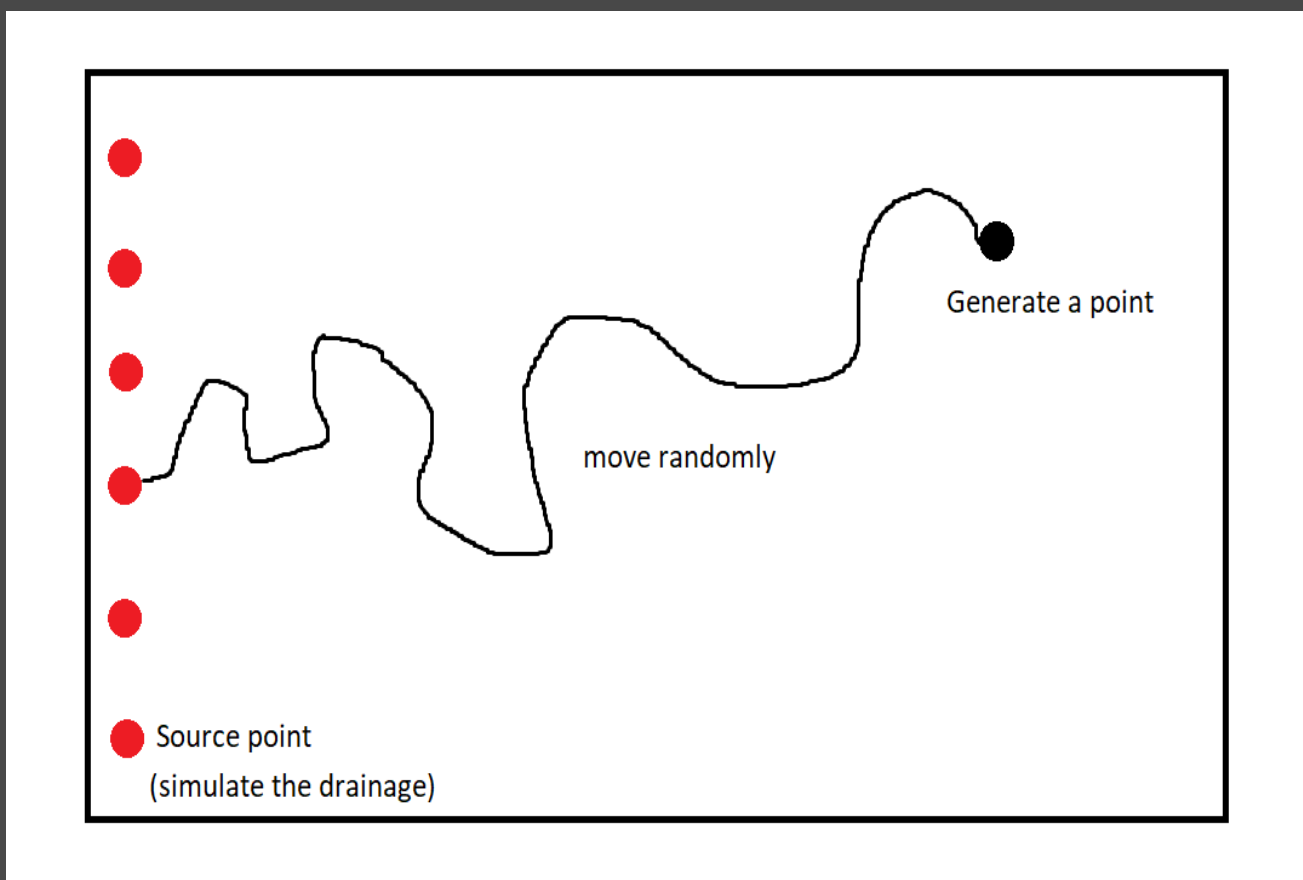


Fig. 4

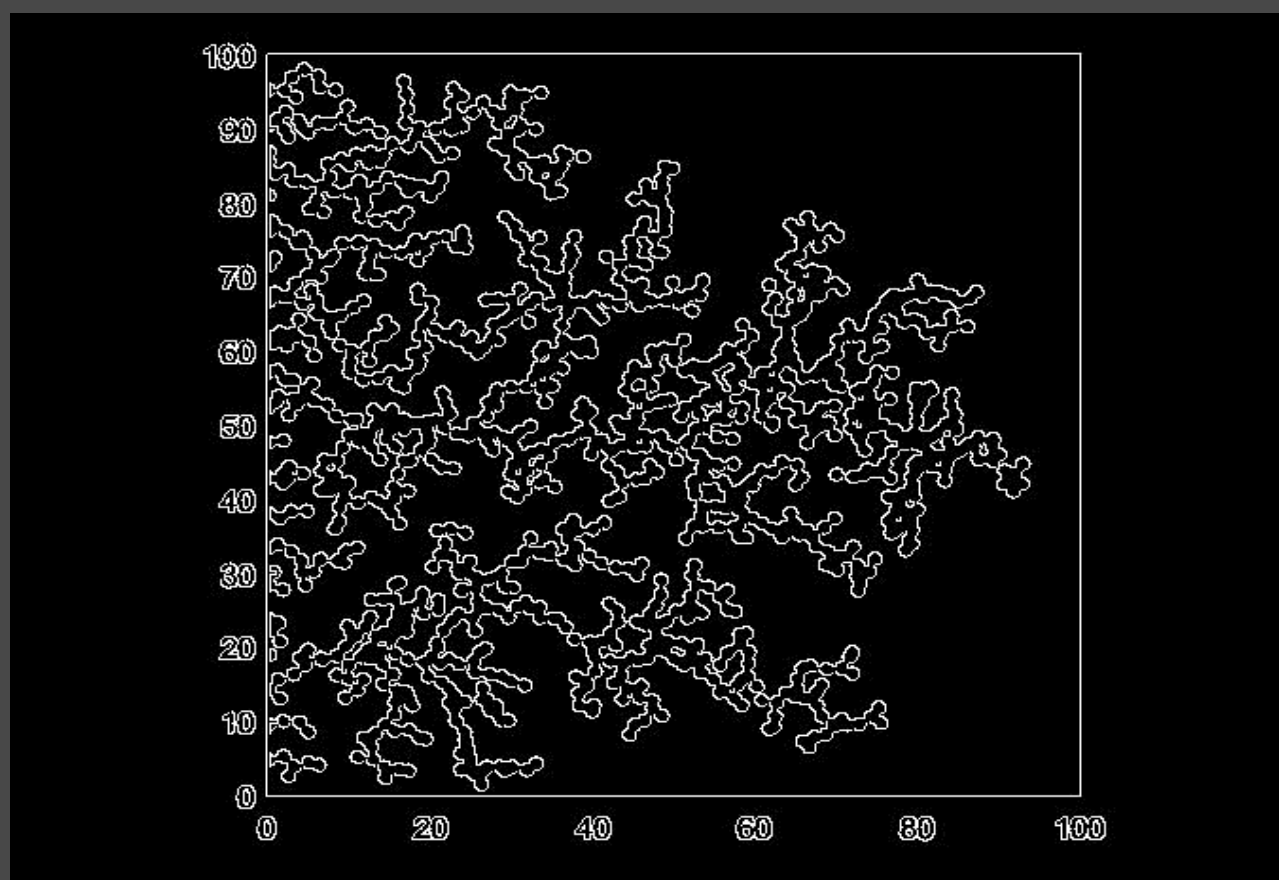


Fig. 5



Fig. 6



Fig. 7

## Analysis

- Fractal-dimension

The trend of lines in Fig 9. The fractal-dimension seems to increase and then decrease with the area of ink.

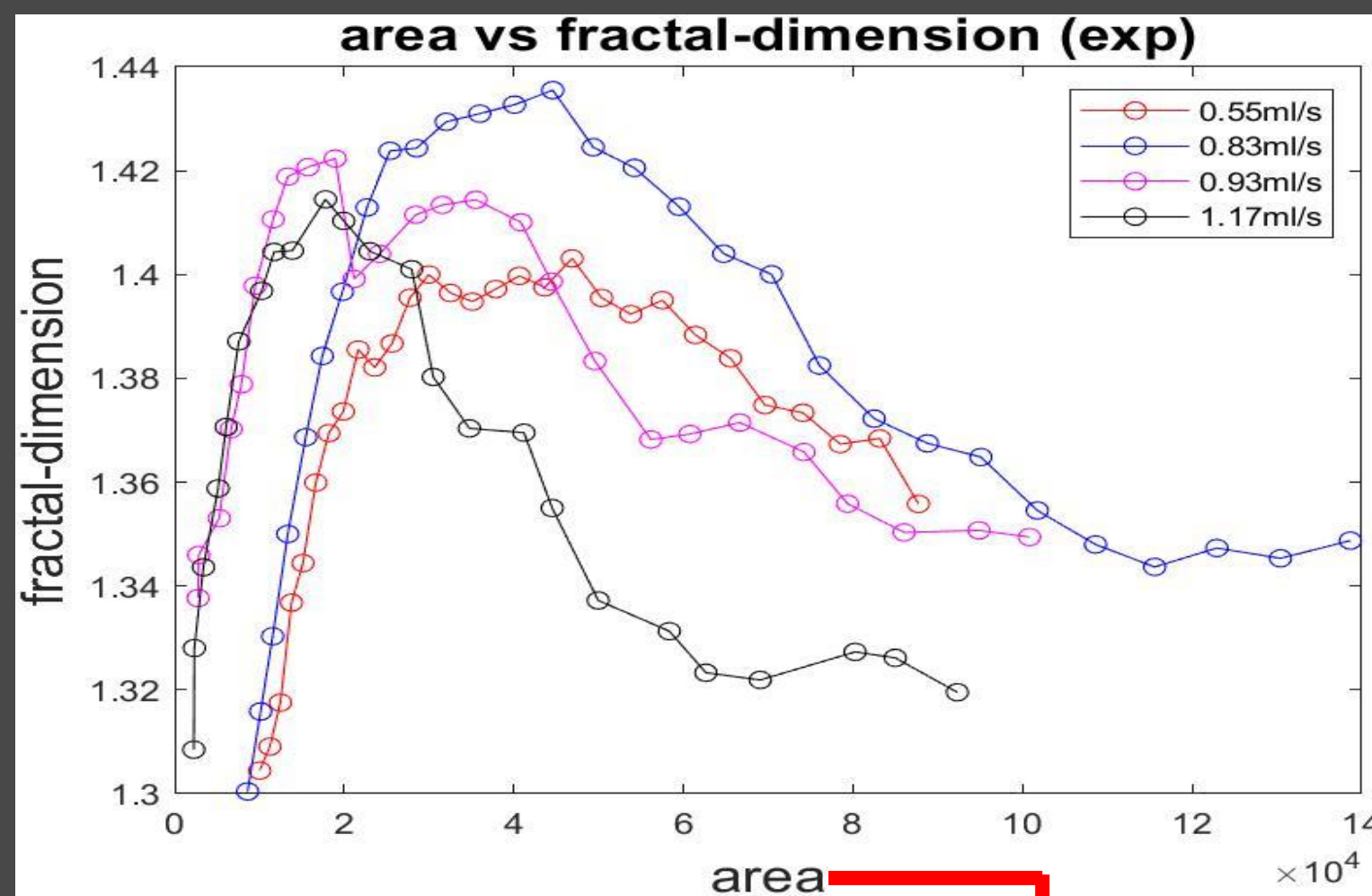
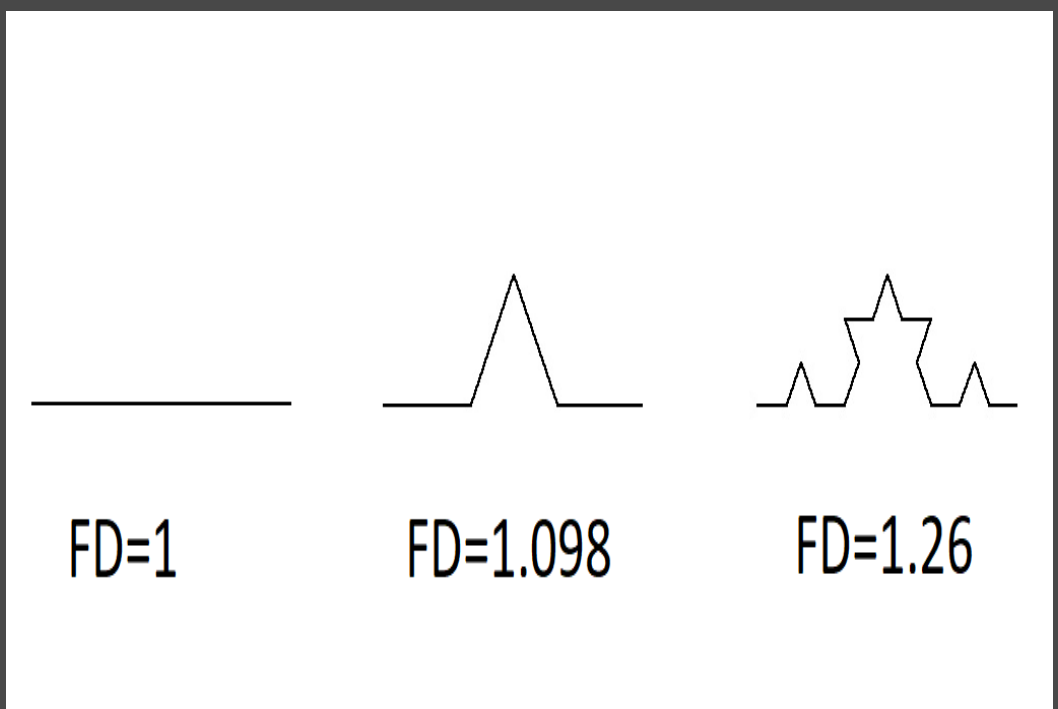


Fig. 9

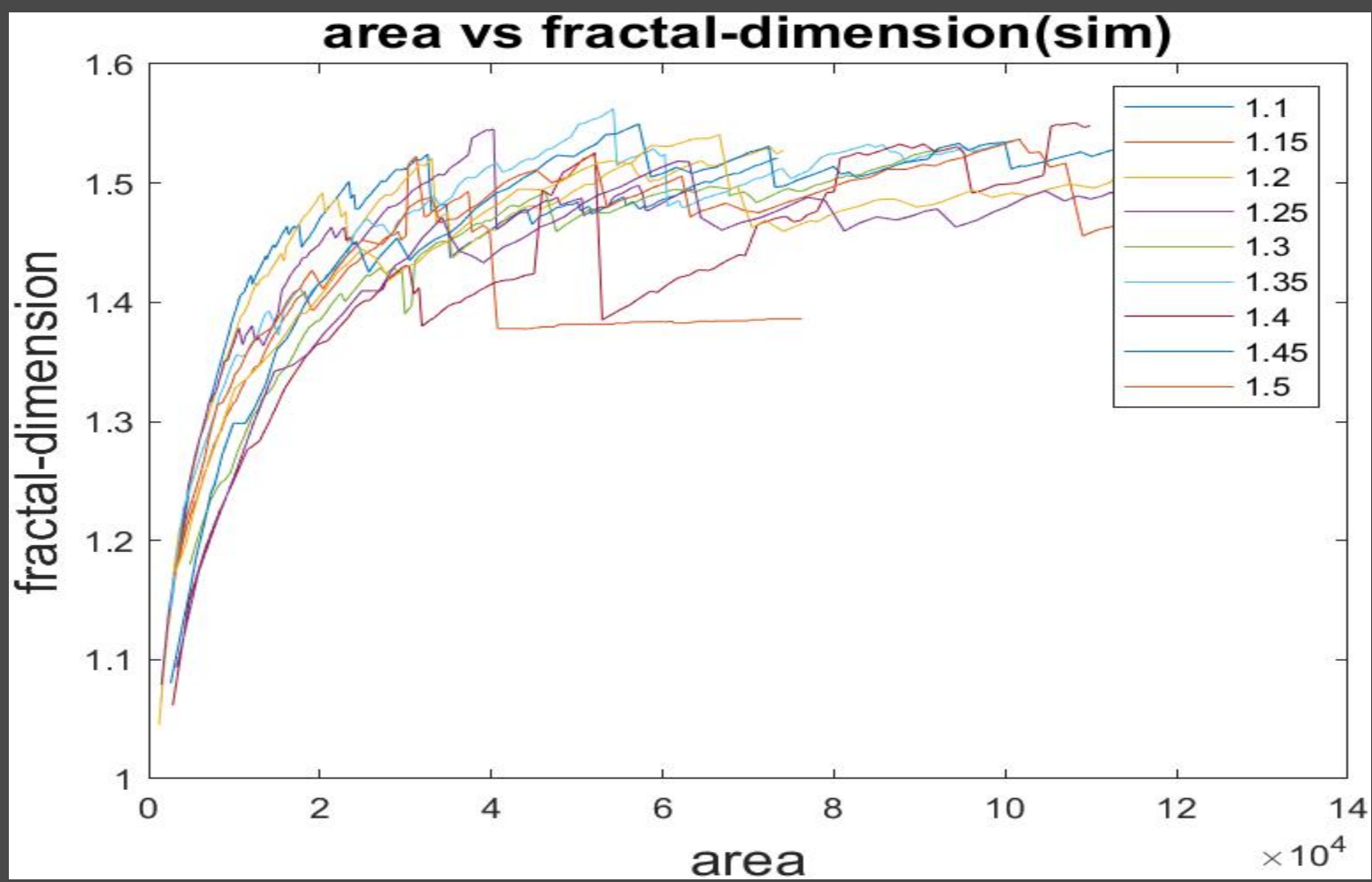


Fig. 10

- Finger number

We find that with the area of ink increase, the finger numbers divided by perimeter will decrease to a value.

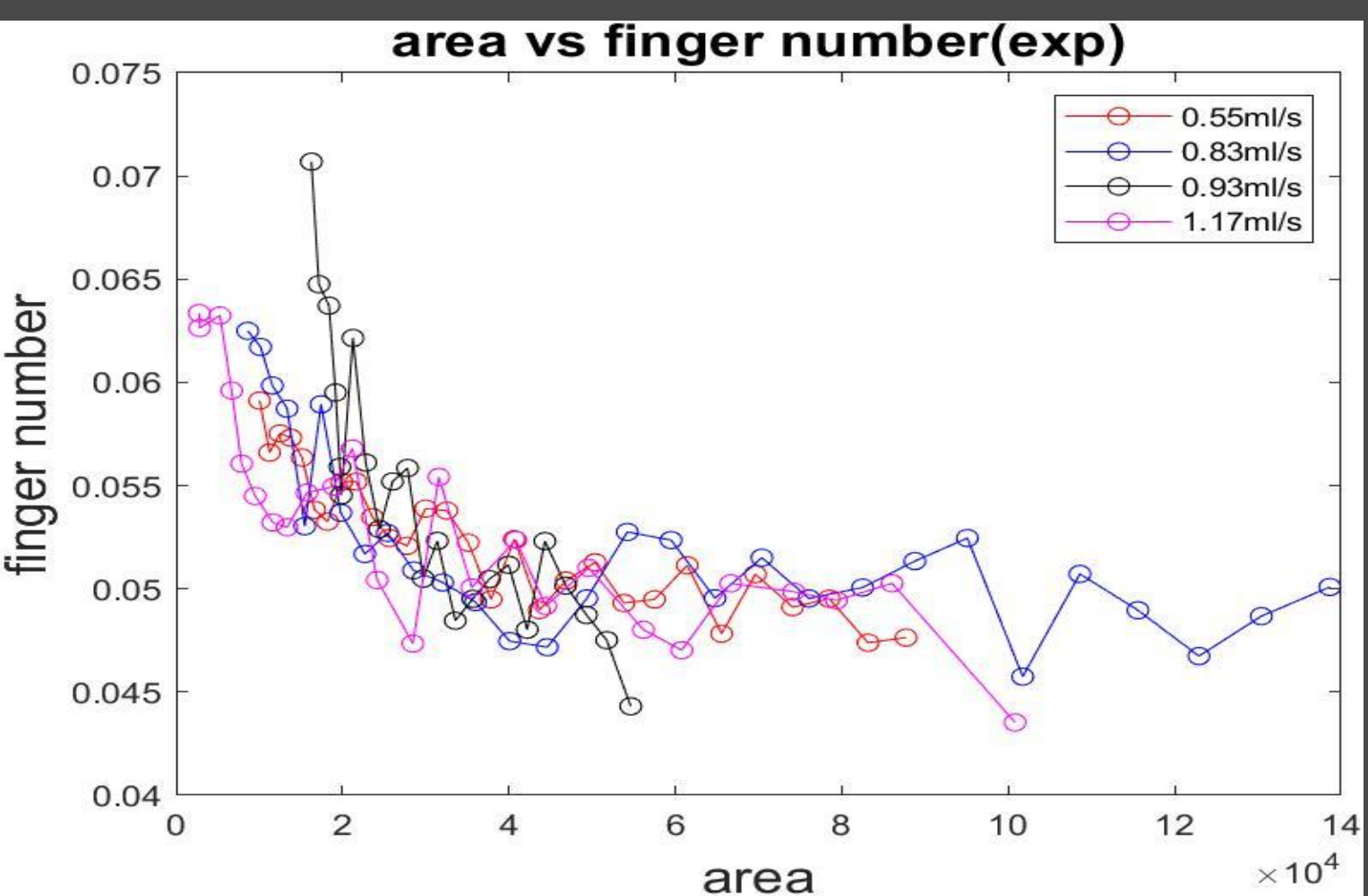
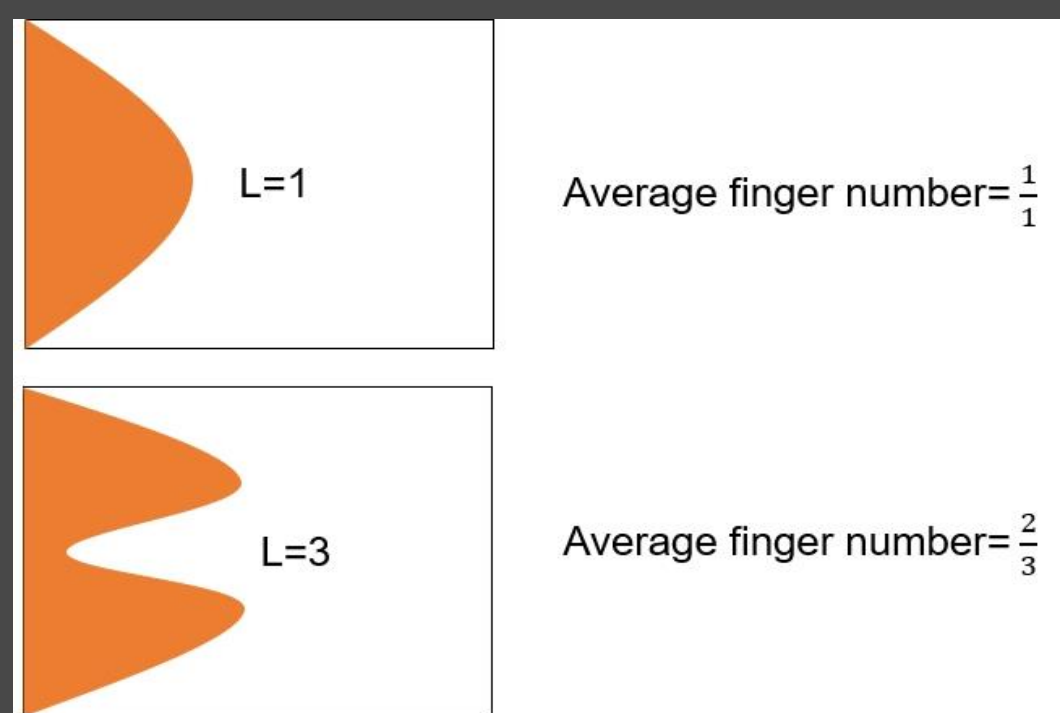


Fig. 11

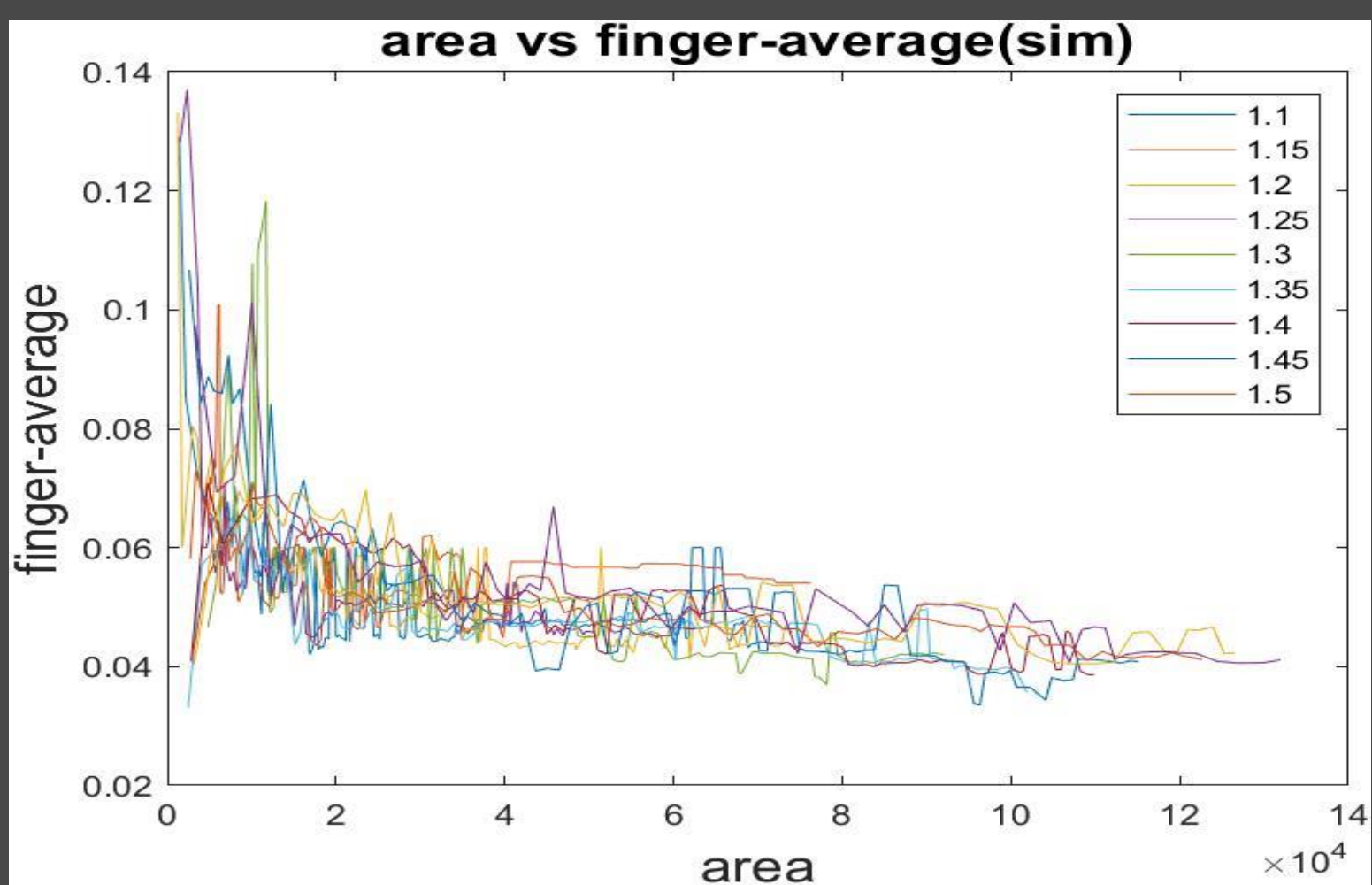


Fig. 12

## Conclusion

- Fractal-dimension closes to a fixed value. For the experiment, later frame will drop because water will stuck together.
- Finger number drops to a fixed value.
- Both experiment and simulation show no relationship between water injection rate and fractal-dimension, between water injection rate and finger number.

## Reference

[1] Witten, T. A., & Sander, L. M. (1981). Diffusion-Limited Aggregation, a Kinetic Critical Phenomenon. Physical Review Letters, 47(19), 1400–1403.

[2] CONFORMAL MAPPING METHODS FOR INTERFACIAL DYNAMICS Martin Z. Bazant<sup>1</sup> and Darren Crowdy<sup>2</sup>

[3] Davidovitch, B., Hentschel, H. G. E., Olami, Z., Procaccia, I., Sander, L. M., & Somfai, E. (1999). Diffusion limited aggregation and iterated conformal maps. Physical Review E, 59(2), 1368–1378.

[4] Complex Analysis and Conformal Mapping by Peter J. OlverUniversity of Minnesota

[5] Saffman, P. G.; Taylor, G. (1958). "The Penetration of a Fluid into a Medium or Hele-Shaw Cell Containing a more Viscous Liquid". Proceedings of the Royal Society of London, Series A. 245 (1242): 312–329.

[6] E. Somfai, R.C. Ball, J.P. DeVita, and L.M. Sander, "Diffusion-limited aggregation in channel geometry," Phys. Rev. E, 68, 020401, 2003.

[7] Simulating 2D diffusion-limited aggregation (DLA) with JavaScript

[8] Coding Challenge #34: Diffusion-Limited Aggregation