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A model for cyst lumen expansion and size regulation via fluid secretion

Many internal epithelial organs derive from cysts, which are tissues comprised of bent epithelial cell layers enclosing a lumen. Ion accumulation in the lumen drives water influx and consequently water accumulation and cyst expansion. Lumen-size recognition is important for the regulation of organ size. When lumen size and cyst size are not controlled, diseases can result; for instance, renal failure of the kidney. We develop a mechanistic mathematical model of lumen expansion in order to investigate the mechanisms for saturation of cyst growth. We include fluid accumulation in the lumen, osmotic and elastic pressure, ion transport and stretch-induced cell division. We find that the lumen volume increases in two phases: first, due to fluid accumulation stretching the cells, then in the second phase, the volume increase follows the increase in cell number until proliferation ceases as stretch forces relax. The model is quantitatively fitted to published data of in vitro cyst growth and predicts steady state lumen size as a function of the model parameters.