SOME ASPECTS OF POLLEN TUBE GROWTH IN A CREEPING FLOW

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THE DAVID CRIGHTON FUND

The University of Nottingham

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Introduction

The growth of a pollen tube, a protuberance of the germinating pollen grain, is vital for plant reproduction. This growth is extremely rapid and involves targeted intracellular cargo-transport, and the expansion of a pollen tube as a high-pressure vessel strongly depends on the mechanical properties of the cell wall.

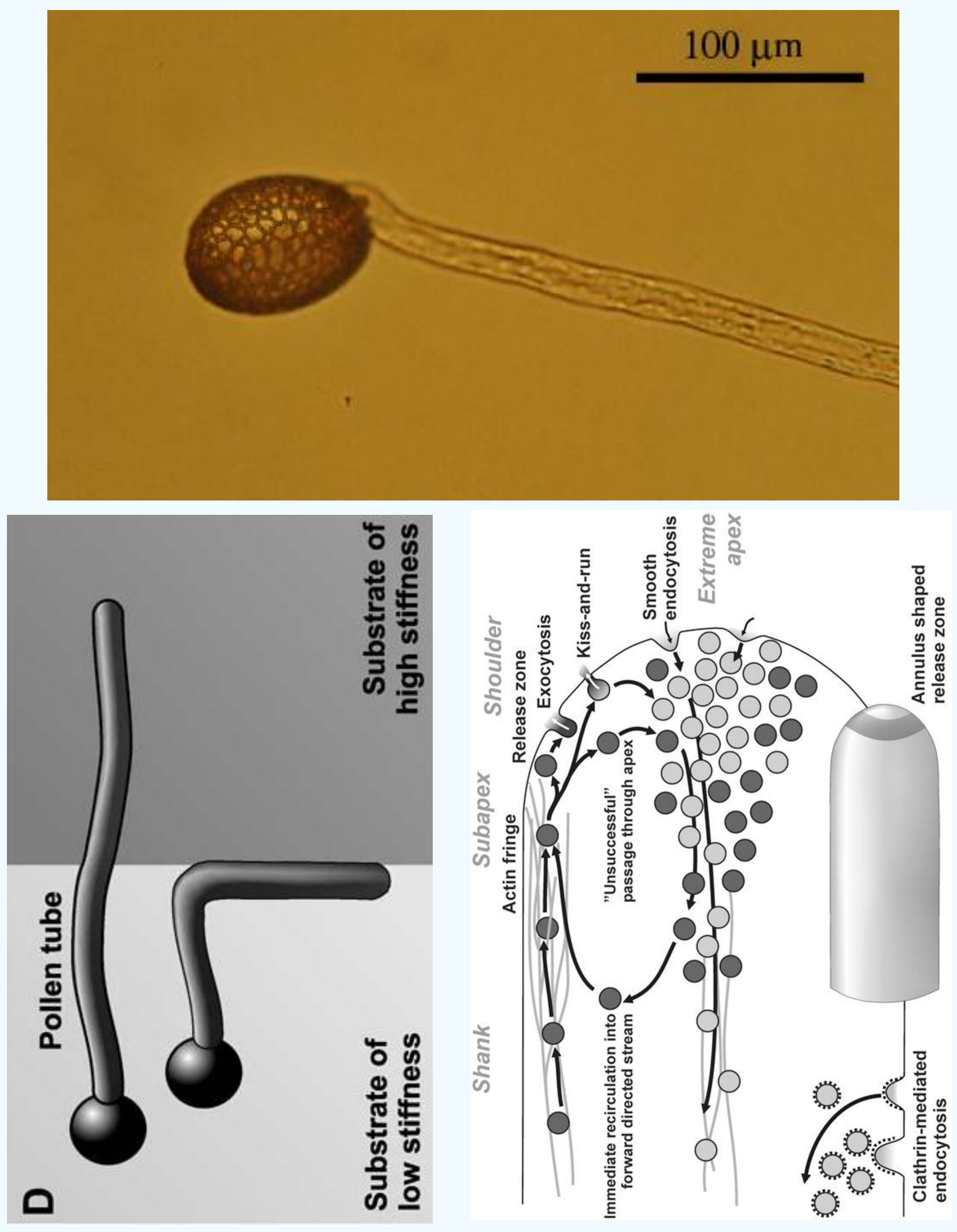

Fig.1. Top: the pollen grain and tube of *Lilium columbianum*; bottom-left: a schematic of the pollen tube response to a mechanical obstacle [1,2]; bottom-right: vesicle transport in a pollen tube [3].

Objectives:

- What is the effect of external mechanical stress on pollen tube growth?
- Does the geometry of the tube affect intracellular streaming?

Analytical Methods

We model the drag-generating actin filaments [4, 5] of the pollen tube as a distribution of Stokeslets, and analyse the resulting motion of the cytosol.

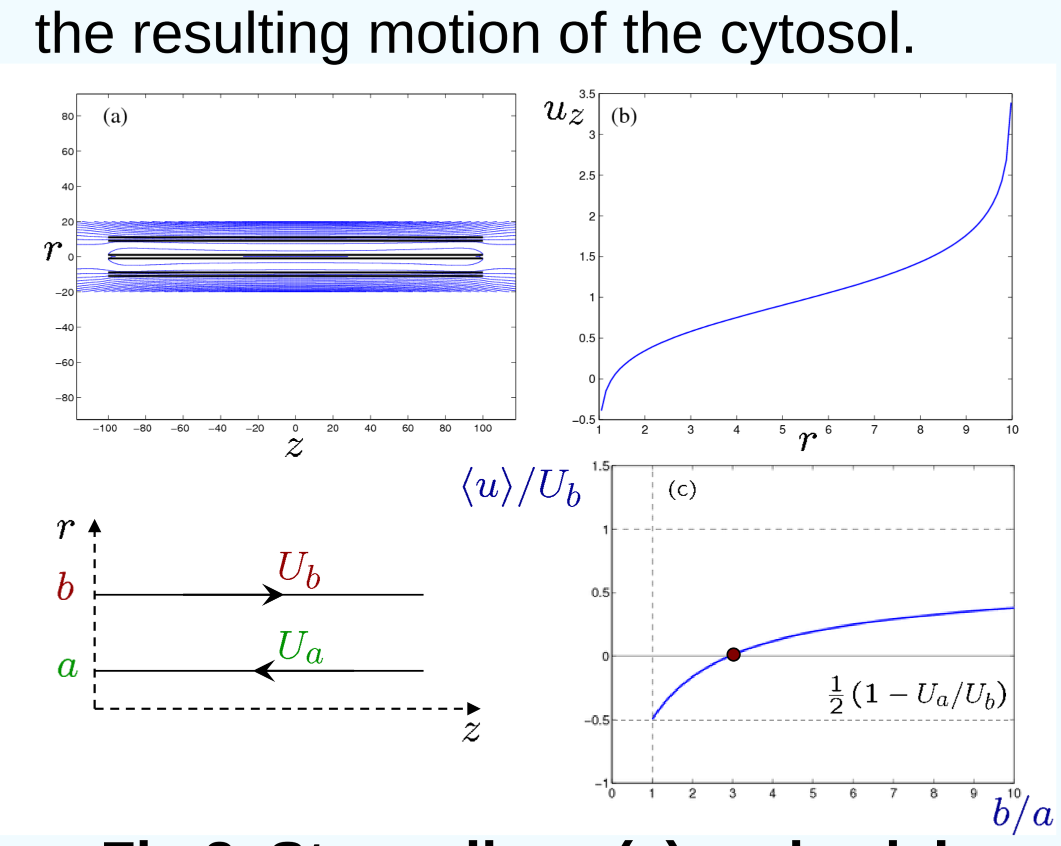

Fig.2. Streamlines (a) and axial velocity profile at z=0 (b) for co-planar line Stokeslets; (c) mean velocity of shear flow *vs.* tube geometry

Experimental Methods

To probe the impact of mechanical stress distributed over the pollen tube surface on the growth of the cell, we have employed controlled perfusion in a microchannel. We have subjected germinating pollen grains to a uniform Hele-Shaw flow (Re ~ 10^{-3} – 10^{-2}) in a rectangular channel, with wall shear stress τ ~ 10^{-2} – 10^{-1} Pa.

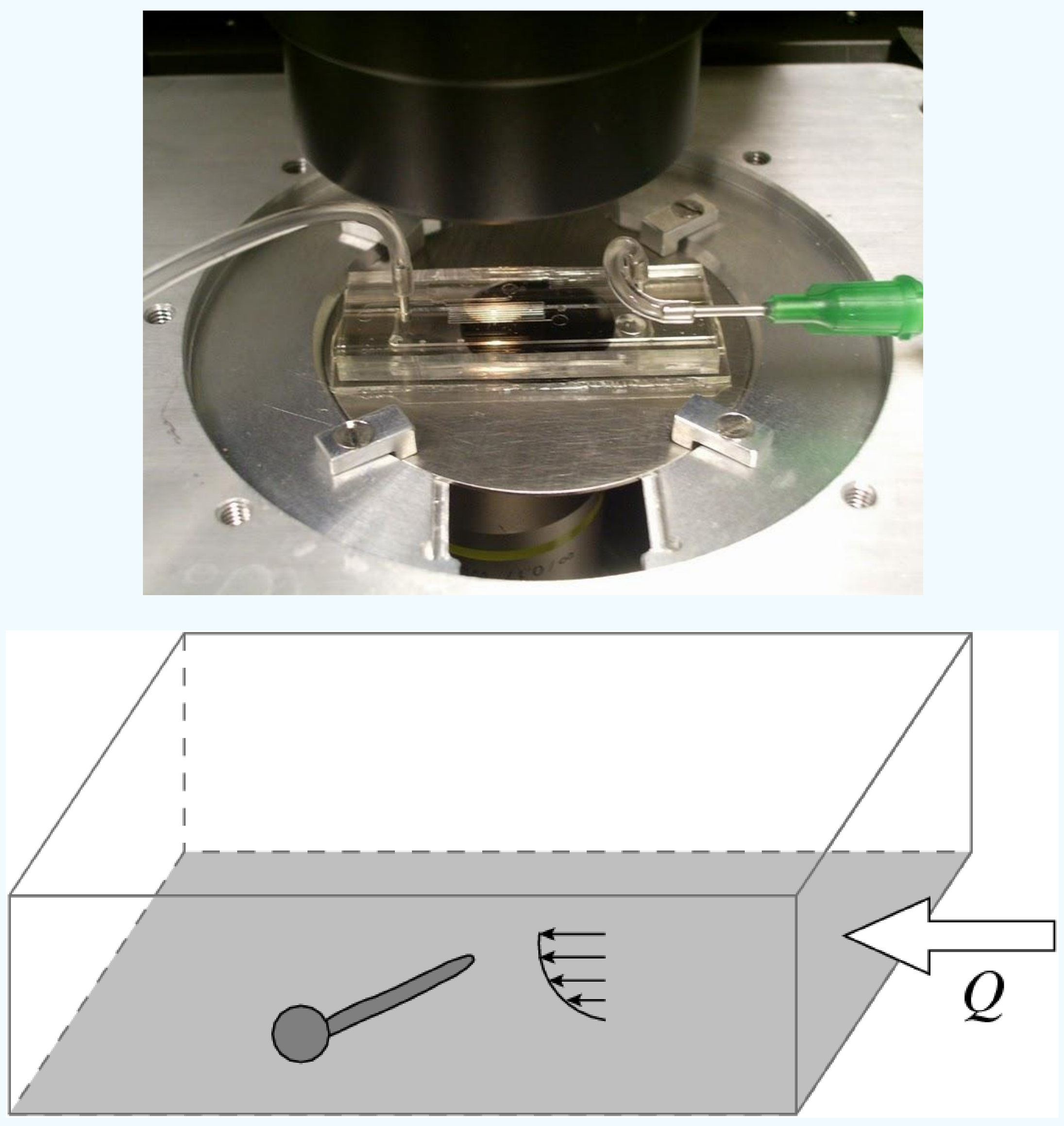

Fig. 3. Top: microchannel setup on the microscope stage; bottom: geometry of the channel (not to scale) with a pollen grain adhered to the base.

Results

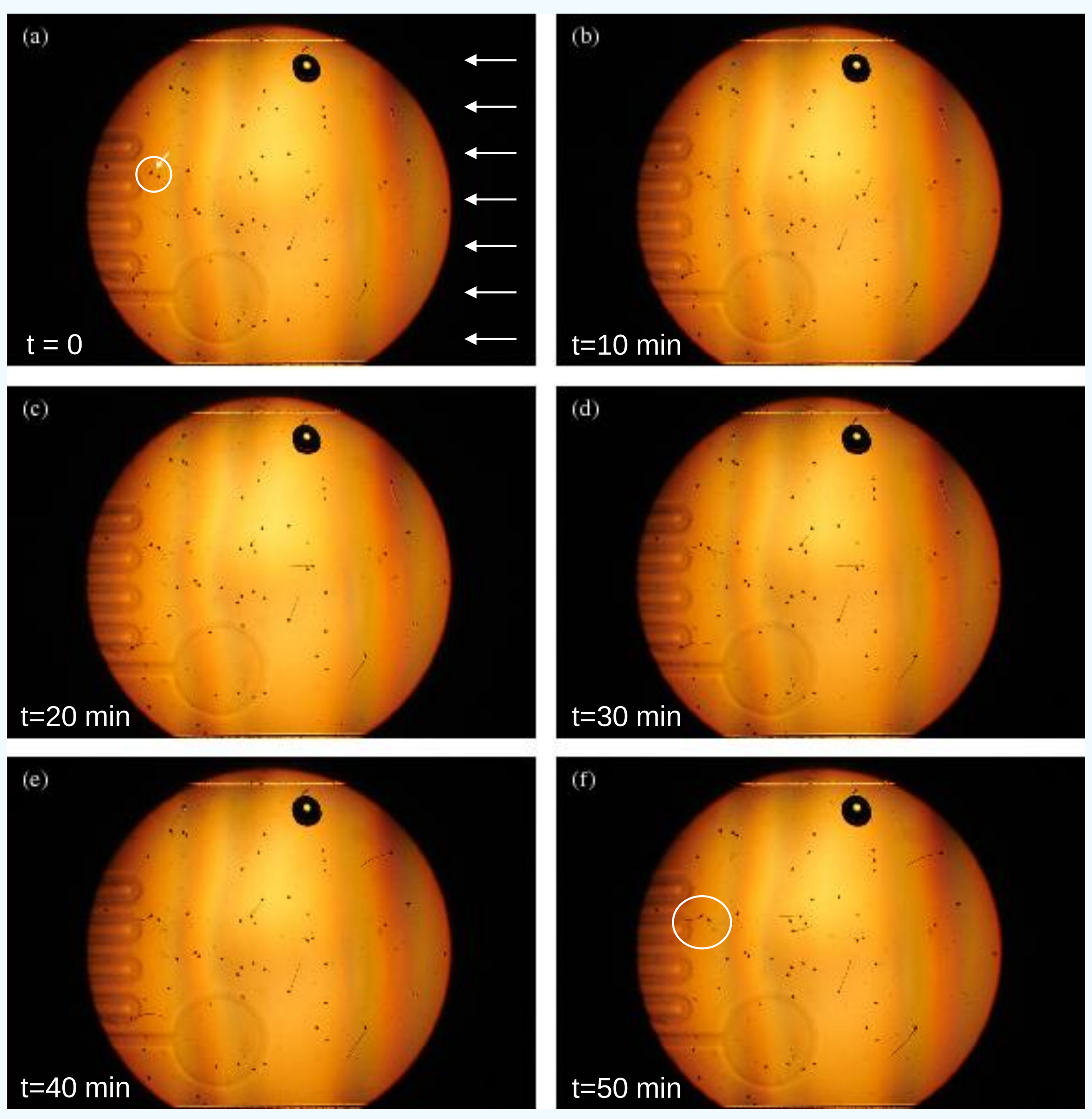

Fig. 4. Time-lapse macroscopic survey (2× objective) of pollen growth in a unidirectional Hele-Shaw flow (arrows). Note the streamlined growth of a pair of pollen tubes (marked by white circle), with the co-flow oriented tube exhibiting a higher growth rate.

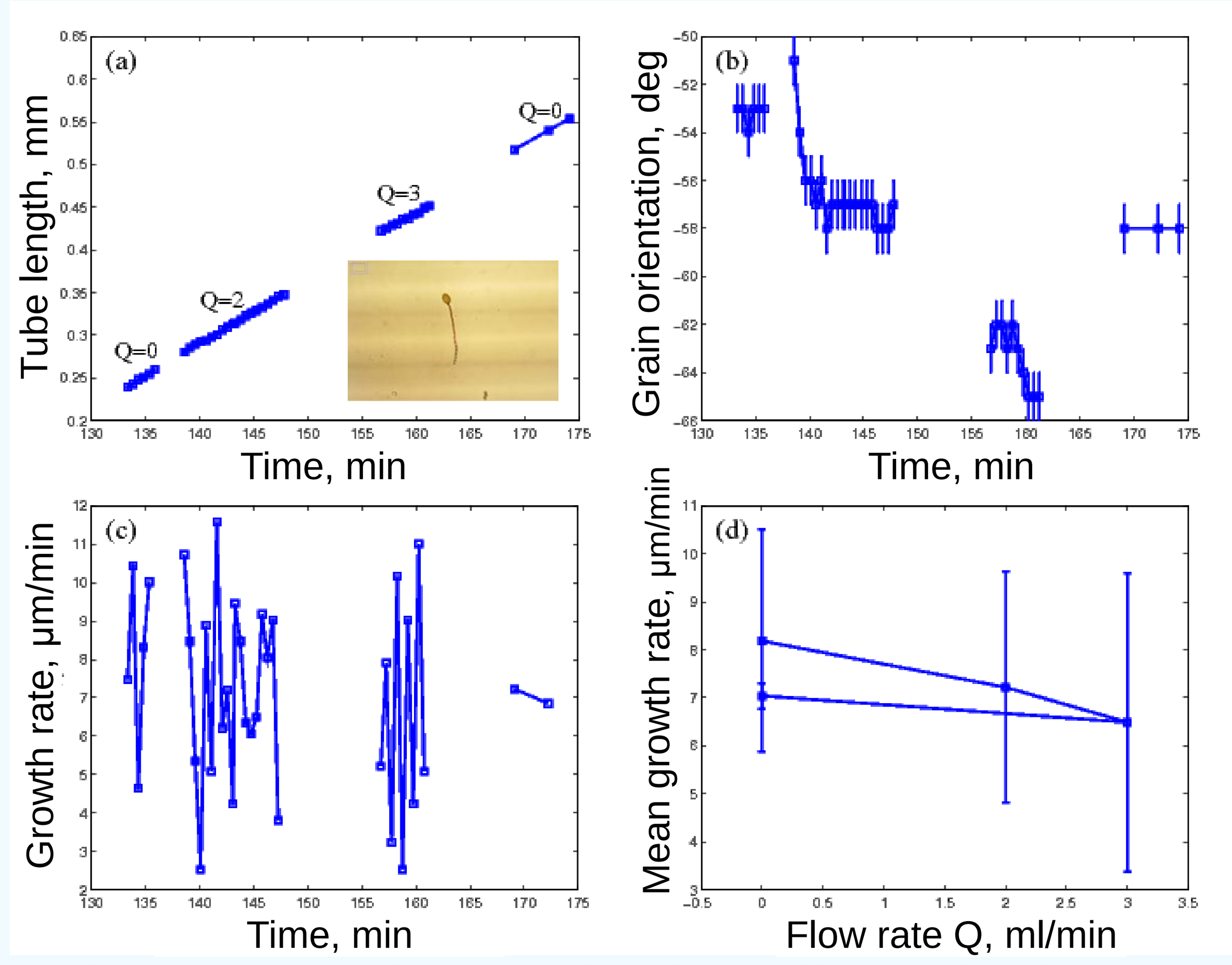

Fig. 5. Growth of a single pollen tube in the perfused microchannel; (d) indicates a reversible drop in the mean growth rate with an increase in flow rate Q.

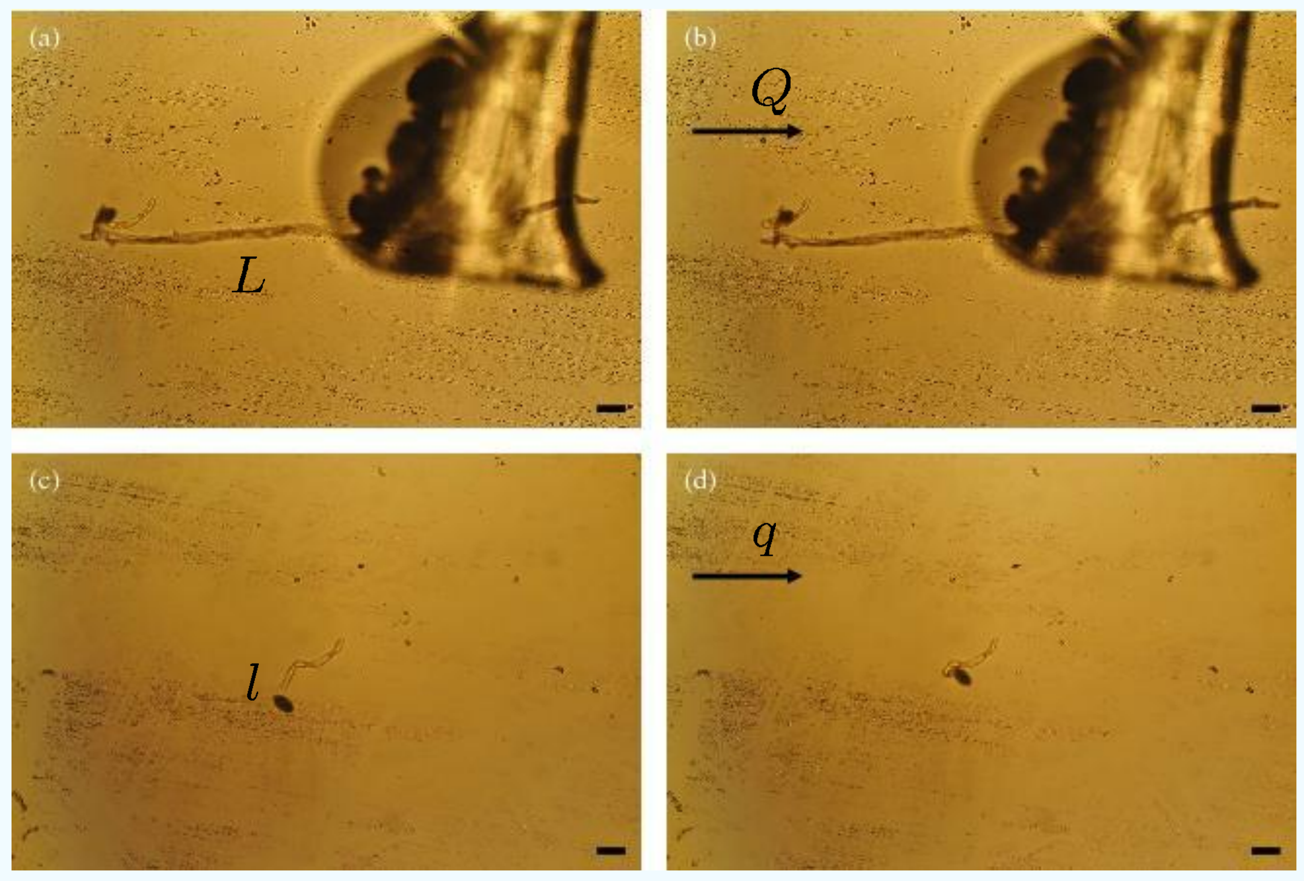

Fig. 6. Drag-induced bending of a pollen tube. Top: pollen tube with attached debris of length L at Q=0 (a) and Q=3.5 ml/min (b). Bottom: pollen tube with a free floating segment of length l at Q=0 (c) and Q=28 ml/min (d) (bar = 100 µm).

From the slender-body theory of Taylor [6] we have $F_\perp \approx 2F_\parallel \implies L/l \approx 2q/Q$, so that this technique can be used to estimate the bending moment of a pollen tube.

Conclusions

We have explored both internal and external mechanics of a growing pollen tube.

- We found some indication of orientation and growth attenuation responses in pollen tubes subjected to an external Hele-Shaw flow; further study is however required.
- High turgor pressure (~ 10^5 Pa) in the pollen tube [1], when compared to the applied external shear stress, makes a purely passive mechanics insufficient to account for the observed effects, and thus they likely involve intracellular regulation.
- Cytoskeletal geometry of the pollen tube is shown to be an important determinant of the mean velocity of cytosolic motion.

References

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