Supplementary Information

Shear rate calculation

The fluid flow in our microchannels was laminar up to and including the maximum flow rates, which is indicated by the Reynolds number that remained $Re \leq 80$. Images of the cells were taken at positions at least 1 mm from the channel inlet, which is larger than the entrance length. This requirement ensured a fully developed fluid velocity profile in the interrogation regions selected for imaging. We can also assume a no-slip boundary condition on both PDMS and glass surfaces since the slip lengths reported for similar surfaces and flow speeds (shear rates) in our microchannels are below 100 nm which are negligible in comparison to the channel height (50 μm)[1–3]. For example, for a parallel plate channel corresponding to our microchannel dimensions, errors in the reported shear rate due to potential slip are approximately 1%. The laminar, fully developed fluid velocity profile in a rectangular cross section channel (Fig. 1B) is given by:

$$u(y,z) = \frac{1}{2\mu}\left(-\frac{\Delta p}{L}\right)\left[\frac{H^2}{4} - z^2 + \frac{8}{H}\sum_{n=1}^{\infty}\frac{(-1)^n}{\alpha_n^3}\cos(\alpha_n z)\frac{\cosh(\alpha_n y)}{\cosh\left(\frac{\alpha_n W}{2}\right)}\right], \quad (1)$$

$$\alpha_n = (2n-1)\frac{\pi}{H}$$

where the center of the Cartesian coordinate system is on the center of the rectangular cross section, x is in the flow direction, y is in the transverse flow direction in the image plane, and z is along the optical axis in the channel depth direction[4]. L, H, and W are the length, depth, and width of the channel respectively, μ is the dynamic fluid viscosity, and Δp is the pressure difference between the inlet and the outlet of the channel. In our experiments, a syringe pump specifies the volumetric flow rate, *Q,* which is related to the pressure gradient as follows:

$$Q = \frac{H^3 W}{12\mu}\left(-\frac{\Delta p}{L}\right)\left[1 - \frac{192}{H^4 W}\sum_{n=1}^{\infty}\frac{\tanh\left(\frac{\alpha_n W}{2}\right)}{\alpha_n^5}\right] \quad (2)$$

The fluid shear rate describes the rate of deformation of the fluid elements in flow, which is the key parameter relating fluid flow kinematics to the forces (i.e. stress) conferred to the surface attached cells in our system. For a simple Newtonian fluid at low Reynolds number such as our buffer solution, these forces are linearly proportional to the shear rate through the viscosity (see below). In our microfluidic channels, we take the wall shear rate at the center of the microfluidic channel:

$$S = \frac{\partial u}{\partial z}(y = 0, z = -H/2) \quad (3)$$

The high aspect ratio of our channel width to the depth ($W/H = 8$) ensures that variations in the shear rate across the microchannel wall in the transverse direction to flow are relatively minor.

Drag force on a single yeast cell

Fluid flow exerts a drag force on the spherical, surface attached cells which can detach from the substrate if it exceeds the adhesive force between the cell and the solid surface. The drag force F_D on a spherical particle in a simple, near-wall shear flow in low Reynolds number (i.e. Stokes flow) regime is given by[5]:

$$F_D = \frac{1}{2}\rho U_p^2 C_D A, \qquad C_D = 1.7009\frac{24}{Re_p} \quad (4)$$

where ρ is the density of the fluid, U_p is the velocity of the fluid at the center of the particle, C_D is the drag coefficient, A is the cross-sectional area of the particle, and Re_p is the Reynolds number of the particle.

Since the average diameter of a yeast cell, $d_p = 10\ \mu m$, is much smaller than the channel height, we assume a simple shear flow to calculate the drag force applied on the cell. For the minimum flow rate in our experiments (i.e. $Q = 1\ \mu L/min$), the flow speed in the center of the cell using Eq. 1 and 2 is $U_p = 500\ \mu m/s$. Therefore, the Reynolds number of the cell is $Re_p = \rho U_p d_p/\mu = 0.006$ which gives a maximum drag force of $F_D = 72\ pN$ using Eq. 4. This force on the cell increases linearly with increasing shear rate. However, at the largest shear rates examined ($10^4\ s^{-1} < S < 1.1 \times 10^5 s^{-1}$, corresponding to flow rates $90\ \mu L/min < Q < 1000\ \mu L/min$) the Reynolds number is large ($0.5 < Re_p < 6$) and the fluid flow is out of Stokes regime. Hence, at those corresponding shear rates, the forces on the cells are likely larger than our estimate due to inertial effects.

Obtaining mean detachment shear rates from the fraction of the cells remaining on the surface

The fraction of surface attached yeast cells remaining on the substrate at each shear rate *f*(*S*) represents the survival probability of cell attachment beyond a shear rate S. Therefore, the probability of detachment by a shear rate less than or equal to S is

$$F(S) = 1 - f(S) \tag{5}$$

which is equivalent to the cumulative probability function, $F(S) = \Pr(\hat{S} \leq S)$ where $\hat{S}$ is the detachment shear rate. The mean (expected) value of a continuous random variable X, $E[X]$ in terms of its cumulative density function is[6]:

$$E[X] = \int_0^\infty (1 - F(x))dx - \int_{-\infty}^0 F(x)dx \tag{6}$$

if at least one of the integrals is finite. The detachment shear rate, $\hat{S}$ is a continuous nonnegative variable and the second integral in Eq.4 is zero as $\hat{S} \geq 0$. Therefore, the mean (expected) detachment shear rate, $E[\hat{S}]$ is

$$E[\hat{S}] = \int_0^\infty f(S)dx \tag{7}$$

This integral was numerically calculated from our experimental data using MATLAB via the trapezoidal method. One caveat of the computation of the mean is that for the stickiest strains examined, the maximal detachment shear rate for the yeast cells is unknown. Due to experimental limitations, a small fraction ($f \approx 0.01\ to\ 0.1$) of these cells remained on the surface even in the highest shear rate of the experiments. Therefore, since f does not converge to zero on those cases, the computation of the mean is only approximate.

Single shear rate experiments

Single shear rate experiments were performed to test if data obtained from our adhesion assay, which implements increasing shear rate to release cells adhered to surface, stand true when a single shear rate is applied. Comparison between the two approaches – increasing vs. single shear rates, aims at answering the question of whether stepwise increase in shear rate introduces bias toward slip bond mediated adhesion and discriminates against adhesion relying on catch bonds. If the latter stands true, application of single shear rate per experiment would result in less cells being released from surface due to shear-induced activation of protein domains mediating catch bonding.

Σ1278b cell suspensions were prepared as for main adhesion assay (see section 2.1), introduced into the microchannels and a shear rate of 2.63×10^3 s^{-1}, 7.62×10^3 s^{-1} or 22.05×10^3 s^{-1} was applied following 30-minute incubation. Cells on the channel surface were imaged before and after shearing to determine

the number of cells remaining attached. With exception of the result obtained with $7.62x10^3$ s^{-1}, the outcome of these experiments (orange circles on Figure S6) nicely falls within the error range of data points from the adhesion assay. Taken together with the results from our separate $14.33x10^3 s^{-1}$ assay used for Σ1278b strain fractionation (not discussed in this manuscript) and shown as black circle on Figure S6, these single shear rate experiments straddle our original measurements - and support the findings from the adhesion assay. This generally good consistency with the smoothly increasing shear rate suggests that adhesion assay described here provides a generalized profile of adhesive properties of measured strains without favouring one type of attachment bonds, like slip bonds, over the other, like catch bonds.

Fractionation of weakly adherent strain W303

Fractionation of early-detaching W303 strain from a mixed suspension of W303 and Σ1278b was performed as follows. Cell suspension containing a mixture of two strains in the ratio of 1:1 was introduced into the microchannels and cells were allowed to settle for 30 minutes as described in the main text. Next, we used shear rate of 531.9 s^{-1} which should remove 85% of W303 cells while minimally affecting strongly adhered Σ1278b cells. Chosen shear rate was applied for 4 minutes as in our adhesion assay, outlet tubing was removed and manually flushed with 5 mL of buffer into the collection tube to avoid loss of cells due to spontaneous attachment to the polypropylene tubing walls and maximize the number of collected cells. Fresh tubing was then inserted into the outlet opening and the remaining cells were collected from the microchannel surface by applying shear rate of 286,650 s^{-1} for 1 minute. Collected fractions were mixed with 4 times the volume of liquid YPD medium and grown with shaking at 30 °C for 48 hours. Following 48 hours of growth, cell suspension was diluted 10^5-fold, 150ul was plated on YPD plates in triplicate and incubated for three days to allow colony formation. The results of these experiments are presented on Figure S8.

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