## **Supplementary Information**



**Figure S1.** Force-distance approach (red) and retract (blue) for selected control experiments for chitosan–pig gastric mucin and alginate–pig gastic mucin force unbinding experiments. (a) Force distance profiles for aminesilane functionalized AFM tip probed against carboxysilan functionalized mica (aqueous 10 mM Hepes, 150 mM NaCl, pH 7.4); (b) Force-distance profiles for chitosan ( $F_A = 0.01$ ) functionalized AFM tips probed against carboxysilane functionalized mica at pH 5.5 (aqueous 25 mM acetate buffer, 150 mM NaCl); (c) Force distance profiles for chitosan ( $F_A = 0.49$ ) functionalized AFM tips probed against carboxysilane functionalized mica at pH 6.9 (aqueous 25 mM Hepes buffer, 150 mM NaCl). The two uppermost and two lowermost force-distance profiles are among the ones classified within the group displaying interactions and not displaying interactions in the estimated  $P_{int}$ , respectively.



**Figure S2.** Histogram plots of two chosen sub-distributions (from Figure 5), one from the outer barrier and one from the inner barrier for all chitosan–mucin complexes. The blue curves represent fits of the distribution of unbinding forces P(f) (Equation (3)) for v = 1/2.



**Figure S3.** All energy landscape parameters for the outer barrier for chitosan ( $F_A = 0.49$ , pH 5.5)–mucin interactions from both the dynamic strength spectrum approach (blue) and the constant-force rupture-rate method (red) with v = 1/2. The average values are shown in solid lines, with standard deviations in dashed lines. Parameters obtained for 38 numbers of distributions for the whole data set (from which 19 were part of the outer barrier in the lower loading rate region, whilst the remaining 19 were part of the inner barrier at higher loading rates) correspond to the outer barrier values for chitosan ( $F_A = 0.49$ , pH 5.5)–mucin shown in Tables S2 and S3 and plots on Figures 5 and 6 in the main text. Note that not all regressions for the constant-force rupture-rate method were successful as this method requires tremendous amount of data to yield consistent constant-force rupture-rate plots as the ones shown in Figure 5.



**Figure S4.** All energy landscape parameters for the outer barrier for alginate  $F_G = 0.65$  (pH 6.9)–mucin interactions from both the dynamic strength spectrum approach (blue) and the constant-force rupture-rate method (red) with v = 1/2 which were used to calculate the averaged parameters. The average values are shown in solid lines, with standard deviations in dashed lines. Parameters obtained for 20 numbers of distributions for the whole data set (from which all 20 were part of the same barrier) correspond to the barrier values shown in Tables S2 and S3 and plots on Figure 8 in the main text.

**Table S1.** Averaged energy landscape parameters for chitosan-mucin and alginate-mucin interactions obtained from fits of Equation (2) with v=1/2 to analytically obtained constant-force unbinding-rate plots from forced unbinding histograms using Equation (5). The table displays average values over multiple regression analysis. Examples of distributions of unbinding forces and fit of P(f) (Equation (3)) for chitosan-pig gastric mucin interactions are shown in Figure S2.

| Constant Force Rupture Rate ( $v = 1/2$ ) |                            |             |   |               |                          |                                   |  |  |  |
|---|----------------------------|-------------|---|---------------|--------------------------|-----------------------------------|--|--|--|
| Polymer                                   | Solvent pH Range of f (nN) |             | $\langle x_{\beta} \rangle$ (nm) $\langle \tau_{0} \rangle$ (s) |               | $<\Delta G>(k_{\rm B}T)$ | Range of Predicted R <sup>2</sup> |  |  |  |
|   | 5.5                        | 0.018-0.036 | $0.95\pm0.24$   | $5.42\pm3.10$ | $8.06\pm2.03$            | 0.78-0.97                         |  |  |  |
| Chitosan                                  | 5.5                        | 0.037-0.066 | $0.42\pm0.14$   | $0.36\pm0.29$ | $7.02 \pm 1.33$          | 0.71-0.87                         |  |  |  |
| $(F_{\rm A} = 0.49)$                      | 6.9                        | 0.019-0.039 | $0.75\pm0.34$   | $2.10\pm2.26$ | $8.38\pm0.99$            | 0.80-0.95                         |  |  |  |
|   | 6.9                        | 0.043-0.074 | $0.35\pm0.10$   | $0.18\pm0.14$ | $7.97\pm0.91$            | 0.75–0.85                         |  |  |  |
|   | 5.5                        | 0.026-0.045 | $0.92\pm0.15$   | $4.84\pm2.75$ | $9.01\pm2.12$            | 0.80-0.91                         |  |  |  |
| Chitosan                                  | 5.5                        | 0.050-0.086 | $0.40\pm0.10$   | $0.30\pm0.17$ | $7.84 \pm 1.82$          | 0.74-0.85                         |  |  |  |
| $(F_{\rm A} = 0.01)$                      | 6.9                        | 0.029-0.051 | $0.64\pm0.06$   | $2.07\pm0.95$ | $7.70\pm0.86$            | 0.75-0.95                         |  |  |  |
|   | 6.9                        | 0.051-0.097 | $0.33\pm0.11$   | $0.35\pm0.33$ | $7.68\pm0.68$            | 0.73-0.87                         |  |  |  |
| Alginate $(F_{\rm G} = 0.65)$             | 6.9                        | 0.037-0.083 | $0.42 \pm 0.08$   | 2.52 ± 1.18   | $8.53 \pm 0.76$          | 0.80–0.97                         |  |  |  |

**Table S2.** Energy landscape parameters obtained for chitosan-mucin and alginate-mucin interactions with a specific amount of sub-distribution from the dynamic strength spectrum presentation, *i.e.*, fits of mean force  $\langle f \rangle$  versus corresponding mean loading rates  $\langle r_f \rangle$  (Equation (1)) with v = 1/2. These values correspond to Figure 5 in the main text. Note that estimates for v = 1/2 and v = 2/3 are in the same order of magnitude.

| Chitosan–Mucin     |     | Dynamic Strength Spectrum |           |                |            |                                    |           |                |            |                                    |
|--------------------|-----|---------------------------|-----------|----------------|------------|------------------------------------|-----------|----------------|------------|------------------------------------|
|                    |     |                           | (         | Inner Barrier  |            |                                    |           |                |            |                                    |
|                    |     | v                         | Range rf  | x <sub>β</sub> | τ0         | $\Delta G$                         | Range rf  | x <sub>β</sub> | τ0         | ΔG                                 |
|                    |     |                           | (nN/s)    | (nm)           | <b>(s)</b> | ( <i>k</i> <sub>B</sub> <i>T</i> ) | (nN/s)    | (nm)           | <b>(s)</b> | ( <i>k</i> <sub>B</sub> <i>T</i> ) |
| $F_{a}$            | pН  | 1                         |           | 0.41           | 0.27       | -                                  | -         | 0.11           | 0.05       | -                                  |
| 0.49               | 5.5 | 1/2                       | 0.64–1.89 | 1.13           | 2.82       | 7.15                               | 2.01-7.35 | 0.19           | 0.07       | 2.83                               |
|                    |     | 2/3                       |           | 0.82           | 1.37       | 5.88                               |           | 0.15           | 0.07       | 2.43                               |
|                    |     | 1                         |           | 0.36           | 0.17       | -                                  |           | 0.08           | 0.05       | -                                  |
| 0.49               | 6.9 | 1/2                       | 0.68–1.89 | 0.86           | 0.72       | 5.55                               | 2.09–9.46 | 0.13           | 0.06       | 2.44                               |
|                    |     | 2/3                       |           | 0.66           | 0.50       | 4.67                               |           | 0.10           | 0.06       | 2.00                               |
|                    |     | 1                         |           | 0.44           | 0.34       | -                                  |           | 0.10           | 0.04       | -                                  |
| 0.01               | 5.5 | 1/2                       | 1.02–2.57 | 1.19           | 5.34       | 8.27                               | 2.84-7.60 | 0.22           | 0.07       | 2.89                               |
|                    |     | 2/3                       |           | 0.97           | 3.5        | 7.21                               |           | 0.16           | 0.06       | 2.36                               |
|                    |     | 1                         |           | 0.46           | 0.57       | -                                  |           | 0.09           | 0.06       | -                                  |
| 0.01               | 6.9 | 1/2                       | 0.55-1.90 | 0.98           | 3.82       | 7.97                               | 2.08-5.36 | 0.19           | 0.08       | 2.72                               |
|                    |     | 2/3                       |           | 0.76           | 2.13       | 6.75                               |           | 0.13           | 0.08       | 2.18                               |
| Alginate-Mucin     |     | 1                         |           | 0.25           | 0.63       | -                                  | -         | -              | -          | -                                  |
| $F_{\rm G} = 0.65$ | 6.9 | 1/2                       | 0.32-4.96 | 0.44           | 1.92       | 7.41                               | -         | -              | -          | -                                  |
|                    |     | 2/3                       |           | 0.40           | 1.86       | 6.43                               | -         | -              | -          | -                                  |

**Table S3.** Energy landscape parameters for chitosan-mucin and alginate-mucin interactions with a specific amount of sub-distribution obtained from fits of Equation (2) with v = 1/2 to analytically obtained constant-force unbinding-rate plots from forced unbinding histograms using Equation (5). These values correspond to Figure 6 in the main text. Note that estimates for v = 1/2 and v = 2/3 are in the same order of magnitude.

| Chitosan–Mucin     |     | Constant-Force Rupture-Rate |             |                |            |                |             |           |            |                                    |  |
|--------------------|-----|-----------------------------|-------------|----------------|------------|----------------|-------------|-----------|------------|------------------------------------|--|
|                    |     |                             | Ou          | ter Barrio     | er         | Inner Barrier  |             |           |            |                                    |  |
|                    |     | ν                           | Range f     | x <sub>β</sub> | $	au_0$    | $\Delta G$     | Range f     | $x_{eta}$ | $	au_0$    | $\Delta G$                         |  |
|                    |     |                             | (nN)        | (nm)           | <b>(s)</b> | $(k_{\rm B}T)$ | (nN)        | (nm)      | <b>(s)</b> | ( <i>k</i> <sub>B</sub> <i>T</i> ) |  |
| Fa                 | pН  | 1                           |             | 0.49           | 1.00       | -              |             | 0.16      | 0.06       | -                                  |  |
| 0.49               | 5.5 | 1/2                         | 0.018-0.036 | 0.91           | 3.19       | 8.20           | 0.037–0.066 | 0.23      | 0.08       | 7.11                               |  |
|                    |     | 2/3                         |             | 0.83           | 2.82       | 7.03           |             | 0.22      | 0.08       | 5.80                               |  |
|                    |     | 1                           |             | 0.44           | 0.60       | -              |             | 0.15      | 0.04       | -                                  |  |
| 0.49               | 6.9 | 1/2                         | 0.019-0.039 | 1.00           | 3.97       | 8.49           | 0.043-0.074 | 0.24      | 0.04       | 6.94                               |  |
|                    |     | 2/3                         |             | 0.84           | 2.72       | 7.37           |             | 0.22      | 0.03       | 6.42                               |  |
|                    |     | 1                           |             | 0.33           | 0.39       | -              |             | 0.16      | 0.05       | -                                  |  |
| 0.01               | 5.5 | 1/2                         | 0.026-0.045 | 1.12           | 8.85       | 8.63           | 0.050–0.086 | 0.39      | 0.29       | 7.04                               |  |
|                    |     | 2/3                         |             | 0.90           | 5.23       | 7.50           |             | 0.32      | 0.20       | 5.98                               |  |
|                    |     | 1                           |             | 0.33           | 0.64       | -              |             | 0.14      | 0.06       | -                                  |  |
| 0.01               | 6.9 | 1/2                         | 0.029-0.051 | 0.86           | 6.86       | 8.65           | 0.051-0.097 | 0.19      | 0.08       | 7.90                               |  |
|                    |     | 2/3                         |             | 0.68           | 3.57       | 7.32           |             | 0.18      | 0.08       | 6.45                               |  |
| Alginate-Mucin     |     | 1                           | -           | 0.18           | 0.38       | -              | -           | -         | -          | -                                  |  |
| $F_{\rm G} = 0.65$ | 6.9 | 1/2                         | 0.037-0.083 | 0.39           | 1.37       | 7.12           | _           | -         | -          | -                                  |  |
|                    |     | 2/3                         |             | 0.33           | 1.02       | 6.14           | -           | -         | -          | -                                  |  |



**Figure S5.** Histogram plots of two chosen sub-distributions (from Figure 8), both from the same energy barrier for the alginate-mucin complex. The purple curves represent fits of the distribution of unbinding forces P(f) (Equation (3)) for v = 1/2.