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Plant leaves as templates for soft lithography

Electronic Supplementary Material

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1 Biodiversity

As shown in Fig. S1r ~ s, the large variety of natural microvascular networks can be transferred to PDMS microfluidic devices with high fidelity. As shown in Fig. S1r, hair like trichomes feature like holes in the PDMS replicas. Fig. S1s, shows the replication of wrinkles of 400 nm ~ 1.2 μm in width.

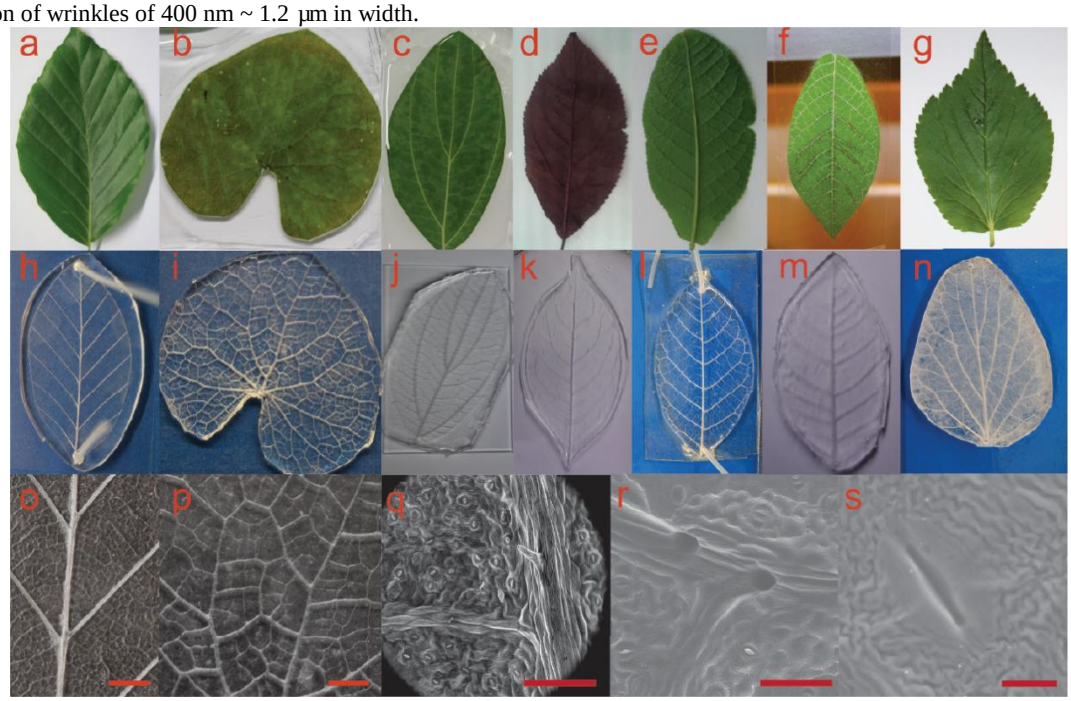

Fig. S1 Diverse biomimetic microchips directly fabricated from various natural leaves. Examples of leaves and their replicates. (a) Leaf of Carpinus betulus. (b) Leaf-template (Glechoma hederacea) immersed with PDMS inside Petridish. (c) Leaf-template (Viburnum davidii) immersed with PDMS inside Petridish. d) Leaf of Prunus cerasifera. (e) Leaf of Prunus avium. (f) Leaf-template (Prunus avium) attached to single-side tape. (g) Simple Leaf of Aegopodium podagraia. (h) ~ (m) Nature inspired microchips fabricated from Carpinus betulus, Glechoma hederacea, Viburnum davidii, Prunus cerasifera, Prunus avium and Fraxinus excelsior. (n) PDMS replica from Aegopodium podagraia leaf. (o) ~ (p) Enlarged microvascular image of biomimetic microchip replicated from Carpinus betulus and (Glechoma hederacea) leaf. (q) SEM image of Aegopodium podagraia leaf. (r) ~ (s) SEM images of biomimetic PDMS mould (prepared at 1:20) replicated from Aegopodium podagraia leaf. Scale bars in (o) ~ (s) are 0.25 cm, 0.25 cm, 200 μm, 100 μm and 10 μm, respectively.

2 Microchannel characterization

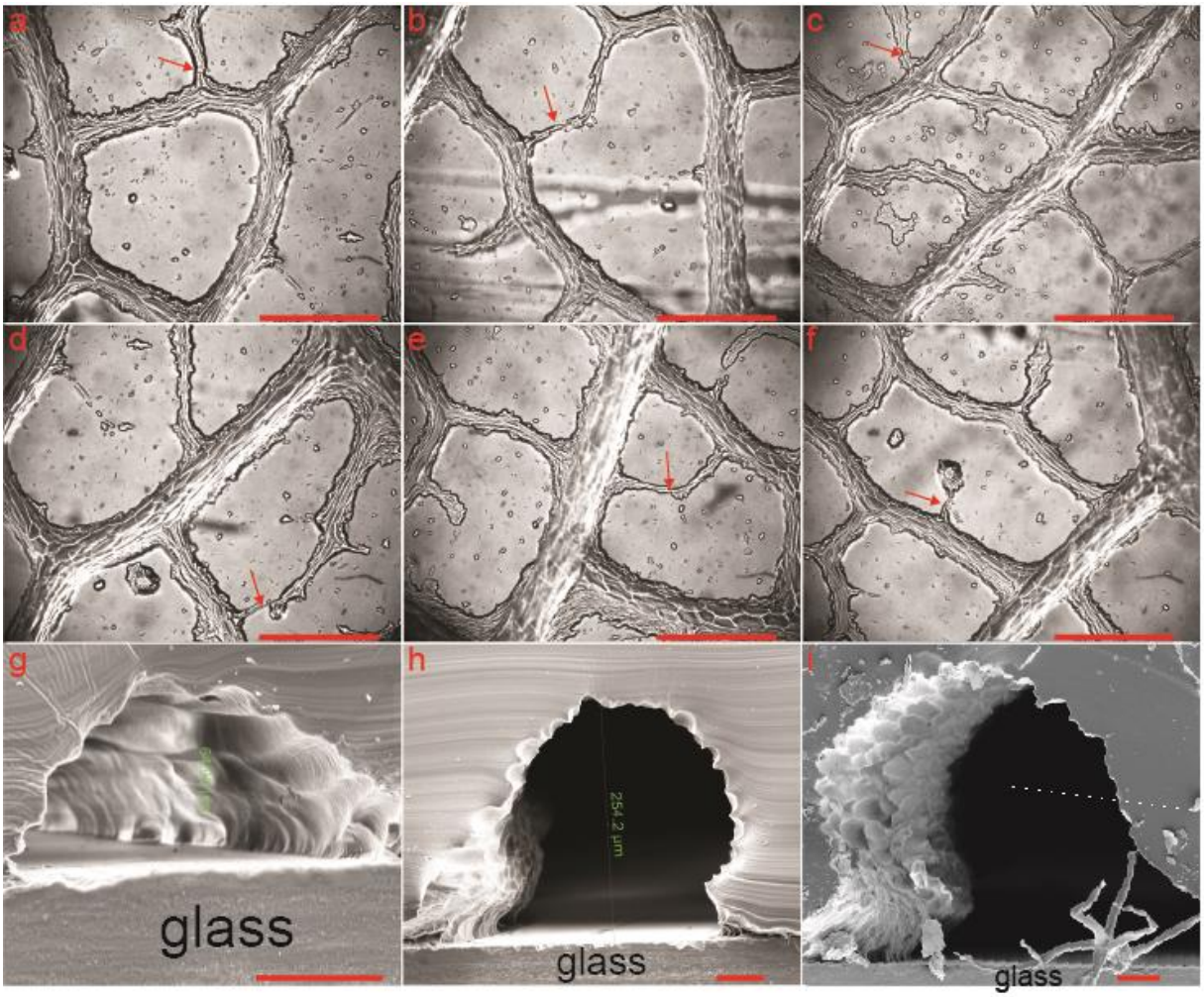

Fig. S2 Microvascular channel of PDMS leaf fabricated from Glechoma hederacea. Scale bars (a) - (f) 500 µm, (g) - (i) 50 µm.

As shown in Fig. S2, the smallest channel width from (a) ~ (f) was found to be 22.3 µm, 8.1 µm, 18.2 µm, 8 µm, 9.7 µm and 9.2 µm, respectively.

As shown in Fig. S2g-i, the biomimetic microvascular channel has varied widths and heights, with micro-scaled topography replicated from the leaves surface onto channel.

3 AFM characterization

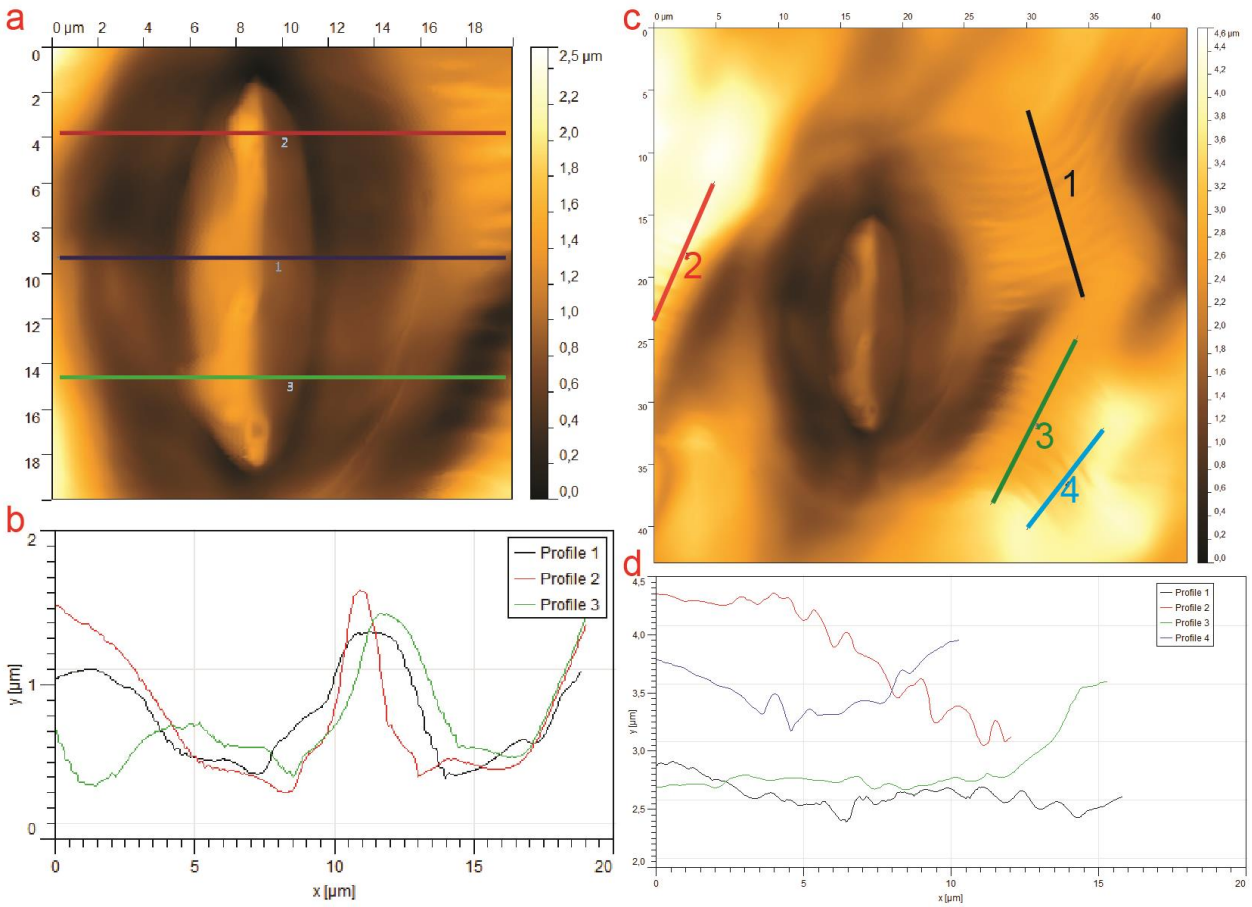

Fig. S3 AFM topography characterization of PDMS leaf. (a) 3D profile of the central part of one stoma on PDMS leaf replicated from Tilia platyphyllos, and corresponding line profiles of the stoma region (b). (c) 3D profile of the peripheral part of one stoma on PDMS leaf replicated from Tilia platyphyllos, and corresponding line profiles of the stoma region (d).

4 HS-GC-MS chromatograms

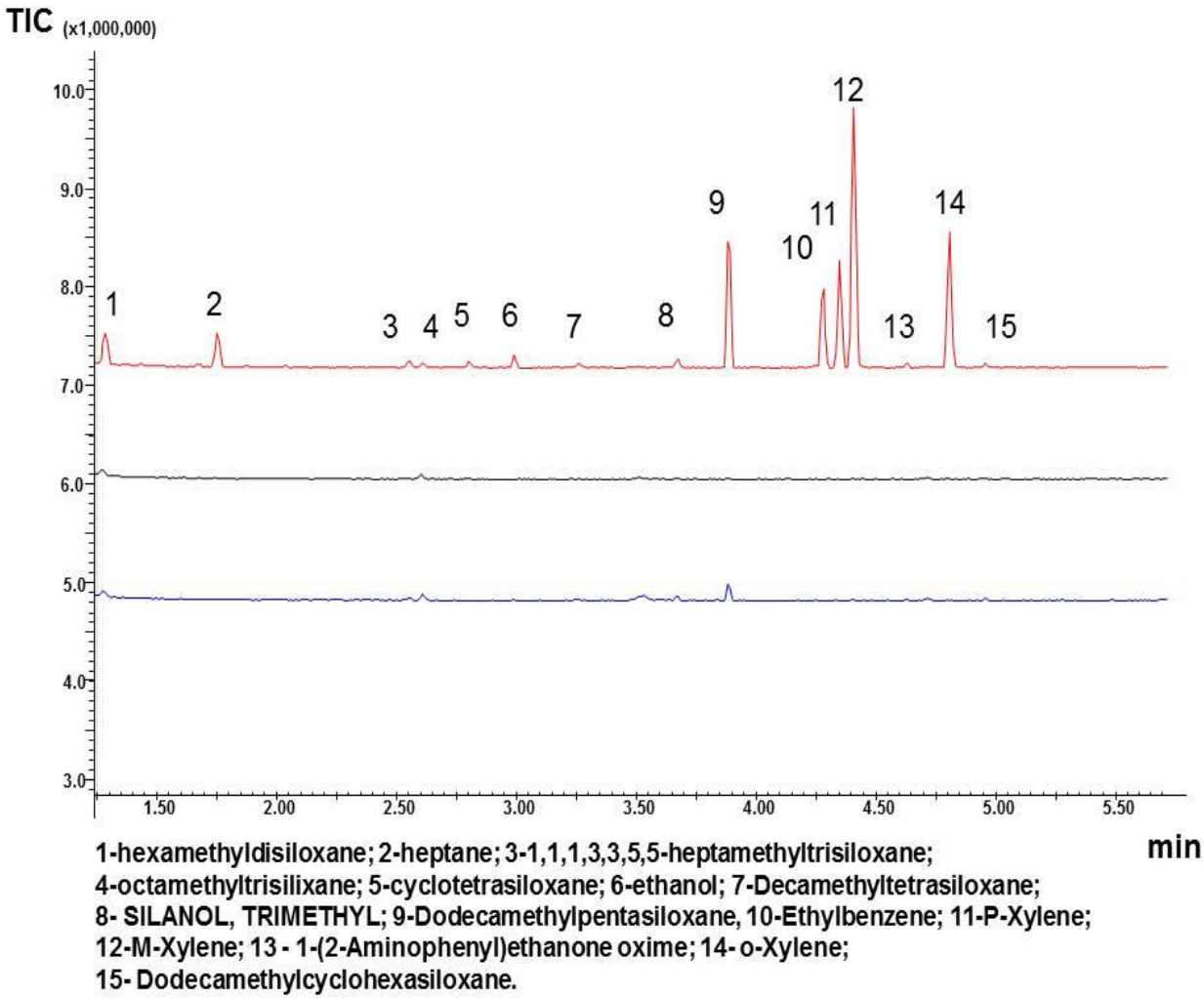

Fig. S4 HS-GC-MS chromatograms of the pure PDMS matrix (red); natural Tilia leaf (blue) after contact with PDMS; one-sided cut of PDMS matrix after contact with a natural Tilia leaf (black), obtained under 50 ℃

5 Longevity endurance of leaf template

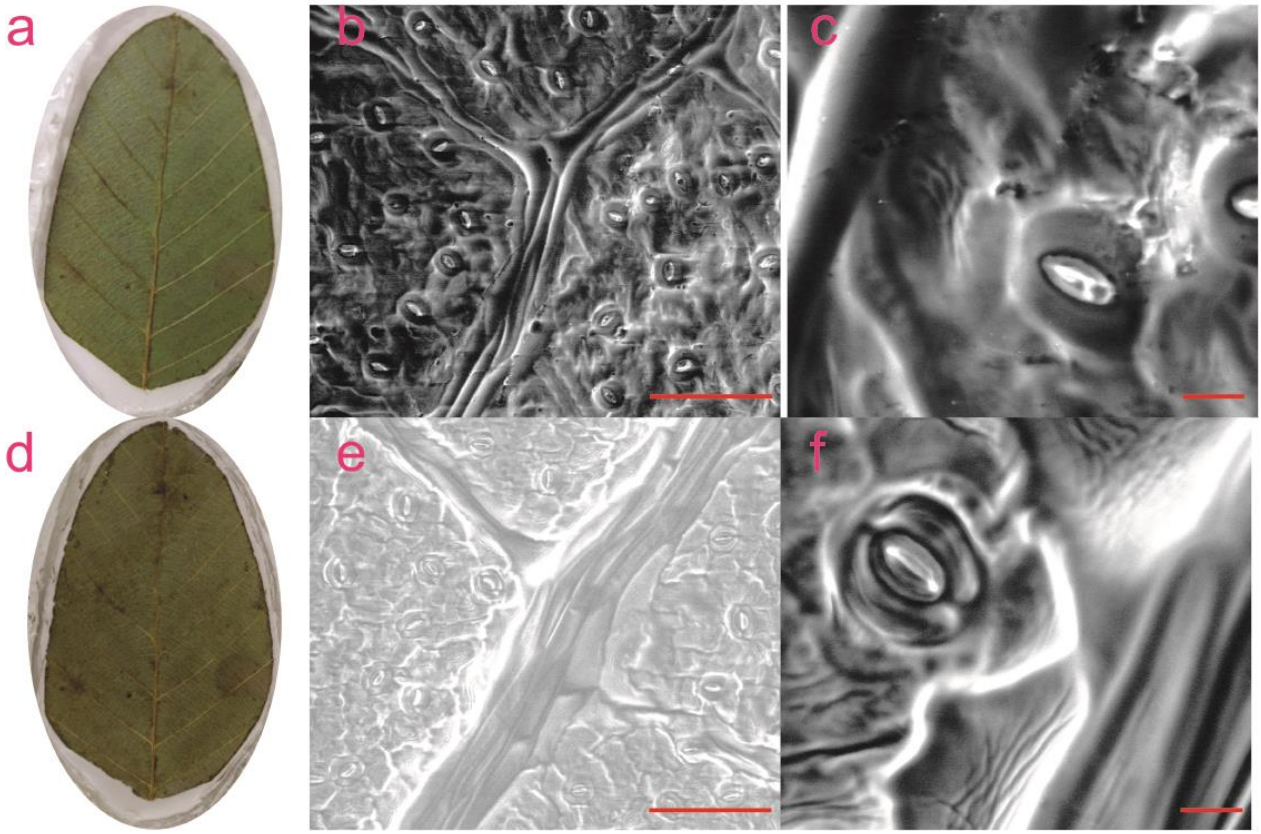

Fig. S5 Carpinus betulus leaf stored in PDMS for one year, utilized for microfabrication of over thirty times during this period. (a) Real image of Carpinus betulus leaf. (b) Microvascular channel in 1:20 PDMS replica from fresh Carpinus betulus leaf. (c) Enlarged image of stomata in 1:20 PDMS replica from fresh Carpinus betulus leaf. a) Real image of one year stored Carpinus betulus leaf. (b) Microvascular channel in 1:20 PDMS replica from one year stored Carpinus betulus leaf. (c) Enlarged image of stomata in 1:20 PDMS replica from one year stored Carpinus betulus leaf. Scale bars (b) and (e) 100 µm, (c) and (f) 10 µm.

6 Self-powered hydraulic flow through microvascular networks of PDMS leaves

We confirmed the pressure applied using the syringe indeed forced the air out of the channels to replace this volume with liquid by visualising the air as bubbles on the PDMS surface when the device was pressurised in a water bath.

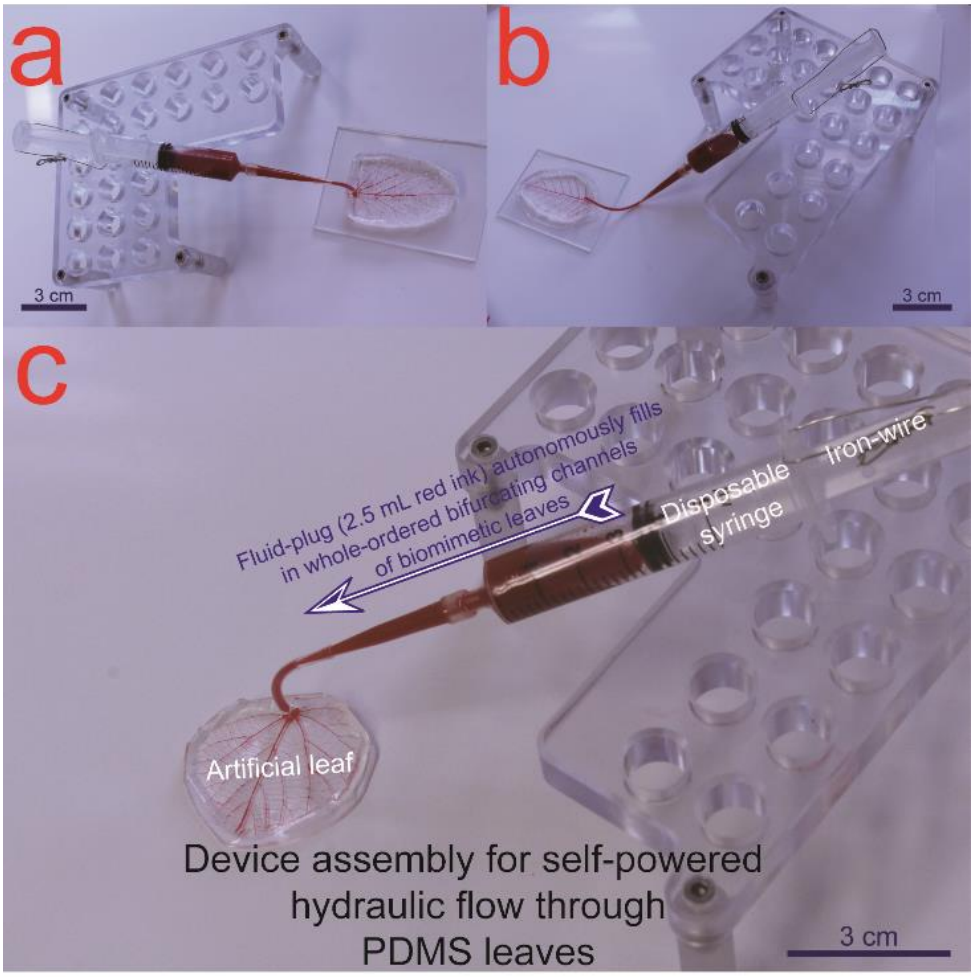

Fig. S6 The filling of the microvascular networks of PDMS replicates using only an inlet channel. (a) The artificial leaf with reticulate networks. (b) The artificial leaf with parallel networks. (c) The artificial leaf with intensive reticular characteristic networks. The scale bar in (a), (b) and (c) are 3 cm.

As shown in Fig. S7, through real-time monitoring of the hydraulic flow inside the microvascular networks, we could evaluate veinal dynamic conductance of biomimetic microvasculature in real time, covering all bifurcating channels ranging from highest order to lowest order. Electronic supplementary information (see ESI 2, ESI 3) is also provided to visually display self-powered flow inside biomimetic microvasculature with complex architectures.

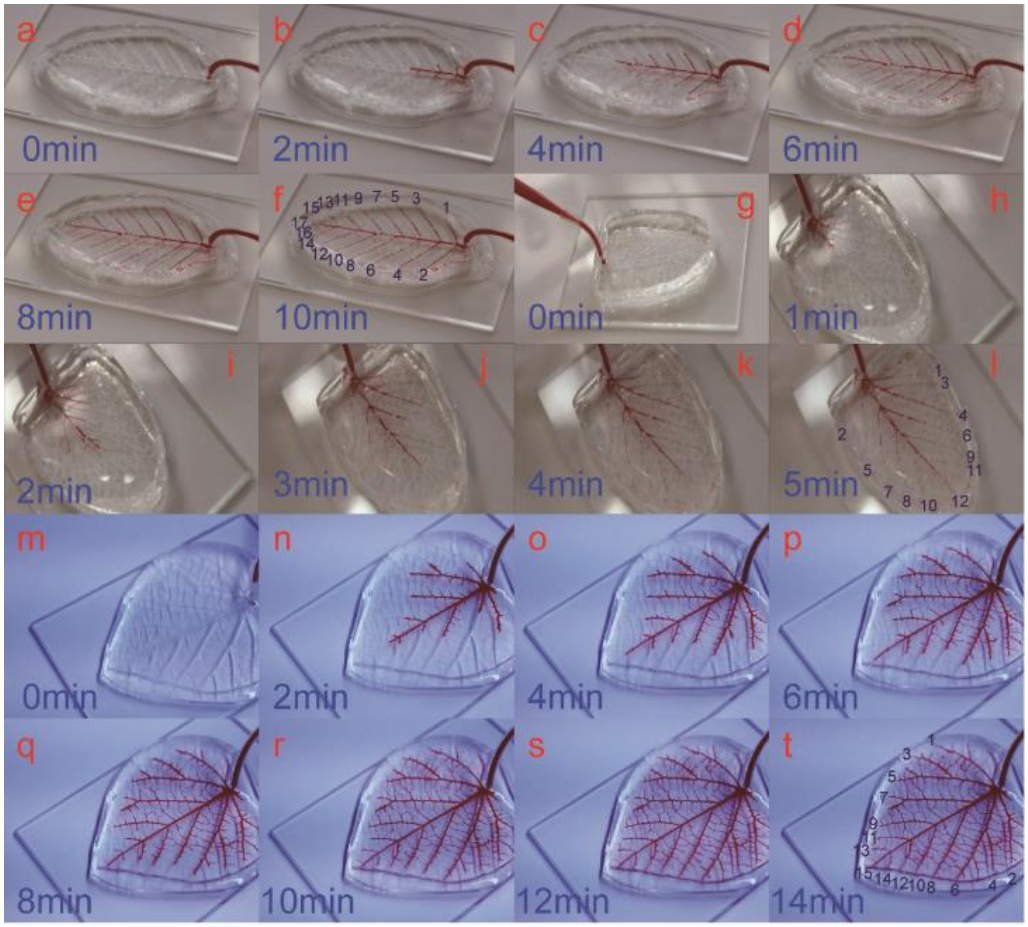

Fig. S7 Nature inspired biomimetic Microchips with whole ordered micronetwork replicated from Tilia platyphyllos, Aegopodium podagraia and Carpinus betulus, for self-powered flow analogy. (a) ~ (f) Self-powered flow analogy inside PDMS leaf containing parallel networks replicated from Carpinus betulus, with a time interval of 2 mins. (g) ~ (l) Self-powered flow analogy inside PDMS leaf replicated from Aegopodium podagraia, with a time interval of 1 min. (m) ~ (t) Self-powered flow analogy inside PDMS leaf replicated from Tilia platyphyllos, with a time interval of 2 mins.

The first PDMS leaf from Carpinus betulus (Fig. S7a~f) had 2-order microvascular bifurcating structures, with one 4.7 cm long first-ordered microchannel (No. 17 in Fig. S7f) in leaf's center and sixteen parallel second-ordered micochannels (No. 1 ~ 16 in Fig. S7f) extending from the central microchannel. As shown in Fig. S7f, the length of second ordered channel varied from 1.7 cm (No. 5, 6) to 0.3 cm (No. 15, 16), with average length of second-ordered microchannels of 1.2 cm. Based in real-time monitor of flow, we found the duration time in first-ordered microchannel was around 628 seconds, while the duration time in second-ordered microchannels gradually decreased from 470 seconds (No. 1, 2) to 110 seconds (No. 15, 16). Correspondingly, the average flowing rate in first-ordered microchannel and second-ordered microchannel were calculated to be 0.00357 cm/sec and 0.00745 cm/sec, respectively. So the flow rate of first-ordered microchannel was 2.08 times of the average rage in second-ordered microchannels.

The second PDMS leaf fabricated from Aegopodium podagraia (Fig. S7h~m) had 2-order microvascular bifurcating structures. But different from the first PDMS leaf, the second PDMS leaf had five first-ordered microchannels extending from the inlet (No. 1, 2, 4, 5, 12 in Fig. S7l) and various second-ordered microchannels (No. 3, 6 ~ 11 in Fig. S7l). Noticeably, the first-ordered microchannel in the center of PDMS leaf (No. 12) was 4.3 cm in length, much longer than another four first-ordered microchannels (No. 1, 2, 4, 5) with average length of 2.5 cm. The duration in first-ordered microchannels (No. 1, 2, 4, 5, 12) were 150 sec, 130 sec, 210 sec, 140 sec, and 275 sec, respectively, with corresponding flow rate calculated to be 0.0153 cm/sec, 0.0161 cm/sec, 0.0148 cm/sec, 0.0164 cm/sec and 0.0156 cm/sec, respectively. For the second-ordered microchannels, average flow rate were calculated to be 0.0109 cm/sec. So average flow rate in first-ordered microchannel is around 1.43 times of that in second ordered microchannels.

The third PDMS leaf fabricated from Tilia platyphyllos (Fig. S7m~t) had 3-order microvascular bifurcating structures. Herein we calculated the flowing performance in five first-ordered microchannels (No. 1, 2, 5, 6, 15 in Fig. S7t) and ten second-ordered

microchannels (No. 3~4, 7~14 in Fig. S7t). The first-ordered microchannel in the center of PDMS leaf (No. 15) was 4.2 cm in length, while other first-ordered microchannels (No. 1, 2, 5, 6) had average length of 2.55 cm. The average flow rate in all first-ordered microchannels (No. 1, 2, 5, 6, 15) were calculated to be 0.0447 cm/sec; and the average flow rate in second-ordered microchannels (No. 3~4, 7~14 in Fig. S7t) were calculated to be 0.0222 cm/sec. So average flow rate in first-ordered microchannels was 2.17 times of second ordered microchannels.

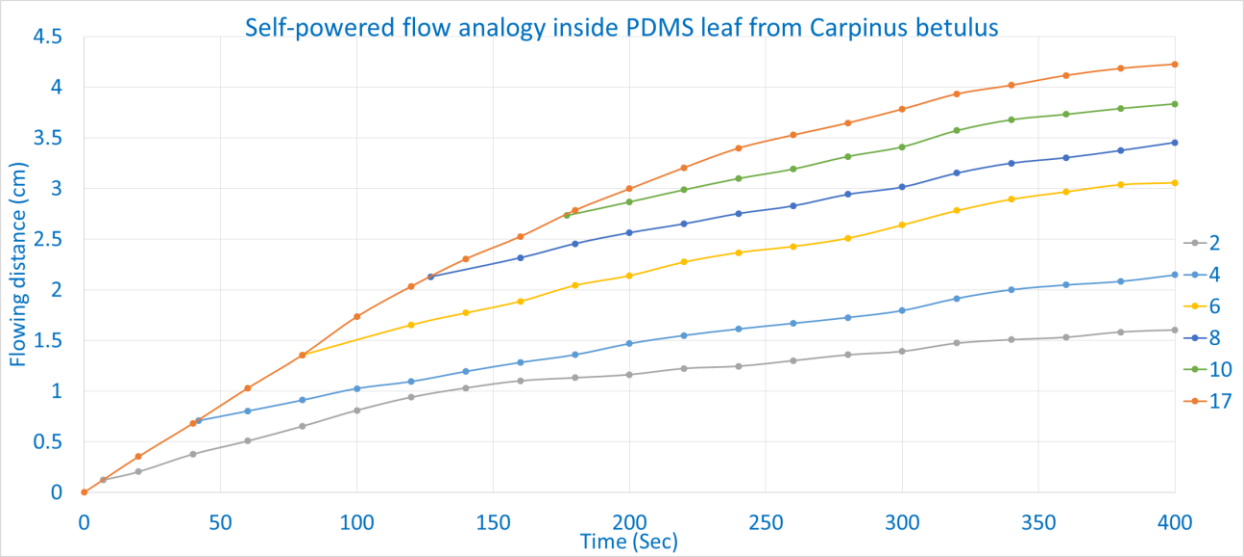

Fig. S8 Quantitative self-powered flow analogy inside PDMS leaf containing parallel networks replicated from Carpinus betulus. The flowing distance is plotted versus time, with a time interval of 20 secs.