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Transitioning from a single-phase fluid to a porous medium: a boundary layer approach MOHIT P. DALWADI, S. JON CHAPMAN, JAMES M. OLIVER, SARAH L. WATERS, University of Oxford — Pressure-driven laminar channel flow is a classic problem in fluid mechanics, and the resultant Poiseuille flow is one of the few exact solutions to the Navier-Stokes equations. If the channel interior is a porous medium (governed by Darcy's law) rather than a single-phase fluid, the resultant behaviour is plug flow. But what happens when these two flow regions are coupled, as is the case for industrial membrane filtration systems or biological tissue engineering problems? How does one flow transition to the other? We use asymptotic methods to investigate pressure-driven flow through a long channel completely blocked by a finite-length porous obstacle. We analytically solve for the flow at both small and large Reynolds number (whilst remaining within the laminar regime). The boundary layer structure is surprisingly intricate for large Reynolds number. In that limit, the structure is markedly different depending on whether there is inflow or outflow through the porous medium, there being six asymptotic regions for inflow and three for outflow. We have extended this result to a wide class of 3D porous obstacles within a Hele-Shaw cell. We obtain general boundary conditions to couple the outer flows, and find that these conditions are far from obvious at higher order.

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