

Microfluidic culturing device

A microfluidic culturing device designed to be operable either by pipette (for certain depth and material combinations), hydrostatic head from reservoir tanks or pumps. The mould components are designed to be laser cut from PMMA sheet and the device itself cast in PDMS bonded to a base layer: device characteristics are given at some standard thicknesses and material choices.

Alongside this document you should have received all Parts as STEP files, an A3 technical drawing and all layouts in SVG format (Figures 2–12), the LaTeX source of this document and all Figures as 300 dpi PNGs, and high-resolution renders of Figure 1 in PNG format.

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License	CC-BY-SA-4.0 International	Notes	All non-exact values given to 3 s.f.

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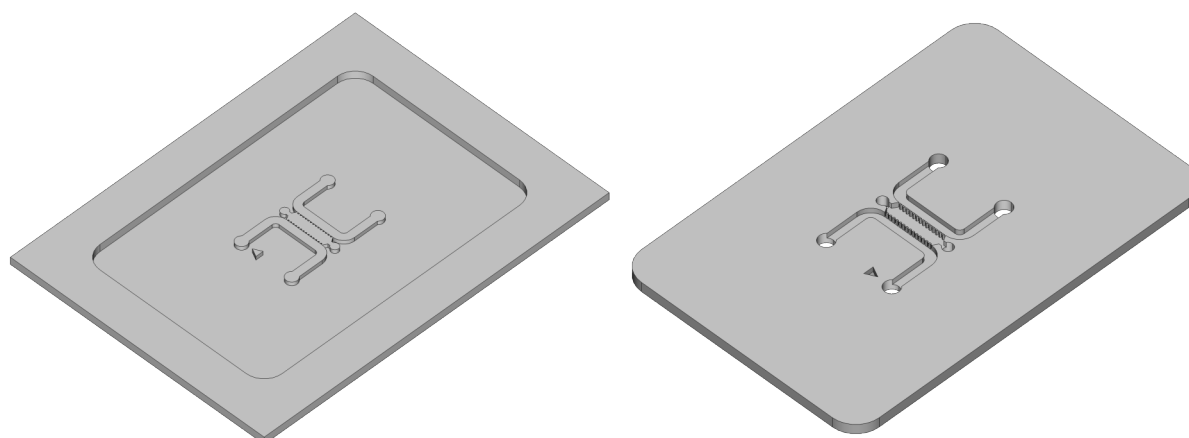


Figure 1: An example mould assembly and the cast device, after punching through the ports.

1 Overview

Gel volume computed by multiplying by feature depth ($1 \text{ mm}^3 = 1 \text{ }\mu\text{L}$).

Table 1: Key properties
Common

Ports (fluid)	4	
Port diameter (fluid)	3	mm
Ports (gel)	2	
Port diameter (gel)	2	mm
Gel width (max)	3	mm
Pillar spacing	200	μm
Variant A		
Pillars	14	
Gel length	10	mm
Gel width (min)	2.5	mm
Gel area	37.0	mm^2
Variant B		
Pillars	9	
Gel length	9.2	mm
Gel width (min)	2.2	mm
Gel area	33.0	mm^2

1.1 Manufacture

The device is intended to be made from PDMS cast around the mould components supplied, with the loading ports punched out and bonded to a base. Layouts are provided (§4) for assembling the mould with the provided parts, which can be engraved or cut into an alignment piece; alternatively, these can be printed and used for labelling experiments. To compute the required PDMS volume for casting when using depths d_i for each part, with n_i instances of Parts 2/3 and A_i for each variant given in Table 2:

$$V_{\text{PDMS}} = d_1 A_1 - n_2 d_2 A_2 - n_3 d_3 A_3. \quad (1)$$

(Note: $1000 \text{ mm}^3 = 1 \text{ mL}$.)

Table 2: Part areas
 i | Area [mm^2]

1a	1910
1b	3850
2a	179
2b	172
3	2

2 Device characteristics

Conversion factors for experiments:

$$\begin{aligned} 1 \text{ mmH}_2\text{O} &= 9.81 \text{ Pa} \\ 1 \text{ }\mu\text{L s}^{-1} &= 3.60 \text{ mL hr}^{-1} \end{aligned}$$

2.1 Capillary pressure

The total capillary pressure for each feature is the sum of the base material and PDMS feature contributions. Assumes the following contact angles with water at 20°C: Glass 0°, PMMA 70.9°, PDMS 107.2°; and water-air surface tension of 0.0728 N m⁻¹. Selecting a base material and depth such that pillar pressure is positive and gel/channel pressure is negative allows for self-filling behaviour. In real-world usage, the true capillary pressures will be impacted by PDMS treatment and base material choice, surfactants in solution and temperature, as well as other factors.

Uses the formula

$$p_c = -\gamma \left(\left(\frac{2}{w} + \frac{1}{d} \right) \cos \theta_f + \frac{\cos \theta_b}{d} \right) \quad (2)$$

Table 3: Capillary pressure (water-air, 20°C)

Depth [mm]	Base material		PDMS feature			
	Glass [mmH ₂ O]	PMMA [mmH ₂ O]	Pillar [mmH ₂ O]	Gel (A) [mmH ₂ O]	Gel (B) [mmH ₂ O]	Channel [mmH ₂ O]
1	-7.42	-2.43	24.1	3.95	4.19	4.39
0.5	-14.8	-4.86	26.3	6.15	6.39	6.59
0.2	-37.1	-12.1	32.9	12.7	13.0	13.2
0.1	-74.2	-24.3	43.9	23.7	23.9	24.1

2.2 Channel resistance

Note that water undergoes a rapid change of dynamic viscosity with temperature around the physiological temperature range. Assumes viscosity of 1.0005 mPa s at 20°C, 0.6922 mPa s at 37°C and laminar flow.

Uses the formula

$$R = \frac{\Delta p}{Q} = 8\mu \frac{(w + d)^2}{(wd)^3} L \quad (3)$$

Table 4: Channel impedance (water)

Depth [mm]	Variant A		Variant B	
	Impedance at 20°C [mmH ₂ O/(μL s ⁻¹)]	Impedance at 37°C [mmH ₂ O/(μL s ⁻¹)]	Impedance at 20°C [mmH ₂ O/(μL s ⁻¹)]	Impedance at 37°C [mmH ₂ O/(μL s ⁻¹)]
1	0.0287	0.0199	0.0280	0.0194
0.5	0.160	0.110	0.155	0.108
0.2	1.93	1.34	1.88	1.30
0.1	14.1	9.74	13.7	9.49

3 Part dimensions

- As a common base material is glass, Part 1a is matched to a standard single microscope slide (1"×3"), whilst Part 1b is matched to a standard double microscope slide (2"×3").
- Part 2b is a channel/gel variant with wider pillars, enabling deeper channels or less precise manufacturing approaches to be used.
- Part 3 is used to create an orientation marker on the device.

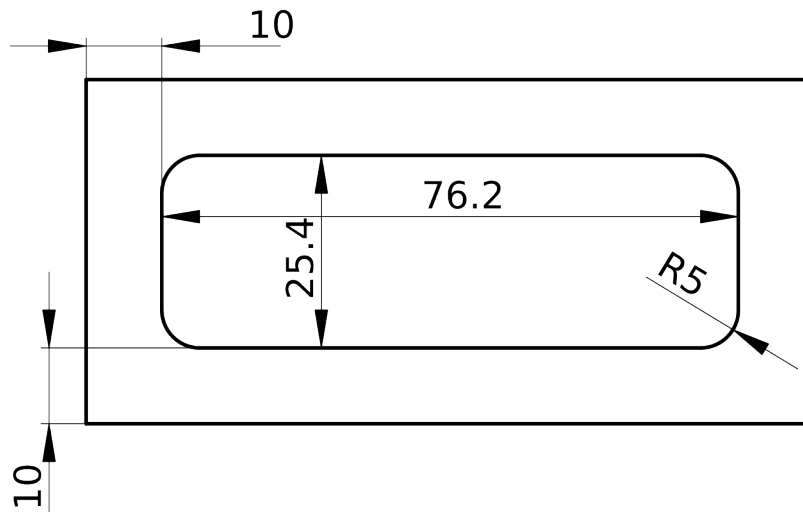


Figure 2: Part 1a (Scale 1:1).

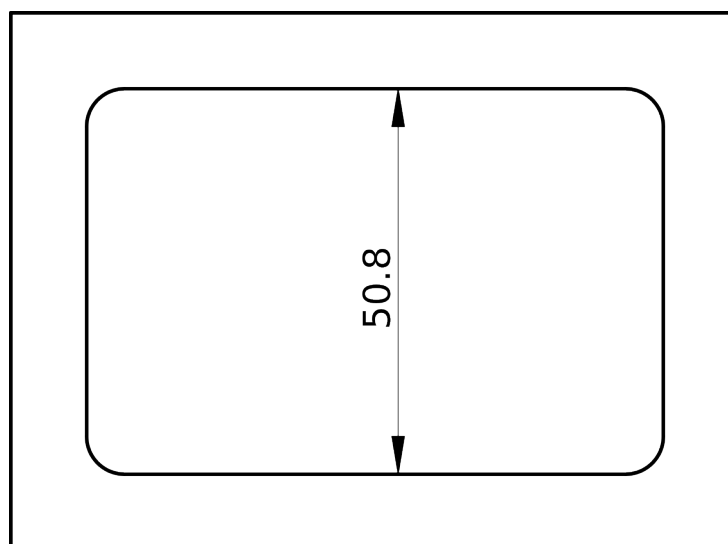


Figure 3: Part 1b, deviations from Part 1a (Scale 1:1).

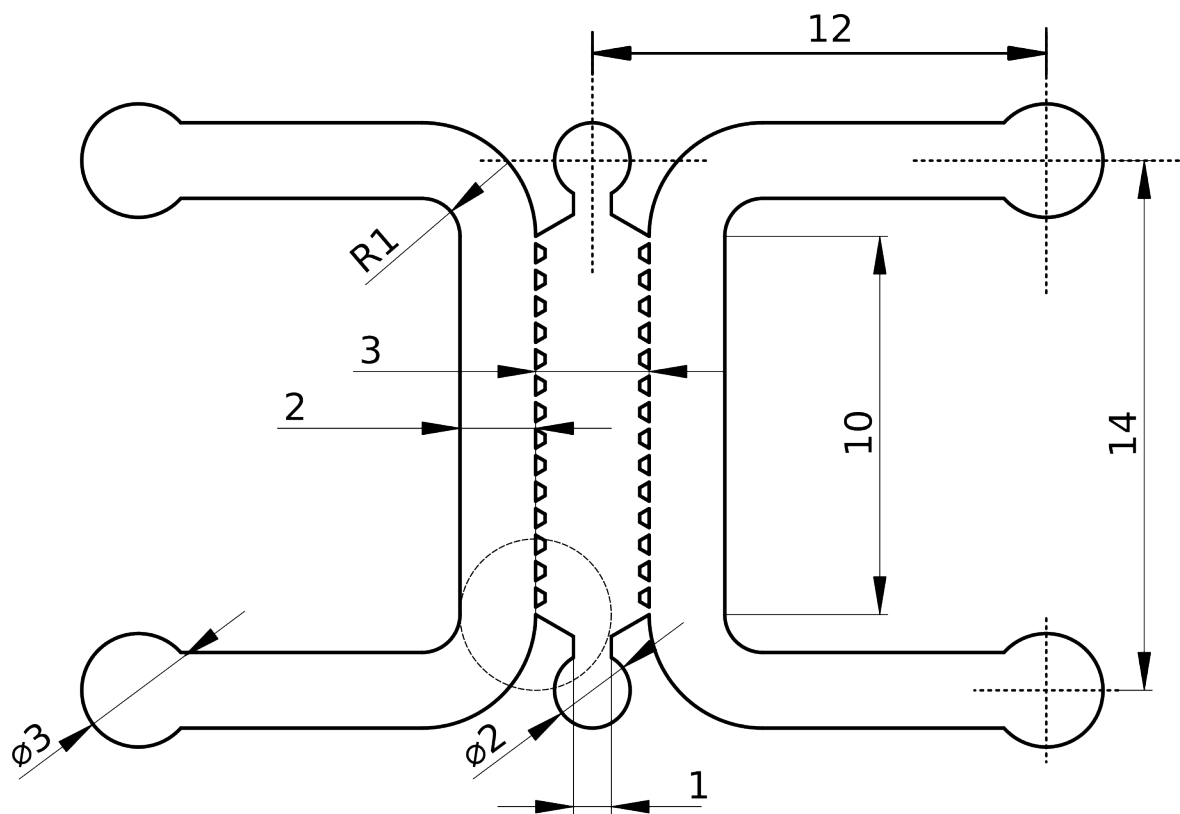


Figure 4: Part 2a (Scale 5:1).

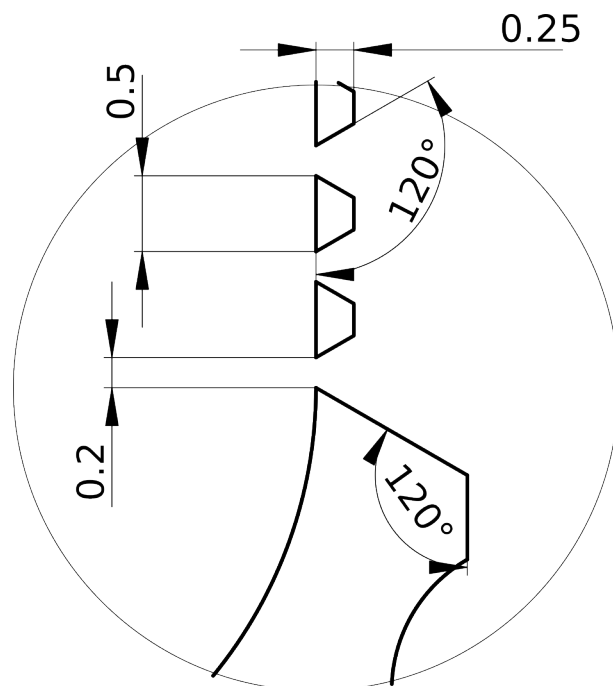


Figure 5: Part 2a detail (Scale 20:1).

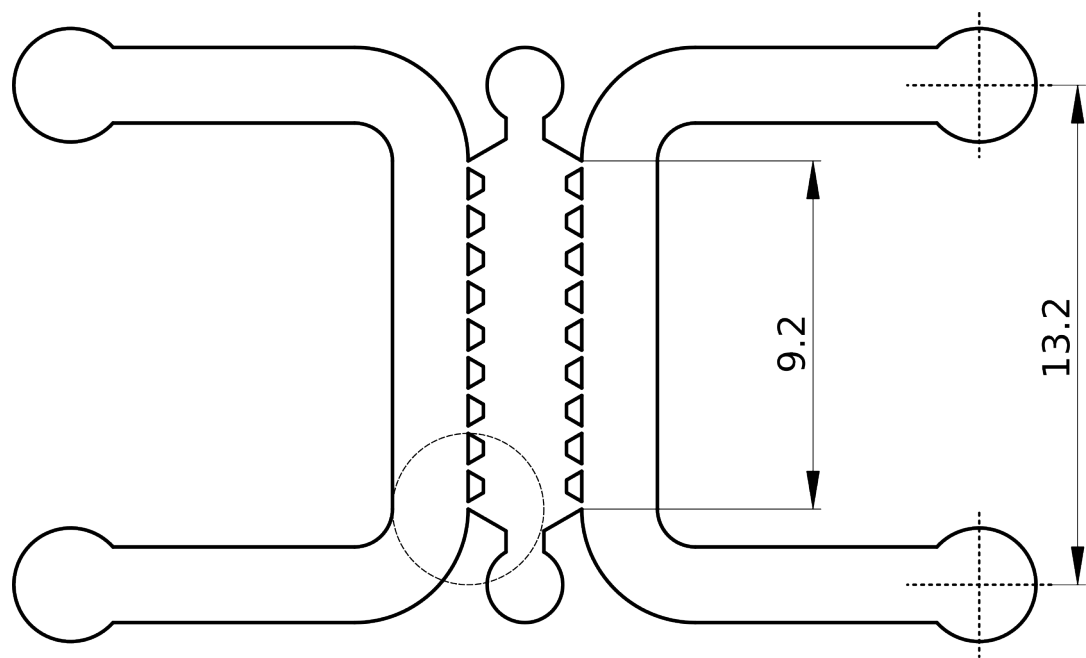


Figure 6: Part 2b, deviations from Part 2a (Scale 5:1).

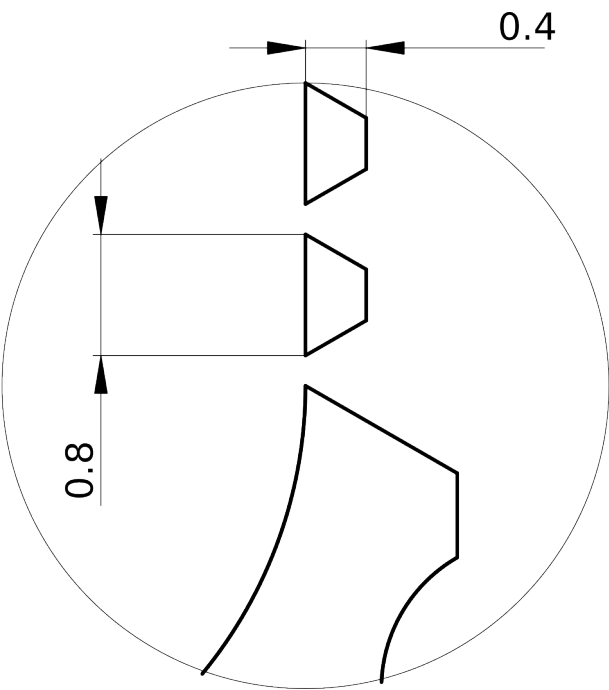


Figure 7: Part 2b detail, deviations from Part 2a (Scale 20:1).

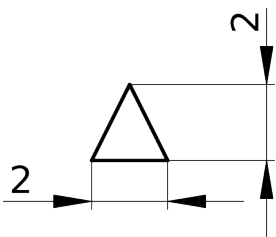


Figure 8: Part 3 (Scale 5:1).

4 Layouts

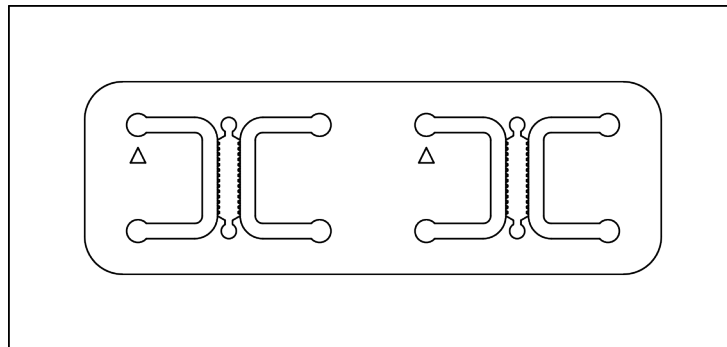


Figure 9: Layout 1a/2a (Scale 1:1).

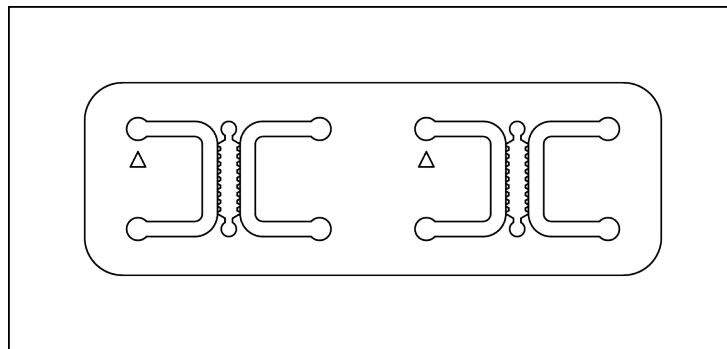


Figure 10: Layout 1a/2b (Scale 1:1).

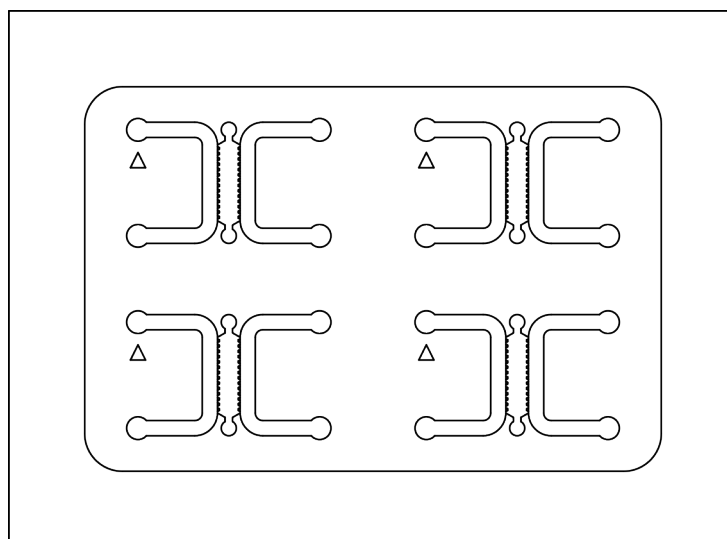


Figure 11: Layout 1b/2a (Scale 1:1).

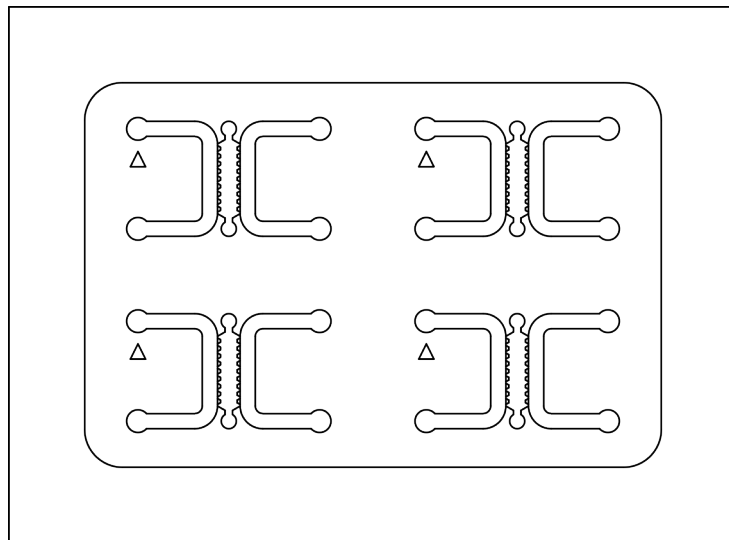


Figure 12: Layout 1b/2b (Scale 1:1).