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Effect of water flow and chemical environment on microbiota growth and composition in the human colon

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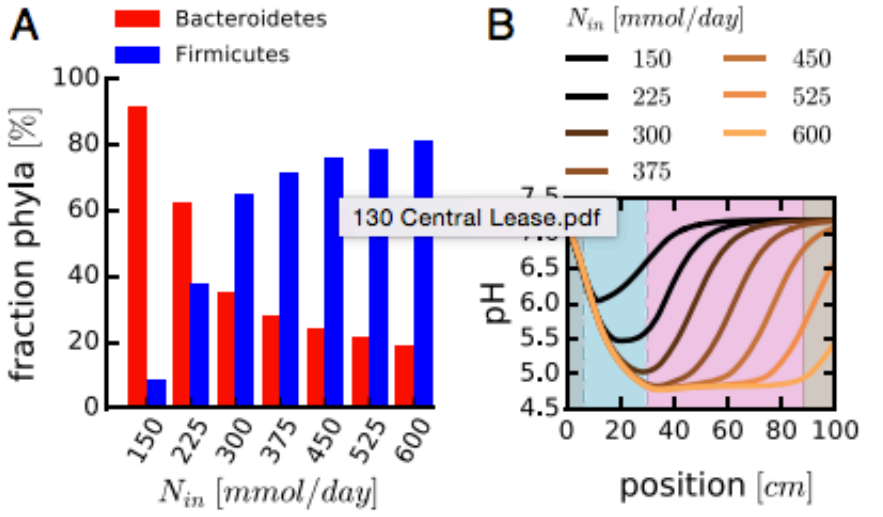

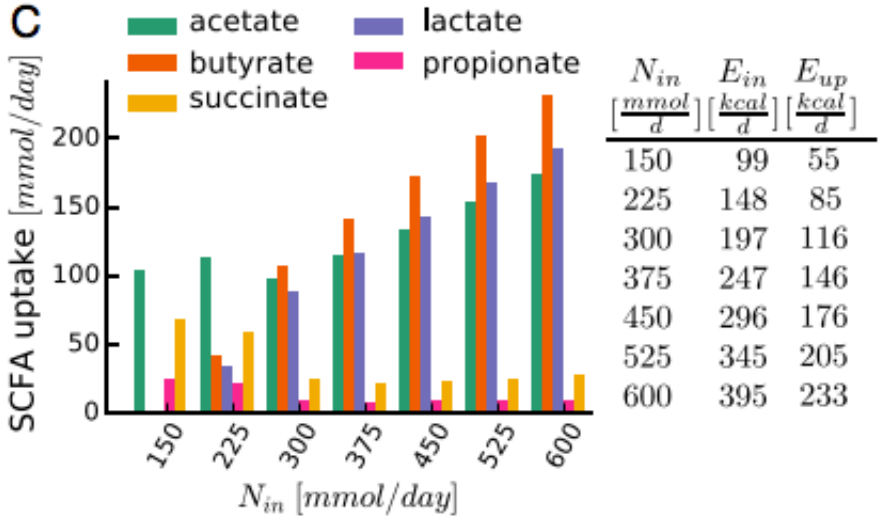

N_{in} $[\frac{mmol}{d}]$	E_{in} $[\frac{kcal}{d}]$	E_{up} $[\frac{kcal}{d}]$
150	99	55
225	148	85
300	197	116
375	247	146
450	296	176
525	345	205
600	395	233

130 Central Lease.pdf

Fig. 4. Changing nutrient intake affects microbiota composition and SCFA availability. The spatiotemporal dynamics of bacterial growth was analyzed for different rates of nutrient influx (N_{in}, in millimoles of glucose equivalents per day). (*A*) Relative abundance of Bacteroidetes and Firmicutes in the distal colon (mimicking "fecal" content), depending on nutrient influx. (*B*) pH profiles along the length of the colon; each colored line represents the result of a specific nutrient influx. (*C*) Epithelial uptake of different SCFAs (integrated along the length of the colon) for different nutrient influx. SCFA ratios are calculated based on measured excretion rates (Fig. 1*A*) and model results for phyla composition in *A*. Table provides the relationship between the nutrient influx (N_{in}), their corresponding energy content (E_{in}), and the amount of energy taken up by the epithelium in the form of SCFAs (E_{up}). The case of $N_{in} = 300$ mmol/d corresponds to the results shown in Fig. 3. Other parameters are as in *SI Appendix*, Tables S1 and S2. Values in *A* for position $x = 1.89$ m (end of colon). Values 130 Central Lease.pdf excretion profiles of different strains (Fig. 1*A* and *SI Appendix*, section 5.7). Simulation for 120 h. Profiles of other variables are shown in *SI Appendix*, Fig. S7 *A*–*C*.

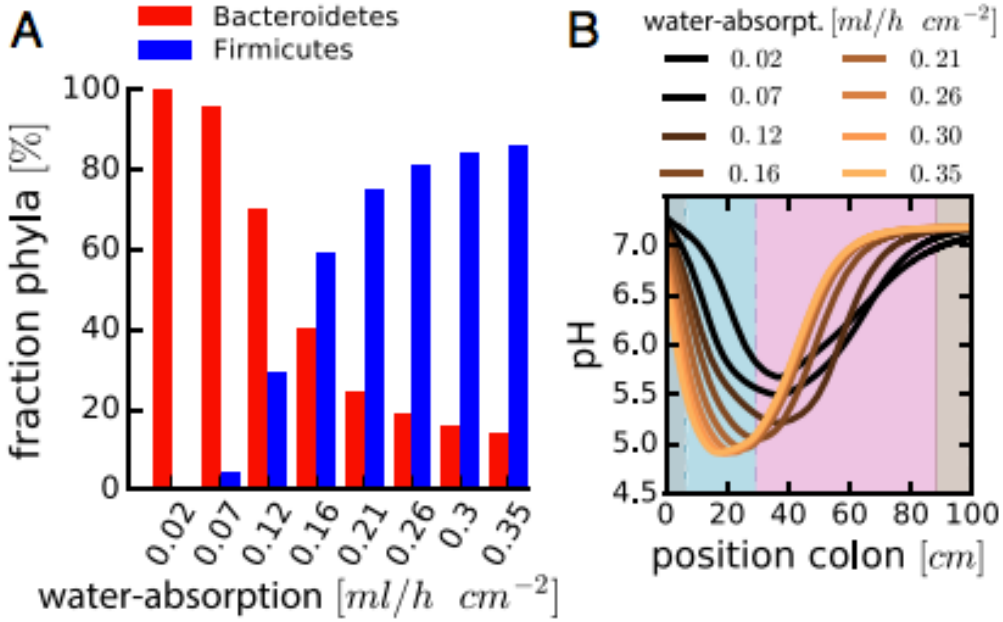

Fig. 5. The effect of colonic water uptake on microbiota composition. (*A*) Relative abundances of Bacteroidetes and Firmicutes in the distal colon for different values of water uptake. (*B*) pH profiles along the length of the colon; each colored line represents the result for a specific level of water absorption (water-absorpt). (*C*) Table relates water uptake to colonic transit times (TT) and stool consistency (BSS); see *SI Appendix*, section 5.8 and Fig. S5, for how these relations were determined. Water uptake of 0.25 mL/h·cm^2 corresponds to the results shown in Fig. 3. Other parameters are as in *SI Appendix*, Tables S1 and S2. Values in *A* for position $x = 1.89$ m (end of colon). Simulations for 120 h. Profiles of other variables are shown in *SI Appendix*, Fig. S7 *D–F*. Similar results are observed for changes in water inflow and outflow rates (*SI Appendix*, Fig. S8).

C

absorption $[ml/h \cdot cm^2]$	0.02	0.07	0.12	0.16	0.21	0.26	0.3	0.35
transit time $[h]$	24	72	85	91	94	96	97	98
BSS	5	3	2	2	2	1	1	1

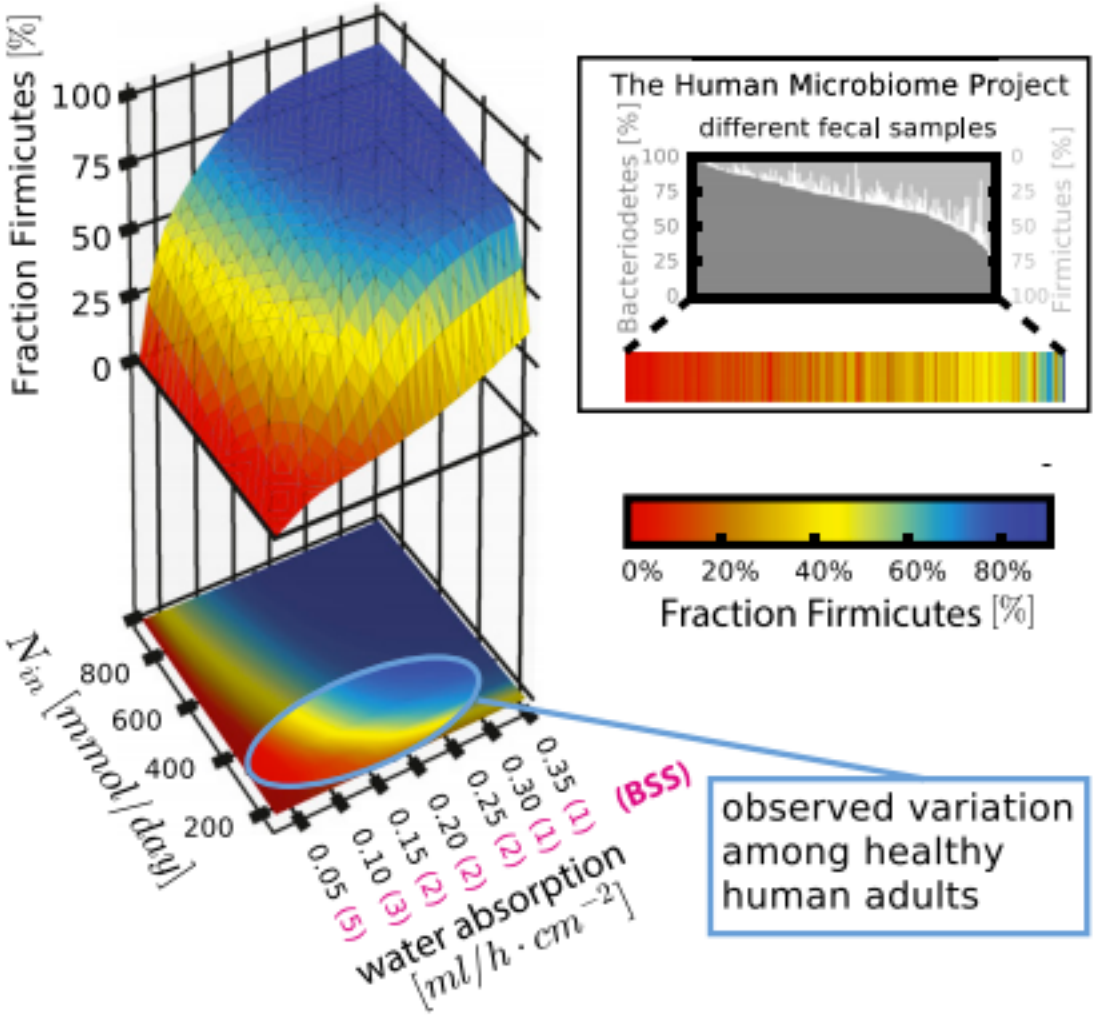

Fig. 6. Variation in microbiota composition for typical physiological parameters of the human host. Summarized results of our model investigating how the interplay of human and bacterial physiology mediated by water flow, absorption, and active mixing shape microbiota composition. The 3D plot shows the fraction of Firmicutes depending on the [redacted] rate of water uptake, as manifested by stool consistency (BSS). The bright area highlighted on the 2D projection indicates the parameter variations estimated for healthy adults consuming a Western diet (*SI Appendix*, sections 2.6 and 5.8). The bar plot in the *Inset* shows data on phyla composition in 242 healthy subjects from the Human Microbiome Project (6) (heat map corresponds to heat map in main panel). The observed variation in phyla can be readily accounted for by differences in nutrient intake and stool consistency. Corroborating this observation, BSS has been identified as the single most important determinant for microbiota composition among 69 covariates studied (44). Parameters are as in *SI Appendix*, Tables S1 and S2. Simulation for 120 h. Values for $x = 1.89$ m (end of colon).