

## LITERATURVERZEICHNIS

1. Brandtzaeg, P. et al. Nature and properties of the human gastrointestinal immune system. in *Immunology of the gastrointestinal tract*. 1–85 (1987).
2. Brandtzaeg, P. et al. The B-cell system of human mucosae and exocrine glands. *Immunological Reviews* 171, 45–87 (1999).
3. Kaetzel, C. S. Cooperativity among secretory IgA, the polymeric immunoglobulin receptor, and the gut microbiota promotes host-microbial mutualism. *Immunology Letters* 162, 10–21 (2014).
4. Furness, J. B. Integrated Neural and Endocrine Control of Gastrointestinal Function. in *The Enteric Nervous System: 30 Years Later* (eds. Brierley, S. & Costa, M.) 159–173 (Springer International Publishing, 2016). doi:10.1007/978-3-319-27592-5\_16.
5. Furness, J. B. The enteric nervous system and neurogastroenterology. *Nature Reviews Gastroenterology & Hepatology* 9, 286–294 (2012).
6. Schmidt, R. F. & Lang, F. *Physiologie des Menschen mit Pathophysiologie*. (Springer, 2007).
7. Silbernagel, S. & Agamemnon, D. *Taschenatlas Physiologie*. (Thieme Verlag, 2007).
8. Helander, H. F. & Fändriks, L. Surface area of the digestive tract - revisited. *Scandinavian Journal of Gastroenterology* 49, 681–689 (2014).
9. Schünke, M., Schulte, E. & Schumacher, U. *Prometheus - Lern Atlas der Anatomie Innere Organe*. (Georg Thieme Verlag, 2011).
10. Lüllmann-Rauch, R. & Asan, E. *Taschenlehrbuch Histologie*. (Georg Thieme Verlag, 2019).
11. Niess, J. H. & Reinecker, H.-C. Dendritic cells in the recognition of intestinal microbiota. *Cellular Microbiology* 8, 558–564 (2006).
12. Kararli, T. T. Comparison of the gastrointestinal anatomy, physiology, and biochemistry of humans and commonly used laboratory animals. *Biopharmaceutics & Drug Disposition* 16, 351–380 (1995).
13. Macdonald, T. T. & Monteleone, G. Immunity, inflammation, and allergy in the gut. *Science* 307, 1920–1925 (2005).
14. Fröhlich, E., Mercuri, A., Wu, S. & Salar-Behzadi, S. Measurements of Deposition, Lung Surface Area and Lung Fluid for Simulation of Inhaled Compounds. *Frontiers in Pharmacology* 7, 181 (2016). doi: 10.3389/fphar.2016.00181.
15. Iacob, S. & Iacob, D. G. Infectious Threats, the Intestinal Barrier, and Its Trojan Horse: Dysbiosis. *Frontiers in Microbiology* 10, 1676 (2019). doi: 10.3389/fmicb.2019.01676.
16. Natividad, J. M. M. & Verdu, E. F. Modulation of intestinal barrier by intestinal microbiota: pathological and therapeutic implications. *Pharmacological Research* 69, 42–51 (2013).
17. Hooper, L. V. Do symbiotic bacteria subvert host immunity? *Nature Reviews Microbiology* 7, 367–374 (2009).
18. Cerf-Bensussan, N. & Gaboriau-Routhiau, V. The immune system and the gut microbiota: friends or foes? *Nature Reviews Immunology* 10, 735–744 (2010).
19. Ganai-Vonarburg, S. C. & Duerr, C. U. The interaction of intestinal microbiota and innate lymphoid cells in health and disease throughout life. *Immunology* 159, 39–51 (2020).
20. Aurora, R. & Sanford, T. Host Microbiota Contributes to Health and Response to Disease. *Missouri Medicine* 112, 317–322 (2014).
21. Bohnhoff, M., Drake, B. L. & Miller, C. P. Effect of Streptomycin on Susceptibility of Intestinal Tract to Experimental Salmonella Infection. *Proceedings of the Society for Experimental Biology and Medicine* 86, 132–137 (1954).
22. Miller, C. P. Protective action of the normal microflora against enteric infection: an experimental study in the mouse. *Medical Bulletin* 25, 272–279 (1959).
23. Pickard, J. M., Zeng, M. Y., Caruso, R. & Núñez, G. Gut microbiota: Role in pathogen colonization, immune responses, and inflammatory disease. *Immunological Reviews* 279, 70–89 (2017).
24. Li, Z. et al. Effects of Metabolites Derived From Gut Microbiota and Hosts on Pathogens. *Frontiers in Cellular and Infection Microbiology* 8, 314 (2018). doi: 10.3389/fcimb.2018.00314.
25. Cheng, H.-Y., Ning, M.-X., Chen, D.-K. & Ma, W.-T. Interactions Between the Gut Microbiota and the Host Innate Immune Response Against Pathogens. *Frontiers in Immunology* 10, 607 (2019). doi: 10.3389/fimmu.2019.00607.
26. Surendran Nair, M., Amalaradjou, M. A. & Venkitanarayanan, K. Antivirulence Properties of Probiotics in Combating Microbial Pathogenesis. *Advances in Applied Microbiology* 98, 1–29 (2017).
27. Schwalfenberg, G. K. The Alkaline Diet: Is There Evidence That an Alkaline pH Diet Benefits Health? *Journal of Environmental and Public Health* (2012). doi: 10.1155/2012/727630.
28. Fallingborg, J. Intraluminal pH of the human gastrointestinal tract. *Danish Medical Bulletin* 46, 183–196 (1999).
29. Hensgens, M. P. M., Goorhuis, A., Dekkers, O. M. & Kuijper, E. J. Time interval of increased risk for *Clostridium difficile* infection after exposure to antibiotics. *Journal of Antimicrobial Chemotherapy* 67, 742–748 (2012).
30. Lakshminarayanan, B. et al. Isolation and characterization of bacteriocin-producing bacteria from the intestinal microbiota of elderly Irish subjects. *Journal of Applied Microbiology* 114, 886–898 (2013).
31. Casey, P. G. et al. Isolation and characterization of anti-Salmonella lactic acid bacteria from the porcine gastrointestinal tract. *Letters in Applied Microbiology* 39, 431–438 (2004).
32. Corr, S. C. et al. Bacteriocin production as a mechanism for the anti-infective activity of *Lactobacillus salivarius* UCC118. *Proceedings of the National Academy of Sciences* 104, 7617–7621 (2007).
33. Allende, A. et al. Growth and bacteriocin production by lactic acid bacteria in vegetable broth and their effectiveness at reducing *Listeria monocytogenes* in vitro and in fresh-cut lettuce. *Food Microbiology* 24, 759–766 (2007).
34. Stern, N. J. et al. Isolation of a *Lactobacillus salivarius* Strain and Purification of Its Bacteriocin, Which Is Inhibitory to *Campylobacter jejuni* in the Chicken Gastrointestinal System. *Antimicrobial Agents and Chemotherapy* 50, 3111–3116 (2006).
35. Svetoch, E. A. et al. Isolation of *Lactobacillus salivarius* 1077 (NRRL B-50053) and Characterization of Its Bacteriocin, Including the Antimicrobial Activity Spectrum. *Applied and Environmental Microbiology* 77, 2749–2754 (2011).
36. Rea, M. C. et al. Antimicrobial activity of lacticin 3147 against clinical *Clostridium difficile* strains. *Journal of Medical Microbiology* 56, 940–946 (2007).
37. Brashears, M. M., Jaroni, D. & Trimble, J. Isolation, selection, and characterization of lactic acid bacteria for a competitive exclusion product to reduce shedding of *Escherichia coli* O157:H7 in cattle. *Journal of Food Protection* 66, 355–363 (2003).
38. Knaus, U. G., Hertzberger, R., Pircalabioru, G. G., Yousefi, S. P. M. & Branco dos Santos, F. Pathogen control at the intestinal mucosa – H<sub>2</sub>O<sub>2</sub> to the rescue. *Gut Microbes* 8, 67–74 (2017).
39. Liu, D. et al. The mechanisms and safety of probiotics against toxigenic *clostridium difficile*. *Expert Review of Anti-infective Therapy* 18, 967–975 (2020).
40. Stadlbauer, V. Immunosuppression and probiotics: are they effective and safe? *Beneficial Microbes* 6, 823–828 (2015).
41. Hooper, L., Littman, D. R. & Macpherson, A. J. Interactions between the microbiota and the immune system. *Science* 336, 1268–1273 (2012).
42. Niers, L. E. M. et al. Selection of probiotic bacteria for prevention of allergic diseases: immunomodulation of neonatal dendritic cells. *Clinical and Experimental Immunology* 149, 344–352 (2007).
43. de Rooij, S. et al. Lactic acid bacteria differ in their ability to induce functional regulatory T cells in humans. *Clinical & Experimental Allergy* 40, 103–110 (2010).
44. Bischoff, S. C. et al. Intestinal permeability—a new target for disease prevention and therapy. *BMC Gastroenterology* 14, 189 (2014). doi: 10.1186/s12876-014-0189-7.
45. Ohland, C. L. & Macnaughton, W. K. Probiotic bacteria and intestinal epithelial barrier function. *American Journal of Physiology. Gastrointestinal and Liver Physiology* 298, G807–G819 (2010).
46. Ulluwishewa, D. et al. Regulation of tight junction permeability by intestinal bacteria and dietary components. *Journal of Nutrition* 141, 769–776 (2011).
47. Resta-Lenert, S. & Barrett, K. E. Live probiotics protect intestinal epithelial cells from the effects of infection with enteroinvasive *Escherichia coli* (EIEC). *Gut* 52, 988–997 (2003).
48. Karczewski, J. et al. Regulation of human epithelial tight junction proteins by *Lactobacillus plantarum* in vivo and protective effects on the epithelial barrier. *American Journal of Physiology. Gastrointestinal and Liver Physiology* 298, G851–G859 (2010).
49. Deplancke, B. & Gaskins, H. R. Microbial modulation of innate defense: goblet cells and the intestinal mucus layer. *American Journal of Clinical Nutrition* 73, 1131S–1141S (2001).

50. Burger-van Paassen, N. et al. The regulation of intestinal mucin MUC2 expression by short-chain fatty acids: implications for epithelial protection. *Biochemical Journal* 420, 211–219 (2009).
51. Mack, D. R., Michail, S., Wei, S., McDougall, L. & Hollingsworth, M. A. Probiotics inhibit enteropathogenic *E. coli* adherence in vitro by inducing intestinal mucin gene expression. *American Journal of Physiology* 276, G941-G950 (1999).
52. Kim, Y. S. & Ho, S. B. Intestinal goblet cells and mucins in health and disease: recent insights and progress. *Current Gastroenterology Reports* 12, 319–330 (2010).
53. Cornick, S., Tawiah, A. & Chadee, K. Roles and regulation of the mucus barrier in the gut. *Tissue Barriers* 3, e982426 (2015).
54. Mattar, A. F. et al. Probiotics up-regulate MUC-2 mucin gene expression in a Caco-2 cell-culture model. *Pediatric Surgery International* 18, 586–590 (2002).
55. Otani, T. & Furuse, M. Tight Junction Structure and Function Revisited. *Trends in Cell Biology* 30, 805–817 (2020).
56. Xue, Y. et al. Host inflammatory response inhibits *Escherichia coli* O157:H7 adhesion to gut epithelium through augmentation of mucin expression. *Infection and Immunity* 82, 1921–1930 (2014).
57. Pelaseyed, T. et al. The mucus and mucins of the goblet cells and enterocytes provide the first defense line of the gastrointestinal tract and interact with the immune system. *Immunological Reviews* 260, 8–20 (2014).
58. Paone, P. & Cani, P. D. Mucus barrier, mucins and gut microbiota: the expected slimy partners? *Gut* 69, 2232–2243 (2020).
59. Sontheimer-Phelps, A. et al. Human Colon-on-a-Chip Enables Continuous In Vitro Analysis of Colon Mucus Layer Accumulation and Physiology. *Cellular and Molecular Gastroenterology and Hepatology* 9, 507–526 (2020).
60. Gustafsson, J. K. et al. An ex vivo method for studying mucus formation, properties, and thickness in human colonic biopsies and mouse small and large intestinal explants. *American Journal of Physiology-Gastrointestinal and Liver Physiology* 302, G430–G438 (2012).
61. Johansson, M. E. et al. The inner of the two Muc2 mucin-dependent mucus layers in colon is devoid of bacteria. *Proceedings of the National Academy of Sciences* 105, 15064–15069 (2008).
62. Johansson, M. E. V. Fast Renewal of the Distal Colonic Mucus Layers by the Surface Goblet Cells as Measured by In Vivo Labeling of Mucin Glycoproteins. *PLoS One* 7, e41009 (2012).
63. Ouwerkerk, J. P. et al. Glycobiome: bacteria and mucus at the epithelial interface. *Best practice & research. Clinical Gastroenterology* 27, 25–38 (2013).
64. Derrien, M., Vaughan, E. E., Plugge, C. M. & Vos, W. M. *Akkermansia muciniphila* gen. nov., sp. nov., a human intestinal mucin-degrading bacterium. *International Journal of Systematic and Evolutionary Microbiology* 54, 1469–1476 (2004).
65. Ottman, N. Action and function of *Akkermansia muciniphila* in microbiome ecology, health and disease. *Best Practice & Research Clinical Gastroenterology* 6, 637–642 (2017).
66. Kosciow, K. & Deppenmeier, U. Characterization of three novel  $\beta$ -galactosidases from *Akkermansia muciniphila* involved in mucin degradation. *International Journal of Biological Macromolecules* 149, 331–340 (2020).
67. Sicard, J.-F., Le Bihan, G., Vogeleer, P., Jacques, M. & Harel, J. Interactions of Intestinal Bacteria with Components of the Intestinal Mucus. *Frontiers in Cellular and Infection Microbiology* 7, 387 (2017). doi: 10.3389/fcimb.2017.00387.
68. Ruas-Madiedo, P., Gueimonde, M., Fernández-García, M., Reyes-Gavilán, C. G. & Margolles, A. Mucin Degradation by Bifidobacterium Strains Isolated from the Human Intestinal Microbiota. *Applied and Environmental Microbiology* 74, 1936–1940 (2008).
69. Subramani, D. B., Johansson, M. E., Dahlén, G. & Hansson, G. C. Lactobacillus and Bifidobacterium species do not secrete protease that cleaves the MUC2 mucin which organises the colon mucus. *Beneficial Microbes* 1, 343–350 (2010).
70. Ruseler-van Embden, J. G., Lieshout, L. M., Gosselink, M. J. & Marteau, P. Inability of Lactobacillus casei strain GG, L. acidophilus, and Bifidobacterium bifidum to degrade intestinal mucus glycoproteins. *Scandinavian Journal of Gastroenterology* 30, 675–680 (1995).
71. Gao, J. et al. A Novel Postbiotic From Lactobacillus rhamnosus GG With a Beneficial Effect on Intestinal Barrier Function. *Frontiers in Microbiology* 10, 477 (2019). doi: 10.3389/fmicb.2019.00477.
72. Michielan, A. & D'Inca, R. Intestinal Permeability in Inflammatory Bowel Disease: Pathogenesis, Clinical Evaluation, and Therapy of Leaky Gut. *Mediators of Inflammation* 2015, 628157 (2015).
73. McCole, D. F. IBD candidate genes and intestinal barrier regulation. *Inflammatory Bowel Diseases* 20, 1829–1849 (2014).
74. Png, C. W. et al. Mucolytic Bacteria With Increased Prevalence in IBD Mucosa Augment In Vitro Utilization of Mucin by Other Bacteria. *American Journal of Gastroenterology* 105, 2420–2428 (2010).
75. Salzman, N. H., Underwood, M. A. & Bevins, C. L. Paneth cells, defensins, and the commensal microbiota: A hypothesis on intimate interplay at the intestinal mucosa. *Seminars in Immunology* 19, 70–83 (2007).
76. Courth, L. F. et al. Crohn's disease-derived monocytes fail to induce Paneth cell defensins. *Proceedings of the National Academy of Sciences of the United States of America* 112, 14000–14005 (2015).
77. Donaldson, G. P. et al. Gut microbiota utilize immunoglobulin A for mucosal colonization. *Science* 360, 795–800 (2018).
78. Lebeer, S., Vanderleyden, J. & De Keersmaecker, S. C. J. Genes and Molecules of Lactobacilli Supporting Probiotic Action. *Microbiology and Molecular Biology Reviews* 72, 728–764 (2008).
79. Vareille, M., Kieninger, E., Edwards, M. R. & Regamey, N. The Airway Epithelium: Soldier in the Fight against Respiratory Viruses. *Clinical Microbiology Reviews* 24, 210–229 (2011).
80. Brandtzaeg, P. Mucosal immunity: induction, dissemination, and effector functions. *Scandinavian Journal of Immunology* 70, 505–515 (2009).
81. Macallan, D., Borghans, J. & Asquith, B. Human T Cell Memory: A Dynamic View. *Vaccines* 5, 5 (2017).
82. Pabst, O. & Mowat, A. M. Oral tolerance to food protein. *Mucosal Immunology* 5, 232–239 (2012).
83. Jain, A. & Pasare, C. Innate Control of Adaptive Immunity: Beyond the Three-Signal Paradigm. *Journal of Immunology* 198, 3791–3800 (2017).
84. Dillon, A. & Lo, D. D. M Cells: Intelligent Engineering of Mucosal Immune Surveillance. *Frontiers in Immunology* 10, 1499 (2019). doi: 10.3389/fimmu.2019.01499.
85. Neutra, M. R., Mantis, N. J. & Kraehenbuhl, J.-P. Collaboration of epithelial cells with organized mucosal lymphoid tissues. *Nature Immunology* 2, 1004–1009 (2001).
86. Mowat, A. M. Anatomical basis of tolerance and immunity to intestinal antigens. *Nature Reviews Immunology* 3, 331–341 (2003).
87. Macpherson, A. J. & Smith, K. Mesenteric lymph nodes at the center of immune anatomy. *Journal of Experimental Medicine* 203, 497–500 (2006).
88. Ermund, A., Gustafsson, J. K., Hansson, G. C. & Keita, A. Mucus properties and goblet cell quantification in mouse, rat and human ileal Peyer's patches. *PLoS One* 8, e83688 (2013).
89. Ermund, A., Schütte, A., Johansson, M. E., Gustafsson, J. K. & Hansson, G. C. Studies of mucus in mouse stomach, small intestine, and colon. I. Gastrointestinal mucus layers have different properties depending on location as well as over the Peyer's patches. *American Journal of Physiology. Gastrointestinal and Liver Physiology* 305, G341–G347 (2013).
90. Suzuki, K. et al. The Sensing of Environmental Stimuli by Follicular Dendritic Cells Promotes Immunoglobulin A Generation in the Gut. *Immunity* 33, 71–83 (2010).
91. Carrega, P. & Ferlazzo, G. Natural killer cell distribution and trafficking in human tissues. *Frontiers in Immunology* 3, 347 (2012). doi: 10.3389/fimmu.2012.00347.
92. Walker, W. A. & Iyengar, R. S. Breast milk, microbiota, and intestinal immune homeostasis. *Pediatric Research* 77, 220–228 (2015).
93. Walker, W. A. Initial intestinal colonization in the human infant and immune homeostasis. *Annals of Nutrition & Metabolism* 63 Suppl 2, 8–15 (2013).
94. Shi, H. N. & Walker, A. Bacterial colonization and the development of intestinal defences. *Canadian Journal of Gastroenterology* 18, 493–500 (2004).
95. Goto, Y. & Kiyono, H. Epithelial barrier: an interface for the cross-communication between gut flora and immune system. *Immunological Reviews* 245, 147–163 (2012).
96. Kelly, D., Delday, M. I. & Mulder, I. Microbes and microbial effector molecules in treatment of inflammatory disorders. *Immunological Reviews* 245, 27–44 (2012).
97. Raphael, I., Nalawade, S., Eagar, T. N. & Forsthuber, T. G. T cell subsets and their signature cytokines in autoimmune and inflammatory diseases. *Cytokine* 74, 5–17 (2015).
98. Fonseca-Camarillo, G. & Yamamoto-Furusho, J. K. Immunoregulatory Pathways Involved in Inflammatory Bowel Disease. *Inflammatory Bowel Diseases* 21, 2188–2193 (2015).
99. Fava, F. & Danese, S. Intestinal microbiota in inflammatory bowel disease: friend or foe? *World Journal of Gastroenterology* 17, 557–566 (2011).

100. Sartor, R. B. Microbial Influences in Inflammatory Bowel Diseases. *Gastroenterology* 134, 577–594 (2008).
101. McFadden, J. P., Thyssen, J. P., Basketter, D. A., Puangpet, P. & Kimber, I. T helper cell 2 immune skewing in pregnancy/early life: chemical exposure and the development of atopic disease and allergy. *British Journal of Dermatology* 172, 584–591 (2015).
102. West, C. E., Jenmalm, M. C. & Prescott, S. L. The gut microbiota and its role in the development of allergic disease: a wider perspective. *Clinical and Experimental Allergy* 45, 43–53 (2015).
103. Sepp, E., Julge, K., Mikelsaar, M. & Björkstén, B. Intestinal microbiota and immunoglobulin E responses in 5-year-old Estonian children. *Clinical & Experimental Allergy* 35, 1141–1146 (2005).
104. Gore, C. et al. *Bifidobacterium pseudocatenulatum* is associated with atopic eczema: A nested case-control study investigating the fecal microbiota of infants. *Journal of Allergy and Clinical Immunology* 121, 135–140 (2008).
105. Chen, K. & Cerutti, A. Vaccination strategies to promote mucosal antibody responses. *Immunity* 33, 479–491 (2010).
106. Brandtzaeg, P. Induction of secretory immunity and memory at mucosal surfaces. *Vaccine* 25, 5467–5484 (2007).
107. Macpherson, A. J., McCoy, K. D., Johansen, F.-E. & Brandtzaeg, P. The immune geography of IgA induction and function. *Mucosal Immunology* 1, 11–22 (2008).
108. Brandtzaeg, P. The mucosal immune system and its integration with the mammary glands. *Journal of Pediatrics* 156, S8–S15 (2010).
109. Dollé, L., Tran, H. Q., Etienne-Mesmin, L. & Chassaing, B. Policing of gut microbiota by the adaptive immune system. *BMC Medicine* 14, 27 (2016).
110. Pabst, O., Cerovic, V. & Hornef, M. Secretory IgA in the Coordination of Establishment and Maintenance of the Microbiota. *Trends in Immunology* 37, 287–296 (2016).
111. Kikuchi, Y. et al. In vivo dose response and in vitro mechanistic analysis of enhanced immunoglobulin A production by *Lactobacillus plantarum* AYA. *Bioscience of Microbiota, Food and Health* 34, 53–58 (2015).
112. Wang, P. et al. Isolation of *Lactobacillus reuteri* from Peyer's patches and their effects on sIgA production and gut microbiota diversity. *Molecular Nutrition & Food Research* (2016). doi:10.1002/mnfr.201501065.
113. Pietrzak, B., Tomela, K., Olejnik-Schmidt, A., Mackiewicz, A. & Schmidt, M. Secretory IgA in Intestinal Mucosal Secretions as an Adaptive Barrier against Microbial Cells. *International Journal of Molecular Sciences* 21, 9254 (2020). doi: 10.3390/ijms21239254.
114. Robert Koch-Institut (RKI). Krebs in Deutschland | 2015/2016. (2019).
115. Stallmach, A., Häuser, W., L'hoest, H. & Marschall, U. Die chronisch entzündlichen Darmerkrankungen Morbus Crohn und Colitis ulcerosa. *Barmer GEK Gesundheitswesen aktuell* 2012, 286–309 (2012).
116. Wehkamp, J., Götz, M., Herrlinger, K., Steurer, W. & Stange, E. F. Inflammatory Bowel Disease: Crohn's disease and ulcerative colitis. *Deutsches Ärzteblatt Online* (2016). doi:10.3238/arztebl.2016.0072.
117. Stausberg, J. Epidemiologie der Clostridium-difficile-Infektion. *Deutsches Ärzteblatt International* 112, 345 (2015). doi: 10.3238/arztebl.2015.0345a.
118. Hua, X., Goedert, J. J., Pu, A., Yu, G. & Shi, J. Allergy associations with the adult fecal microbiota: Analysis of the American Gut Project. *EBioMedicine* 3, 172–179 (2015).
119. Hong, P.-Y. et al. Comparative Analysis of Fecal Microbiota in Infants with and without Eczema. *PLoS One* 5, e9964 (2010).
120. Zheng, H. et al. Altered Gut Microbiota Composition Associated with Eczema in Infants. *PLoS One* 11, e0166026 (2016).
121. Abrahamsson, T. R. et al. Low diversity of the gut microbiota in infants with atopic eczema. *Journal of Allergy and Clinical Immunology* 129, 434–440.e2 (2012).
122. Sonnenburg, J. L. & Bäckhed, F. Diet-microbiota interactions as moderators of human metabolism. *Nature* 535, 56–64 (2016).
123. Liang, S., Wu, X., Hu, X., Wang, T. & Jin, F. Recognizing Depression from the Microbiota-Gut-Brain Axis. *International Journal of Molecular Sciences* 19, 1592 (2018). doi: 10.3390/ijms19061592.
124. Camilleri, M. The Leaky Gut: Mechanisms, Measurement and Clinical Implications in Humans. *Gut* 68, 1516–1526 (2019).
125. Vogelsang, H., Schwarzenhofer, M. & Oberhuber, G. Changes in gastrointestinal permeability in celiac disease. *Digestive Diseases* 16, 333–336 (1998).
126. Li, L. et al. Increased small intestinal permeability and RNA expression profiles of mucosa from terminal ileum in patients with diarrhoea-predominant irritable bowel syndrome. *Digestive and Liver Disease* 48, 880–887 (2016).
127. González-Castro, A. M. et al. Mucosal pathobiology and molecular signature of epithelial barrier dysfunction in the small intestine in Irritable Bowel Syndrome. *Journal of Gastroenterology and Hepatology* (2016). doi:10.1111/jgh.13417.
128. Landy, J. et al. Tight junctions in inflammatory bowel diseases and inflammatory bowel disease associated colorectal cancer. *World Journal of Gastroenterology* 22, 3117–3126 (2016).
129. Arcangelis, A. et al. Hemidesmosome integrity protects the colon against colitis and colorectal cancer. *Gut* (2016). doi:10.1136/gutjnl-2015-310847.
130. Fasano, A. Zonulin, regulation of tight junctions, and autoimmune diseases. *Annals of the New York Academy of Sciences* 1258, 25–33 (2012).
131. Maffei, C. et al. Association between intestinal permeability and fecal microbiota composition in Italian children with beta cell autoimmunity at risk for type 1 diabetes. *Diabetes/Metabolism Research and Reviews* (2016). doi:10.1002/dmrr.2790.
132. Yeoh, N., Burton, J. P., Suppiah, P., Reid, G. & Stebbings, S. The Role of the Microbiome in Rheumatic Diseases. *Current Rheumatology Reports* 15, 314 (2013).
133. Buscarino, M. C. et al. Altered intestinal permeability in patients with relapsing-remitting multiple sclerosis: A pilot study. *Multiple Sclerosis* (2016). doi:10.1177/1352458516652498.
134. Nouri, M., Bredberg, A., Westrom, B. & Lavasani, S. Intestinal barrier dysfunction develops at the onset of experimental autoimmune encephalomyelitis, and can be induced by adoptive transfer of auto-reactive T cells. *PLoS One* 9, e106335 (2014).
135. Miele, L. et al. Increased intestinal permeability and tight junction alterations in nonalcoholic fatty liver disease. *Hepatology* 49, 1877–1887 (2009).
136. Fukui, H. Gut-liver axis in liver cirrhosis: How to manage leaky gut and endotoxemia. *World Journal of Hepatology* 7, 425–442 (2015).
137. Lin, R., Zhou, L., Zhang, J. & Wang, B. Abnormal intestinal permeability and microbiota in patients with autoimmune hepatitis. *International Journal of Clinical and Experimental Pathology* 8, 5153–5160 (2015).
138. Ilan, Y. Leaky gut and the liver: a role for bacterial translocation in nonalcoholic steatohepatitis. *World Journal of Gastroenterology* 18, 2609–2618 (2012).
139. Peng, S.-N., Zeng, H.-H., Fu, A.-X., Chen, X.-W. & Zhu, Q.-X. Effects of rhein on intestinal epithelial tight junction in IgA nephropathy. *World Journal of Gastroenterology* 19, 4137–4145 (2013).
140. Terpstra, M. L., Singh, R., Geerlings, S. E. & Bemelman, F. J. Measurement of the intestinal permeability in chronic kidney disease. *World Journal of Nephrology* 5, 378–388 (2016).
141. Anders, H.-J., Andersen, K. & Stecher, B. The intestinal microbiota, a leaky gut, and abnormal immunity in kidney disease. *Kidney International* 83, 1010–1016 (2013).
142. Mokkala, K. et al. Gut Microbiota Richness and Composition and Dietary Intake of Overweight Pregnant Women Are Related to Serum Zonulin Concentration, a Marker for Intestinal Permeability. *Journal of Nutrition* (2016). doi:10.3945/jn.116.235358.
143. Heberling, C. A. et al. Hypothesis for a systems connectivity model of Autism Spectrum Disorder pathogenesis: links to gut bacteria, oxidative stress, and intestinal permeability. *Medical Hypotheses* 80, 264–270 (2013).
144. Leblhuber, F., Geisler, S., Steiner, K., Fuchs, D. & Schütz, B. Elevated fecal calprotectin in patients with Alzheimer's dementia indicates leaky gut. *Journal of Neural Transmission* 122, 1319–1322 (2015).
145. Barreto, M. et al. Intestinal permeability in children with recurrent respiratory and gastrointestinal symptoms. *Journal of Paediatrics and Child Health* 51, 1214–1220 (2015).
146. Järvinen, K. M. et al. Intestinal permeability in children with food allergy on specific elimination diets. *Pediatric Allergy and Immunology* 24, 589–595 (2013).
147. Chen, T. et al. Food allergens affect the intestinal tight junction permeability in inducing intestinal food allergy in rats. *Asian Pacific Journal of Allergy and Immunology* 32, 345–353 (2014).
148. Lerner, A. & Matthias, T. Changes in intestinal tight junction permeability associated with industrial food additives explain the rising incidence of autoimmune disease. *Autoimmunity Reviews* 14, 479–489 (2015).
149. Williams, K. M., Gokulan, K., Cerniglia, C. E. & Khare, S. Size and dose dependent effects of silver nanoparticle exposure on intestinal permeability in an in vitro model of the human gut epithelium. *Journal of Nanobiotechnology* 14, 62 (2016).
150. Romero, A. et al. Mycotoxins modify the barrier function of Caco-2 cells through differential gene expression of specific claudin isoforms: Protective effect of illite mineral clay. *Toxicology* 353, 21–33 (2016).
151. Minihane, A. M. et al. Low-grade inflammation, diet composition and health:

- current research evidence and its translation. *British Journal of Nutrition* 114, 999–1012 (2015).
152. Bischoff, S. C. Ernährung und Darmmikrobiom. *Der Gastroenterologe* 14, 172–178 (2019).
  153. Sender, R., Fuchs, S. & Milo, R. Revised estimates for the number of human and bacteria cells in the body. *PLoS Biology* 14, e1002533 (2016).
  154. Sender, R. et al. Are We Really Vastly Outnumbered? Revisiting the Ratio of Bacterial to Host Cells in Humans. *Cell* 164, 337–340 (2016).
  155. Costello, E. K. et al. Bacterial community variation in human body habitats across space and time. *Science* 326, 1694–1697 (2009).
  156. Ruan, W., Engevik, M. A., Spinler, J. K. & Versalovic, J. Healthy Human Gastrointestinal Microbiome: Composition and Function After a Decade of Exploration. *Digestive Diseases and Sciences* 65, 695–705 (2020).
  157. Vasapolli, R. et al. Analysis of Transcriptionally Active Bacteria Throughout the Gastrointestinal Tract of Healthy Individuals. *Gastroenterology* 157, 1081–1092.e3 (2019).
  158. Sundin, O. H. et al. The human jejunum has an endogenous microbiota that differs from those in the oral cavity and colon. *BMC Microbiology* 17, 160 (2017). doi: 10.1186/s12866-017-1059-6.
  159. Yatera, K., Noguchi, S. & Mukae, H. The microbiome in the lower respiratory tract. *Respiratory Investigation* 56, 432–439 (2018).
  160. NIH HMP Working Group et al. The NIH Human Microbiome Project. *Genome Research* 19, 2317–2323 (2009).
  161. Ehrlich, S. D., MetaHIT Consortium. MetaHIT: The European Union Project on Metagenomics of the Human Intestinal Tract. in *Metagenomics of the Human Body* (ed. Nelson, K. E.). 307–316 (Springer, 2011). doi:10.1007/978-1-4419-7089-3\_15.
  162. Luckey, T. D. Introduction to intestinal microecology. *American Journal of Clinical Nutrition* 25, 1292–1294 (1972).
  163. Savage, D. C. Microbial Ecology of the Gastrointestinal Tract. *Annual Review of Microbiology* 31, 107–133 (1977).
  164. Byrd, A. L., Belkaid, Y. & Segre, J. A. The human skin microbiome. *Nature Reviews Microbiology* 16, 143–155 (2018).
  165. Ghannoum, M. A. et al. Characterization of the Oral Fungal Microbiome (Mycobiome) in Healthy Individuals. *PLoS Pathogens* 6, e1000713 (2010).
  166. Bik, E. M. et al. Bacterial diversity in the oral cavity of 10 healthy individuals. *ISME Journal* 4, 962–974 (2010).
  167. Dewhirst, F. E. et al. The Human Oral Microbiome. *Journal of Bacteriology* 192, 5002–5017 (2010).
  168. Rajilić-Stojanović, M. et al. Systematic review: gastric microbiota in health and disease. *Alimentary Pharmacology & Therapeutics* 51, 582–602 (2020).
  169. Hunt, R. H. & Yaghoobi, M. The Esophageal and Gastric Microbiome in Health and Disease. *Gastroenterology Clinics of North America* 46, 121–141 (2017).
  170. Costa, A. N., Costa, F. M., Campos, S. V., Salles, R. K. & Athanzio, R. A. The pulmonary microbiome: challenges of a new paradigm. *Jornal Brasileiro de Pneumologia* 44, 424–432 (2018).
  171. Gupta, S., Kakkar, V. & Bhushan, I. Crosstalk between Vaginal Microbiome and Female Health: A review. *Microbial Pathogenesis* 136, 103696 (2019).
  172. Kalia, N., Singh, J. & Kaur, M. Microbiota in vaginal health and pathogenesis of recurrent vulvovaginal infections: a critical review. *Annals of Clinical Microbiology and Antimicrobials* 19, 5 (2020).
  173. Smith, S. B. & Ravel, J. The vaginal microbiota, host defence and reproductive physiology. *Journal of Physiology* 595, 451–463 (2017).
  174. Mendling, W. Vaginal Microbiota. in *Microbiota of the Human Body* (ed. Schwertz, A.). 83–93 (Springer International Publishing, 2016).
  175. Qin, J. et al. A human gut microbial gene catalogue established by metagenomic sequencing. *Nature* 464, 59–65 (2010).
  176. Rajilić-Stojanović, M. & Vos, W. M. The first 1000 cultured species of the human gastrointestinal microbiota. *FEMS Microbiology Reviews* 38, 996–1047 (2014).
  177. Rajilić-Stojanović, M., Heilig, H. G. H. J., Tims, S., Zoetendal, E. G. & Vos, W. M. Long-term monitoring of the human intestinal microbiota composition. *Environmental Microbiology* 15, 1146–1159 (2012). doi:10.1111/1462-2920.12023.
  178. Ley, R. E., Turnbaugh, P. J., Klein, S. & Gordon, J. I. Microbial ecology: human gut microbes associated with obesity. *Nature* 444, 1022–1023 (2006).
  179. Turnbaugh, P. J. et al. A core gut microbiome in obese and lean twins. *Nature* 457, 480–484 (2009).
  180. Hamady, M. & Knight, R. Microbial community profiling for human microbiome projects: Tools, techniques, and challenges. *Genome Research* 19, 1141–1152 (2009).
  181. Eckburg, P. B. et al. Diversity of the human intestinal microbial flora. *Science* 308, 1635–1638 (2005).
  182. Human Microbiome Project Consortium. A framework for human microbiome research. *Nature* 486, 215–221 (2012).
  183. Arumugam, M. et al. Enterotypes of the human gut microbiome. *Nature* 473, 174–180 (2011).
  184. Wu, G. D. et al. Linking Long-Term Dietary Patterns with Gut Microbial Enterotypes. *Science* 334, 105–108 (2011).
  185. Knights, D. et al. Rethinking “Enterotypes”. *Cell Host & Microbe* 16, 433–437 (2014).
  186. Cheng, M. & Ning, K. Stereotypes About Enterotype: the Old and New Ideas. *Genomics, Proteomics & Bioinformatics* 17, 4–12 (2019).
  187. Petersen, C. & Round, J. L. Defining dysbiosis and its influence on host immunity and disease. *Cellular Microbiology* 16, 1024–1033 (2014).
  188. Collado, M. C., Rautava, S., Aakko, J., Isolauri, E. & Salminen, S. Human gut colonisation may be initiated in utero by distinct microbial communities in the placenta and amniotic fluid. *Scientific Reports* 6, 23129 (2016).
  189. Chen, C. et al. The microbiota continuum along the female reproductive tract and its relation to uterine-related diseases. *Nature Communications* 8, 875 (2017). doi: 10.1038/s41467-017-00901-0.
  190. Desselberger, U. The Mammalian Intestinal Microbiome: Composition, Interaction with the Immune System, Significance for Vaccine Efficacy, and Potential for Disease Therapy. *Pathogens* 7, 57 (2018). doi: 10.3390/pathogens7030057.
  191. Pezoldt, J. et al. Neonatally imprinted stromal cell subsets induce tolerogenic dendritic cells in mesenteric lymph nodes. *Nature Communications* 9, 3903 (2018). doi: 10.1038/s41467-018-06423-7.
  192. Dzidic, M., Boix-Amorós, A., Selma-Royo, M., Mira, A. & Collado, M. C. Gut Microbiota and Mucosal Immunity in the Neonate. *Medical Sciences* 6, 56 (2018).
  193. Palmer, C., Bik, E. M., DiGiulio, D. B., Relman, D. A. & Brown, P. O. Development of the human infant intestinal microbiota. *PLoS Biology* 5, e177 (2007).
  194. Favier, C. F., Vaughan, E. E., Vos, W. M. & Akkermans, A. D. L. Molecular monitoring of succession of bacterial communities in human neonates. *Applied and Environmental Microbiology* 68, 219–226 (2002).
  195. Sakata, S. et al. Culture-independent analysis of fecal microbiota in infants, with special reference to *Bifidobacterium* species. *FEMS Microbiology Letters* 243, 417–423 (2005).
  196. Kunz, C., Rudloff, S., Baier, W., Klein, N. & Strobel, S. Oligosaccharides in human milk: structural, functional, and metabolic aspects. *Annual Review of Nutrition* 20, 699–722 (2000).
  197. Kashtanova, D. A. et al. Association between the gut microbiota and diet: Fetal life, early childhood, and further life. *Nutrition* 32, 620–627 (2016).
  198. Penders, J. et al. Factors influencing the composition of the intestinal microbiota in early infancy. *Pediatrics* 118, 511–521 (2006).
  199. Fallani, M. et al. Intestinal microbiota of 6-week-old infants across Europe: geographic influence beyond delivery mode, breast-feeding, and antibiotics. *Journal of Pediatric Gastroenterology and Nutrition* 51, 77–84 (2010).
  200. Bezirtzoglou, E., Tsiotsias, A. & Welling, G. W. Microbiota profile in feces of breast- and formula-fed newborns by using fluorescence in situ hybridization (FISH). *Anaerobe* 17, 478–482 (2011).
  201. Koenig, J. E. et al. Succession of microbial consortia in the developing infant gut microbiome. *Proceedings of the National Academy of Sciences of the United States of America* 108 Suppl, 4578–4585 (2011).
  202. Yatsunenko, T. et al. Human gut microbiome viewed across age and geography. *Nature* 486, 222–227 (2012).
  203. Boix-Amorós, A., Collado, M. C. & Mira, A. Relationship between Milk Microbiota, Bacterial Load, Macronutrients, and Human Cells during Lactation. *Frontiers in Microbiology* 7, 492 (2016). doi: 10.3389/fmicb.2016.00492.
  204. Fitzstevens, J. L. et al. Systematic Review of the Human Milk Microbiota. *Nutrition in Clinical Practice* 32, 354–364 (2017).
  205. Chichlowski, M., De Lartigue, G., German, J. B., Raybould, H. E. & Mills, D. A. *Bifidobacteria* Isolated From Infants and Cultured on Human Milk Oligosaccharides Affect Intestinal Epithelial Function. *Journal of Pediatric Gastroenterology and Nutrition* 55, 321–327 (2012).
  206. Lyons, K. E., Ryan, C. A., Dempsey, E. M., Ross, R. P. & Stanton, C. Breast Milk, a Source of Beneficial Microbes and Associated Benefits for Infant Health. *Nutrients* 12, 1039 (2020).
  207. Moossavi, S. et al. Composition and Variation of the Human Milk Microbiota Are

- Influenced by Maternal and Early-Life Factors. *Cell Host & Microbe* 25, 324–335.e4 (2019).
208. Kordy, K. et al. Contributions to human breast milk microbiome and enteromammary transfer of *Bifidobacterium breve*. *PLoS One* 15, e0219633 (2020).
  209. Damaceno, Q. S. et al. Evaluation of Potential Probiotics Isolated from Human Milk and Colostrum. *Probiotics and Antimicrobial Proteins* 9, 371–379 (2017).
  210. Bahreini-Esfahani, N. & Moravejolahkami, A. R. Can Synbiotic Dietary Pattern Predict Lactobacillales Strains in Breast Milk? *Breastfeeding Medicine* 15, 387–393 (2020). doi:10.1089/bfm.2019.0301.
  211. Rajilić-Stojanović, M. et al. Development and application of the human intestinal tract chip, a phylogenetic microarray: analysis of universally conserved phylotypes in the abundant microbiota of young and elderly adults. *Environmental Microbiology* 11, 1736–1751 (2009).
  212. Jalanka-Tuovinen, J. et al. Intestinal microbiota in healthy adults: temporal analysis reveals individual and common core and relation to intestinal symptoms. *PLoS One* 6, e23035 (2011).
  213. Biagi, E. et al. Through ageing, and beyond: gut microbiota and inflammatory status in seniors and centenarians. *PLoS One* 5, e10667 (2010).
  214. Kong, F., Deng, F., Li, Y. & Zhao, J. Identification of gut microbiome signatures associated with longevity provides a promising modulation target for healthy aging. *Gut Microbes* 10, 210–215 (2019).
  215. Claesson, M. J. et al. Gut microbiota composition correlates with diet and health in the elderly. *Nature* 488, 178–184 (2012).
  216. Ferrer, M., Méndez-García, C., Rojo, D., Barbas, C. & Moya, A. Antibiotic use and microbiome function. *Biochemical Pharmacology* 134, 114–126 (2017).
  217. Grönlund, M. M., Lehtonen, O. P., Eerola, E. & Kero, P. Fecal microflora in healthy infants born by different methods of delivery: permanent changes in intestinal flora after cesarean delivery. *Journal of Pediatric Gastroenterology and Nutrition* 28, 19–25 (1999).
  218. Dominguez-Bello, M. G. et al. Delivery mode shapes the acquisition and structure of the initial microbiota across multiple body habitats in newborns. *Proceedings of the National Academy of Sciences* 107, 11971–11975 (2010).
  219. Maier, L. et al. Extensive impact of non-antibiotic drugs on human gut bacteria. *Nature* 555, 623–628 (2018). doi:10.1038/nature25979.
  220. Rothschild, D. et al. Environment dominates over host genetics in shaping human gut microbiota. *Nature* 555, 210–215 (2018).
  221. Schmidt, T. S. B., Raes, J. & Bork, P. The Human Gut Microbiome: From Association to Modulation. *Cell* 172, 1198–1215 (2018).
  222. Korpela, K. & Vos, W. M. Early life colonization of the human gut: microbes matter everywhere. *Current Opinion in Microbiology* 44, 70–78 (2018).
  223. Roca-Saavedra, P. et al. Food additives, contaminants and other minor components: effects on human gut microbiota—a review. *Journal of Physiology and Biochemistry* 74, 69–83 (2018).
  224. Vandegrift, R. et al. Cleanliness in context: reconciling hygiene with a modern microbial perspective. *Microbiome* 5, 76 (2017).
  225. Imhann, F. et al. Proton pump inhibitors affect the gut microbiome. *Gut* 65, 740–748 (2016).
  226. Rogers, M. a. M. & Aronoff, D. M. The influence of non-steroidal anti-inflammatory drugs on the gut microbiome. *Clinical Microbiology and Infection* 22, 178.e1-178.e9 (2016).
  227. Caio, G. et al. Effect of Gluten-Free Diet on Gut Microbiota Composition in Patients with Celiac Disease and Non-Celiac Gluten/Wheat Sensitivity. *Nutrients* 12, 1832 (2020).
  228. Ang, Q. Y. et al. Ketogenic Diets Alter the Gut Microbiome Resulting in Decreased Intestinal Th17 Cells. *Cell* 181, 1263–1275 (2020).
  229. De Filippo, C. et al. Impact of diet in shaping gut microbiota revealed by a comparative study in children from Europe and rural Africa. *Proceedings of the National Academy of Sciences* 107, 14691–14696 (2010).
  230. Martinez, K. B., Leone, V. & Chang, E. B. Western diets, gut dysbiosis, and metabolic diseases: Are they linked? *Gut Microbes* 8, 130–142 (2017).
  231. Statovci, D., Aguilera, M., MacSharry, J. & Melgar, S. The Impact of Western Diet and Nutrients on the Microbiota and Immune Response at Mucosal Interfaces. *Frontiers in Immunology* 8, 838 (2017). doi: 10.3389/fimmu.2017.00838.
  232. Jin, Q. et al. Metabolomics and Microbiomes as Potential Tools to Evaluate the Effects of the Mediterranean Diet. *Nutrients* 11, 207 (2019).
  233. Krznarić, Ž., Vranešić Bender, D. & Meštrović, T. The Mediterranean diet and its association with selected gut bacteria. *Current Opinion in Clinical Nutrition and Metabolic Care* 22, 401–406 (2019).
  234. Tomova, A. et al. The Effects of Vegetarian and Vegan Diets on Gut Microbiota. *Frontiers in Nutrition* 6, 47 (2019).
  235. Glick-Bauer, M. & Yeh, M.-C. The health advantage of a vegan diet: exploring the gut microbiota connection. *Nutrients* 6, 4822–4838 (2014).
  236. David, L. A. et al. Diet rapidly and reproducibly alters the human gut microbiome. *Nature* 505, 559–563 (2014).
  237. Ramakrishna, B. S. Role of the gut microbiota in human nutrition and metabolism. *Journal of Gastroenterology and Hepatology* 28 Suppl 4, 9–17 (2013).
  238. Palm, N. W., Zoete, M. R. & Flavell, R. A. Immune-microbiota interactions in health and disease. *Clinical Immunology* 159, 122–127 (2015).
  239. Cryan, J. F. & O'Mahony, S. M. The microbiome-gut-brain axis: from bowel to behavior. *Neurogastroenterology and Motility* 23, 187–192 (2011).
  240. Aidy, S., Stilling, R., Dinan, T. G. & Cryan, J. F. Microbiome to Brain: Unravelling the Multidirectional Axes of Communication. *Advances in Experimental Medicine and Biology* 874, 301–336 (2016).
  241. Tillisch, K. et al. Consumption of fermented milk product with probiotic modulates brain activity. *Gastroenterology* 144, 1394–1401, 1401.e1–4 (2013).
  242. Foster, J. A., Lyte, M., Meyer, E. & Cryan, J. F. Gut Microbiota and Brain Function: An Evolving Field in Neuroscience. *International Journal of Neuropsychopharmacology* 19 (2015). doi:10.1093/ijnp/pyv114.
  243. Keaney, J. & Campbell, M. The dynamic blood-brain barrier. *FEBS Journal* 282, 4067–4079 (2015).
  244. Braniste, V. et al. The gut microbiota influences blood-brain barrier permeability in mice. *Science Translational Medicine* 6, 263ra158 (2014).
  245. Erny, D. et al. Host microbiota constantly control maturation and function of microglia in the CNS. *Nature Neuroscience* 18, 965–977 (2015).
  246. Berni Canani, R. et al. The epigenetic effects of butyrate: potential therapeutic implications for clinical practice. *Clinical Epigenetics* 4, 4 (2012).
  247. Stilling, R. M., Dinan, T. G. & Cryan, J. F. Microbial genes, brain & behaviour – epigenetic regulation of the gut-brain axis. *Genes, Brain and Behavior* 13, 69–86 (2014).
  248. Scharlau, D. et al. Mechanisms of primary cancer prevention by butyrate and other products formed during gut flora-mediated fermentation of dietary fibre. *Mutation Research/Reviews in Mutation Research* 682, 39–53 (2009).
  249. Ciorba, M. A. A Gastroenterologist's Guide to Probiotics. *Clinical Gastroenterology and Hepatology* 10, 960–968 (2012).
  250. Nicholson, J. K. et al. Host-gut microbiota metabolic interactions. *Science* 336, 1262–1267 (2012).
  251. Ahlawat, S., Asha & Sharma, K. K. Gut-organ axis: a microbial outreach and networking. *Letters in Applied Microbiology* 72, 636–668 (2021). doi:10.1111/lam.13333.
  252. Schroeder, B. O. & Bäckhed, F. Signals from the gut microbiota to distant organs in physiology and disease. *Nature Medicine* 22, 1079–1089 (2016).
  253. O'Neill, C. A., Monteleone, G., McLaughlin, J. T. & Paus, R. The gut-skin axis in health and disease: A paradigm with therapeutic implications. *Bioessays* 38, 1167–1176 (2016).
  254. Wollina, U. Microbiome in atopic dermatitis. *Clinical, Cosmetic and Investigational Dermatology* 10, 51–56 (2017).
  255. Nylund, L. et al. Severity of atopic disease inversely correlates with intestinal microbiota diversity and butyrate-producing bacteria. *Allergy* 70, 241–244 (2015).
  256. Salem, I., Ramser, A., Isham, N. & Ghannoum, M. A. The Gut Microbiome as a Major Regulator of the Gut-Skin Axis. *Frontiers in Microbiology* 9, 1459 (2018).
  257. Friedrich, A. D., Paz, M. L., Leoni, J. & González Maglio, D. H. Message in a Bottle: Dialog between Intestine and Skin Modulated by Probiotics. *International Journal of Molecular Sciences* 18, 1067 (2017).
  258. Lee, S. Y., Lee, E., Park, Y. M. & Hong, S. J. Microbiome in the Gut-Skin Axis in Atopic Dermatitis. *Allergy, Asthma & Immunology Research* 10, 354–362 (2018).
  259. Reid, G. et al. How do probiotics and prebiotics function at distant sites? *Beneficial Microbes* 8, 521–533 (2017).
  260. Yeşilova, Y., Çalka, Ö., Akdeniz, N. & Berktas, M. Effect of probiotics on the treatment of children with atopic dermatitis. *Annals of Dermatology* 24, 189–193 (2012).
  261. Adolph, T. E., Grander, C., Moschen, A. R. & Tilg, H. Liver-Microbiome Axis in Health and Disease. *Trends in Immunology* 39, 712–723 (2018).
  262. Kolodziejczyk, A. A., Zheng, D., Shibolet, O. & Elinav, E. The role of the microbiome in

- NAFLD and NASH. *EMBO Molecular Medicine* 11, e9302 (2019).
263. Bang, C. S. et al. Effects of Korean Red Ginseng (*Panax ginseng*), urushiol (*Rhus vernicifera* Stokes), and probiotics (*Lactobacillus rhamnosus* R0011 and *Lactobacillus acidophilus* R0052) on the gut-liver axis of alcoholic liver disease. *Journal of Ginseng Research* 38, 167–172 (2014).
  264. Sudo, N. et al. Postnatal microbial colonization programs the hypothalamic-pituitary-adrenal system for stress response in mice: Commensal microbiota and stress response. *Journal of Physiology* 558, 263–275 (2004).
  265. Cryan, J. F. et al. The Microbiota-Gut-Brain Axis. *Physiological Reviews* 99, 1877–2013 (2019).
  266. Dinan, T. G. & Cryan, J. F. The Microbiome-Gut-Brain Axis in Health and Disease. *Gastroenterology Clinics of North America* 46, 77–89 (2017).
  267. Dinan, T. G., Stilling, R. M., Stanton, C. & Cryan, J. F. Collective unconscious: How gut microbes shape human behavior. *Journal of Psychiatric Research* 63, 1–9 (2015).
  268. Rieder, R., Wisniewski, P. J., Alderman, B. L. & Campbell, S. C. Microbes and mental health: A review. *Brain, Behavior and Immunity* 66, 9–17 (2017). doi:10.1016/j.bbi.2017.01.016.
  269. Mayer, E. A., Knight, R., Mazmanian, S. K., Cryan, J. F. & Tillisch, K. Gut microbes and the brain: paradigm shift in neuroscience. *Journal of Neuroscience* 34, 15490–15496 (2014).
  270. Bachiller, S. et al. Microglia in Neurological Diseases: A Road Map to Brain-Disease Dependent-Inflammatory Response. *Frontiers in Cellular Neuroscience* 12, 488 (2018).
  271. Graykowski, D. & Cudaback, E. Don't know what you got till it's gone: microglial depletion and neurodegeneration. *Neural Regeneration Research* 16, 1921–1927 (2021).
  272. Liu, Y.-J. et al. Microglia Elimination Increases Neural Circuit Connectivity and Activity in Adult Mouse Cortex. *Journal of Neuroscience* 41, 1274–1287 (2021).
  273. Uriarte Huarte, O., Richart, L., Mittelbronn, M. & Michelucci, A. Microglia in Health and Disease: The Strength to Be Diverse and Reactive. *Frontiers in Cellular Neuroscience* 15, 660523 (2021).
  274. Parracho, H. M. R. T., Bingham, M. O., Gibson, G. R. & McCartney, A. L. Differences between the gut microflora of children with autistic spectrum disorders and that of healthy children. *Journal of Medical Microbiology* 54, 987–991 (2005).
  275. Hsiao, E. Y. et al. Microbiota Modulate Behavioral and Physiological Abnormalities Associated with Neurodevelopmental Disorders. *Cell* 155, 1451–1463 (2013).
  276. Buie, T. Potential Etiologic Factors of Microbiome Disruption in Autism. *Clinical Therapeutics* 37, 976–983 (2015).
  277. Frye, R. E., Rose, S., Slattery, J. & MacFabe, D. F. Gastrointestinal dysfunction in autism spectrum disorder: the role of the mitochondria and the enteric microbiome. *Microbial Ecology in Health & Disease* 26, 27458 (2015).
  278. Reddy, B. L. & Saier, M. H. Autism and Our Intestinal Microbiota. *Journal of Molecular Microbiology and Biotechnology* 25, 51–55 (2015).
  279. Mangiola, F. et al. Gut microbiota in autism and mood disorders. *World Journal of Gastroenterology* 22, 361–368 (2016).
  280. Kelly, J. R. et al. Breaking down the barriers: the gut microbiome, intestinal permeability and stress-related psychiatric disorders. *Frontiers in Cellular Neuroscience* 9, 392 (2015).
  281. Moloney, R. D., Desbonnet, L., Clarke, G., Dinan, T. G. & Cryan, J. F. The microbiome: stress, health and disease. *Mammalian Genome* 25, 49–74 (2014).
  282. Dash, S., Clarke, G., Berk, M. & Jacka, F. N. The gut microbiome and diet in psychiatry: focus on depression. *Current Opinion in Psychiatry* 28, 1–6 (2015).
  283. Berer, K. et al. Commensal microbiota and myelin autoantigen cooperate to trigger autoimmune demyelination. *Nature* 479, 538–541 (2011).
  284. Scheperjans, F. et al. Gut microbiota are related to Parkinson's disease and clinical phenotype. *Movement Disorders* 30, 350–358 (2015).
  285. Öhman, L., Törnblom, H. & Simrén, M. Crosstalk at the mucosal border: importance of the gut microenvironment in IBS. *Nature Reviews Gastroenterology & Hepatology* 12, 36–49 (2015).
  286. Mulak, A. & Bonaz, B. Brain-gut-microbiota axis in Parkinson's disease. *World Journal of Gastroenterology* 21, 10609–10620 (2015).
  287. Kennedy, P. J., Cryan, J. F., Dinan, T. G. & Clarke, G. Irritable bowel syndrome: a microbiome-gut-brain axis disorder? *World Journal of Gastroenterology* 20, 14105–14125 (2014).
  288. Distrutti, E., Monaldi, L., Ricci, P. & Fiorucci, S. Gut microbiota role in irritable bowel syndrome: New therapeutic strategies. *World Journal of Gastroenterology* 22, 2219–2241 (2016).
  289. Dinan, T. G. et al. Psychobiotics: a novel class of psychotropic. *Biological Psychiatry* 74, 720–726 (2013).
  290. Cheng, L.-H., Liu, Y.-W., Wu, C.-C., Wang, S. & Tsai, Y.-C. Psychobiotics in mental health, neurodegenerative and neurodevelopmental disorders. *Journal of Food and Drug Analysis* 27, 632–648 (2019).
  291. Kim, N., Yun, M., Oh, Y. J. & Choi, H.-J. Mind-altering with the gut: Modulation of the gut-brain axis with probiotics. *Journal of Microbiology* 56, 172–182 (2018).
  292. McFarland, L. Epidemiology, risk factors and treatments for antibiotic-associated diarrhea. *Digestive Diseases* 16, 292–307 (1999).
  293. Wright, E. K. et al. Recent advances in characterizing the gastrointestinal microbiome in Crohn's disease: a systematic review. *Inflammatory Bowel Diseases* 21, 1219–1228 (2015).
  294. Lahner, E. et al. Probiotics in the Treatment of Diverticular Disease. A Systematic Review. *Journal of Gastrointestinal and Liver Diseases* 25, 79–86 (2016).
  295. Hold, G. L. Gastrointestinal Microbiota and Colon Cancer. *Digestive Diseases* 34, 244–250 (2016).
  296. Demehri, F. R. et al. Altered fecal short chain fatty acid composition in children with a history of Hirschsprung-associated enterocolitis. *Journal of Pediatric Surgery* 51, 81–86 (2016).
  297. Prince, B. T., Mandel, M. J., Nadeau, K. & Singh, A. M. Gut Microbiome and the Development of Food Allergy and Allergic Disease. *Pediatric Clinics of North America* 62, 1479–1492 (2015).
  298. He, T. et al. The role of colonic metabolism in lactose intolerance. *European Journal of Clinical Investigation* 38, 541–547 (2008).
  299. Zhong, Y. et al. The role of colonic microbiota in lactose intolerance. *Digestive Diseases and Sciences* 49, 78–83 (2004).
  300. Deng, Y., Misselwitz, B., Dai, N. & Fox, M. Lactose Intolerance in Adults: Biological Mechanism and Dietary Management. *Nutrients* 7, 8020–8035 (2015).
  301. Zhang, X. et al. Fructose malabsorption induces cholecystokinin expression in the ileum and cecum by changing microbiota composition and metabolism. *FASEB Journal* 33, 7126–7142 (2019).
  302. Cenit, M. C., Olivares, M., Codoñer-Franch, P. & Sanz, Y. Intestinal Microbiota and Celiac Disease: Cause, Consequence or Co-Evolution? *Nutrients* 7, 6900–6923 (2015).
  303. Marasco, G. et al. Gut Microbiota and Celiac Disease. *Digestive Diseases and Sciences* 61, 1461–1472 (2016).
  304. Zinkernagel, M. S. et al. Association of the Intestinal Microbiome with the Development of Neovascular Age-Related Macular Degeneration. *Scientific Reports* 7, 40826 (2017).
  305. Mack, I. et al. Weight gain in anorexia nervosa does not ameliorate the faecal microbiota, branched chain fatty acid profiles, and gastrointestinal complaints. *Scientific Reports* 6, 26752 (2016).
  306. Hevia, A. et al. Allergic Patients with Long-Term Asthma Display Low Levels of *Bifidobacterium adolescentis*. *PLoS One* 11, e0147809 (2016).
  307. Korpela, K. et al. Intestinal microbiome is related to lifetime antibiotic use in Finnish pre-school children. *Nature Communications* 7, 10410 (2016).
  308. Bisgaard, H. et al. Reduced diversity of the intestinal microbiota during infancy is associated with increased risk of allergic disease at school age. *Journal of Allergy and Clinical Immunology* 128, 646–652.e1–5 (2011).
  309. Roman, P. et al. Are probiotic treatments useful on fibromyalgia syndrome or chronic fatigue syndrome patients? A systematic review. *Beneficial Microbes* 9, 603–611 (2018).
  310. Knip, M. & Siljander, H. The role of the intestinal microbiota in type 1 diabetes mellitus. *Nature Reviews Endocrinology* 12, 154–167 (2016).
  311. Allin, K. H., Nielsen, T. & Pedersen, O. Mechanisms in endocrinology: Gut microbiota in patients with type 2 diabetes mellitus. *European Journal of Endocrinology* 172, R167–R177 (2015).
  312. Boursier, J. & Diehl, A. M. Nonalcoholic Fatty Liver Disease and the Gut Microbiome. *Clinics in Liver Disease* 20, 263–275 (2016).
  313. Haque, T. R. & Barritt, A. S. Intestinal Microbiota in Liver Disease. *Best Practice & Research Clinical Gastroenterology* 30, 133–142 (2016).
  314. Jiang, J.-W., Chen, X.-H., Ren, Z. & Zheng, S.-S. Gut microbial dysbiosis associates hepatocellular carcinoma via the gut-liver axis. *Hepatobiliary & Pancreatic Diseases International* 18, 19–27 (2019).
  315. Taylor, S. L., Wesselingh, S. & Rogers, G. B. Host-microbiome interactions in acute

- and chronic respiratory infections. *Cellular Microbiology* 18, 652–662 (2016).
316. Schuijt, T. J. et al. The gut microbiota plays a protective role in the host defence against pneumococcal pneumonia. *Gut* 65, 575–583 (2016).
  317. Burke, D. G. et al. The altered gut microbiota in adults with cystic fibrosis. *BMC Microbiology* 17, 58 (2017).
  318. Manor, O. et al. Metagenomic evidence for taxonomic dysbiosis and functional imbalance in the gastrointestinal tracts of children with cystic fibrosis. *Scientific Reports* 6, 22493 (2016).
  319. Hoen, A. G. et al. Associations between Gut Microbial Colonization in Early Life and Respiratory Outcomes in Cystic Fibrosis. *Journal of Pediatrics* 167, 138–147.e3 (2015).
  320. Khodor, S. & Shatat, I. F. Gut microbiome and kidney disease: a bidirectional relationship. *Pediatric Nephrology* 32, 921–931 (2016). doi:10.1007/s00467-016-3392-7.
  321. Leal-Lopes, C., Velloso, F. J., Campopiano, J. C., Sogayar, M. C. & Correa, R. G. Roles of Commensal Microbiota in Pancreas Homeostasis and Pancreatic Pathologies. *Journal of Diabetes Research* 2015, 1–20 (2015).
  322. Taur, Y. Intestinal microbiome changes and stem cell transplantation: Lessons learned. *Virulence* 7, 930–938 (2016).
  323. Devaux, C. A., Million, M. & Raoult, D. The Butyrogenic and Lactic Bacteria of the Gut Microbiota Determine the Outcome of Allogenic Hematopoietic Cell Transplant. *Frontiers in Microbiology* 11, 1642 (2020).
  324. Drosos, I., Tavidou, A. & Kolios, G. New aspects on the metabolic role of intestinal microbiota in the development of atherosclerosis. *Metabolism: Clinical and Experimental* 64, 476–481 (2015).
  325. Serino, M., Blasco-Baque, V., Nicolas, S. & Burcelin, R. Far from the eyes, close to the heart: dysbiosis of gut microbiota and cardiovascular consequences. *Current Cardiology Reports* 16, 540 (2014).
  326. Arora, T. & Bäckhed, F. The gut microbiota and metabolic disease: current understanding and future perspectives. *Journal of Internal Medicine* 280, 339–349 (2016). doi:10.1111/joim.12508.
  327. Yang, T. et al. Gut dysbiosis is linked to hypertension. *Hypertension* 65, 1331–1340 (2015).
  328. Pistollato, F. et al. Role of gut microbiota and nutrients in amyloid formation and pathogenesis of Alzheimer disease. *Nutrition Reviews* 74, 624–634 (2016).
  329. Brandscheid, C. et al. Altered Gut Microbiome Composition and Tryptic Activity of the 5xFAD Alzheimer's Mouse Model. *Journal of Alzheimer's Disease* 56, 775–788 1–14 (2017). doi:10.3233/JAD-160926.
  330. Bhattacharjee, S. & Lukiw, W. J. Alzheimer's disease and the microbiome. *Frontiers in Cellular Neuroscience* 7, 153 (2013).
  331. Xu, Y.-Y. et al. Role of gut microbiome in ankylosing spondylitis: an analysis of studies in literature. *Discovery Medicine* 22, 361–370 (2016).
  332. Ohlsson, C. & Sjögren, K. Effects of the gut microbiota on bone mass. *Trends in Endocrinology and Metabolism* 26, 69–74 (2015).
  333. Saydam, B. O. & Yildiz, B. O. Gut-Brain Axis and Metabolism in Polycystic Ovary Syndrome. *Current Pharmaceutical Design* 22, 5572–5587 (2016).
  334. Guo, Y. et al. Association between Polycystic Ovary Syndrome and Gut Microbiota. *PLoS One* 11, e0153196 (2016).
  335. Kelley, S. T., Skarra, D., Rivera, A. J. & Thackray, V. G. The Gut Microbiome Is Altered in a Letrozole-Induced Mouse Model of Polycystic Ovary Syndrome. *PLoS One* 11, e0146509 (2016).
  336. Tremellen, K. & Pearce, K. Dysbiosis of Gut Microbiota (DOGMA) – A novel theory for the development of Polycystic Ovarian Syndrome. *Medical Hypotheses* 79, 104–112 (2012).
  337. Sikora, M. et al. Gut Microbiome in Psoriasis: An Updated Review. *Pathogens* 9, 463 (2020).
  338. Scher, J. U. & Abramson, S. B. The microbiome and rheumatoid arthritis. *Nature Reviews. Rheumatology* 7, 569–578 (2011).
  339. Katz-Agranov, N. & Zandman-Goddard, G. The microbiome and systemic lupus erythematosus. *Immunologic Research* 65, 432–437 (2017). doi:10.1007/s12026-017-8906-2.
  340. Lloyd-Price, J. et al. The healthy human microbiome. *Genome Medicine* 8, 51 (2016).
  341. Human Microbiome Project Consortium. Structure, Function and Diversity of the Healthy Human Microbiome. *Nature* 486, 207–214 (2012).
  342. Blaser, M. J. & Falkow, S. What are the consequences of the disappearing human microbiota? *Nature Reviews Microbiology* 7, 887–894 (2009).
  343. Turnbaugh, P. J. et al. The human microbiome project: exploring the microbial part of ourselves in a changing world. *Nature* 449, 804–810 (2007).
  344. Flores, G. E. et al. Temporal variability is a personalized feature of the human microbiome. *Genome Biology* 15, 531 (2014).
  345. Langdon, A., Crook, N. & Dantas, G. The effects of antibiotics on the microbiome throughout development and alternative approaches for therapeutic modulation. *Genome Medicine* 8, 39 (2016).
  346. Mosca, A., Leclerc, M. & Hugot, J. P. Gut Microbiota Diversity and Human Diseases: Should We Reintroduce Key Predators in Our Ecosystem? *Frontiers in Microbiology* 7, 455 (2016).
  347. Peterfreund, G. L. et al. Succession in the gut microbiome following antibiotic and antibody therapies for *Clostridium difficile*. *PLoS One* 7, e46966 (2012).
  348. Milani, C. et al. Gut microbiota composition and *Clostridium difficile* infection in hospitalized elderly individuals: a metagenomic study. *Scientific Reports* 6, 25945 (2016).
  349. Chang, J. Y. et al. Decreased diversity of the fecal Microbiome in recurrent *Clostridium difficile*-associated diarrhea. *Journal of Infectious Diseases* 197, 435–438 (2008).
  350. Lucas López, R., Grande Burgos, M. J., Gálvez, A. & Pérez Pulido, R. The human gastrointestinal tract and oral microbiota in inflammatory bowel disease: a state of the science review. *Acta Pathologica, Microbiologica, et Immunologica Scandinavica* 125, 3–10 (2017). doi:10.1111/apm.12609.
  351. Abrahamsson, T. R. et al. Low gut microbiota diversity in early infancy precedes asthma at school age. *Clinical and Experimental Allergy* 44, 842–850 (2014).
  352. Pozuelo, M. et al. Reduction of butyrate- and methane-producing microorganisms in patients with Irritable Bowel Syndrome. *Scientific Reports* 5, 12693 (2015).
  353. Giamarellos-Bourboulis, E. et al. Molecular assessment of differences in the duodenal microbiome in subjects with irritable bowel syndrome. *Scandinavian Journal of Gastroenterology* 50, 1076–1087 (2015).
  354. Carroll, I. M., Ringel-Kulka, T., Siddle, J. P. & Ringel, Y. Alterations in composition and diversity of the intestinal microbiota in patients with diarrhea-predominant irritable bowel syndrome. *Neurogastroenterology and Motility* 24, 521–30, e248 (2012).
  355. Vincent, C. & Manges, A. R. Antimicrobial Use, Human Gut Microbiota and *Clostridium difficile* Colonization and Infection. *Antibiotics* 4, 230–253 (2015).
  356. Lozupone, C. A. & Knight, R. Species Divergence and the Measurement of Microbial Diversity. *Federation of European Microbiological Societies* 32, 557–578 (2008).
  357. Wagner, B. D. et al. On the Use of Diversity Measures in Longitudinal Sequencing Studies of Microbial Communities. *Frontiers in Microbiology* 9, 1037 (2018). doi: 10.3389/fmicb.2018.01037.
  358. Kuczynski, J. et al. Experimental and analytical tools for studying the human microbiome. *Nature Reviews Genetics* 13, 47–58 (2011).
  359. Lin, A. et al. Distinct distal gut microbiome diversity and composition in healthy children from Bangladesh and the United States. *PLoS One* 8, e53838 (2013).
  360. Clemente, J. C. et al. The microbiome of uncontacted Amerindians. *Science Advances* 1, e1500183 (2015). doi: 10.1126/sciadv.1500183.
  361. Rivière, A., Selak, M., Lantin, D., Leroy, F. & Vuyst, L. Bifidobacteria and Butyrate-Producing Colon Bacteria: Importance and Strategies for Their Stimulation in the Human Gut. *Frontiers in Microbiology* 7, 979 (2016).
  362. Louis, P., Young, P., Holtrop, G. & Flint, H. J. Diversity of human colonic butyrate-producing bacteria revealed by analysis of the butyryl-CoA:acetate CoA-transferase. *Environmental Microbiology* 12, 304–314 (2010).
  363. Zheng, J. et al. A taxonomic note on the genus *Lactobacillus*: Description of 23 novel genera, emended description of the genus *Lactobacillus* Beijerinck 1901, and union of *Lactobacillaceae* and *Leuconostocaceae*. *International Journal of Systematic and Evolutionary Microbiology*, 70, 2782–2858 (2020).
  364. Lawson, P. A., Citron, D. M., Tyrrell, K. L. & Finegold, S. M. Reclassification of *Clostridium difficile* as *Clostridioides difficile* (Hall and O'Toole 1935) Prévot 1938. *Anaerobe* 40, 95–99 (2016).
  365. Scheppach, W. Effects of short chain fatty acids on gut morphology and function. *Gut* 35, S35–S38 (1994).
  366. Meier, R. & Lochs, H. Prä- und Probiotika. *Revue thérapeutique* 64, 161–169 (2007).
  367. Koh, A. et al. From Dietary Fiber to Host Physiology: Short-Chain Fatty Acids as Key Bacterial Metabolites. *Cell* 165, 1332–1345 (2016).
  368. Corrêa-Oliveira, R., Fachi, J. L., Vieira, A., Sato, F. T. & Vinolo, M. A. R. Regulation of immune cell function by short-chain fatty acids. *Clinical & Translational Immunology*

- 5, e73 (2016).
369. Everard, A. et al. Cross-talk between *Akkermansia muciniphila* and intestinal epithelium controls diet-induced obesity. *Proceedings of the National Academy of Sciences of the United States of America* 110, 9066–9071 (2013).
370. Miquel, S. et al. *Faecalibacterium prausnitzii* and human intestinal health. *Current Opinion in Microbiology* 16, 255–261 (2013).
371. Indiani, C. M. D. S. P. et al. Childhood Obesity and Firmicutes/Bacteroidetes Ratio in the Gut Microbiota: A Systematic Review. *Childhood Obesity* 14, 501–509 (2018).
372. John, G. K. & Mullin, G. E. The Gut Microbiome and Obesity. *Current Oncology Reports* 18, 45 (2016).
373. Vandeputte, D. et al. Stool consistency is strongly associated with gut microbiota richness and composition, enterotypes and bacterial growth rates. *Gut* 65, 57–62 (2016).
374. Kolho, K.-L. et al. Fecal Microbiota in Pediatric Inflammatory Bowel Disease and Its Relation to Inflammation. *American Journal of Gastroenterology* 110, 921–930 (2015).
375. Yukawa, T. et al. Nested culture method improves detection of *Fusobacterium* from stool in patients with ulcerative colitis. *Japanese Journal of Infectious Diseases* 66, 109–114 (2013).
376. Widsinski, A., Weber, J., Loening-Baucke, V., Hale, L. P. & Lochs, H. Spatial organization and composition of the mucosal flora in patients with inflammatory bowel disease. *Journal of Clinical Microbiology* 43, 3380–3389 (2005).
377. Shah, R. et al. Composition and function of the pediatric colonic mucosal microbiome in untreated patients with ulcerative colitis. *Gut Microbes* 7, 384–396 (2016).
378. Rajilić-Stojanović, M., Shanahan, F., Guarner, F. & Vos, W. M. Phylogenetic analysis of dysbiosis in ulcerative colitis during remission. *Inflammatory Bowel Diseases* 19, 481–488 (2013).
379. Maukonen, J. et al. Altered Fecal Microbiota in Paediatric Inflammatory Bowel Disease. *Journal of Crohn's & Colitis* 9, 1088–1095 (2015).
380. Deshpande, N. P., Kaakoush, N. O., Wilkins, M. R. & Mitchell, H. M. Comparative genomics of *Campylobacter concisus* isolates reveals genetic diversity and provides insights into disease association. *BMC genomics* 14, 585 (2013).
381. Saulnier, D. M. et al. Gastrointestinal Microbiome Signatures of Pediatric Patients With Irritable Bowel Syndrome. *Gastroenterology* 141, 1782–1791 (2011).
382. Rajilić-Stojanović, M. et al. Global and deep molecular analysis of microbiota signatures in fecal samples from patients with irritable bowel syndrome. *Gastroenterology* 141, 1792–1801 (2011).
383. Duboc, H. et al. Increase in fecal primary bile acids and dysbiosis in patients with diarrhea-predominant irritable bowel syndrome. *Neurogastroenterology and Motility* 24, 513–520, e246-7 (2012).
384. Baumgartner, M. et al. Mucosal biofilms are an endoscopic feature of irritable bowel syndrome and ulcerative colitis. *Gastroenterology* (2021). doi:10.1053/j.gastro.2021.06.024.
385. Song, Y., Liu, C. & Finegold, S. M. Real-time PCR quantitation of clostridia in feces of autistic children. *Applied and Environmental Microbiology* 70, 6459–6465 (2004).
386. Finegold, S. M. et al. Gastrointestinal microflora studies in late-onset autism. *Clinical Infectious Diseases* 35, S6–S16 (2002).
387. Million, M. et al. Obesity-associated gut microbiota is enriched in *Lactobacillus reuteri* and depleted in *Bifidobacterium animalis* and *Methanobrevibacter smithii*. *International Journal of Obesity* 36, 817–825 (2012).
388. Karlsson, F. H. et al. Symptomatic atherosclerosis is associated with an altered gut metagenome. *Nature Communications* 3, 1245 (2012).
389. McCoy, A. N. et al. *Fusobacterium* is associated with colorectal adenomas. *PLoS One* 8, e53653 (2013).
390. Flanagan, L. et al. *Fusobacterium nucleatum* associates with stages of colorectal neoplasia development, colorectal cancer and disease outcome. *European Journal of Clinical Microbiology & Infectious Diseases* 33, 1381–1390 (2014).
391. Wu, X. et al. Molecular Insight into Gut Microbiota and Rheumatoid Arthritis. *International Journal of Molecular Sciences* 17, 431 (2016).
392. Gong, D., Gong, X., Wang, L., Yu, X. & Dong, Q. Involvement of Reduced Microbial Diversity in Inflammatory Bowel Disease. *Gastroenterology Research and Practice* (2016). doi: 10.1155/2016/6951091.
393. Parker, B. J., Wearsch, P. A., Veloo, A. C. M. & Rodriguez-Palacios, A. The Genus *Alistipes*: Gut Bacteria With Emerging Implications to Inflammation, Cancer, and Mental Health. *Frontiers in Immunology* 11, 906 (2020).
394. Bhattarai, Y., Muniz Pedrego, D. A. & Kashyap, P. C. Irritable bowel syndrome: a gut microbiota-related disorder? *American Journal of Physiology-Gastrointestinal and Liver Physiology* 312, G52–G62 (2017).
395. Tap, J. et al. Identification of an Intestinal Microbiota Signature Associated With Severity of Irritable Bowel Syndrome. *Gastroenterology* 152, 111-123.e8 (2017).
396. Zhuang, X., Xiong, L., Li, L., Li, M. & Chen, M. Alterations of gut microbiota in patients with irritable bowel syndrome: A systematic review and meta-analysis. *Journal of Gastroenterology and Hepatology* 32, 28–38 (2017).
397. Mueller, N. T. et al. Prenatal exposure to antibiotics, cesarean section and risk of childhood obesity. *International Journal of Obesity* 39, 665–670 (2015).
398. Lapin, B. et al. Relationship between prenatal antibiotic use and asthma in at-risk children. *Annals of Allergy, Asthma & Immunology* 114, 203–207 (2015).
399. Metsälä, J. et al. Prenatal and post-natal exposure to antibiotics and risk of asthma in childhood. *Clinical & Experimental Allergy* 45, 137–145 (2015).
400. Stensballe, L. G., Simonsen, J., Jensen, S. M., Bønnelykke, K. & Bisgaard, H. Use of Antibiotics during Pregnancy Increases the Risk of Asthma in Early Childhood. *Journal of Pediatrics* 162, 832-838.e3 (2013).
401. Modi, S. R., Collins, J. J. & Relman, D. A. Antibiotics and the gut microbiota. *Journal of Clinical Investigation* 124, 4212–4218 (2014).
402. Cheng, J. et al. Discordant temporal development of bacterial phyla and the emergence of core in the fecal microbiota of young children. *ISME Journal* 10, 1002–1014 (2016).
403. Dethlefsen, L. & Relman, D. A. Incomplete recovery and individualized responses of the human distal gut microbiota to repeated antibiotic perturbation. *Proceedings of the National Academy of Sciences of the United States of America* 108 Suppl, 4554–4561 (2011).
404. Blaser, M. J. Antibiotic use and its consequences for the normal microbiome. *Science* 352, 544–545 (2016).
405. IGES Institut. Arzneimittel-Atlas-J01 Antibiotika zur systemischen Anwendung – Top 10. URL: <https://www.arzneimittel-atlas.de/arzneimittel/j01-antibiotika-zur-systemischen-anwendung/top-10/index.html> (2016).
406. Jernberg, C., Löfmark, S., Edlund, C. & Jansson, J. K. Long-term impacts of antibiotic exposure on the human intestinal microbiota. *Microbiology* 156, 3216–3223 (2010).
407. Edlund, C. & Nord, C. E. Effect on the human normal microflora of oral antibiotics for treatment of urinary tract infections. *Journal of Antimicrobial Chemotherapy* 46, 41–48 (2000).
408. Sullivan, A., Edlund, C. & Nord, C. E. Effect of antimicrobial agents on the ecological balance of human microflora. *The Lancet Infectious diseases* 1, 101–114 (2001).
409. Spinillo, A., Capuzzo, E., Acciano, S., De Santolo, A. & Zara, F. Effect of antibiotic use on the prevalence of symptomatic vulvovaginal candidiasis. *American Journal of Obstetrics and Gynecology* 180, 14–17 (1999).
410. Vrieze, A. et al. Impact of oral vancomycin on gut microbiota, bile acid metabolism, and insulin sensitivity. *Journal of Hepatology* 60, 824–831 (2014).
411. Dethlefsen, L., Huse, S., Sogin, M. L. & Relman, D. A. The pervasive effects of an antibiotic on the human gut microbiota, as revealed by deep 16S rRNA sequencing. *PLoS Biology* 6, e280 (2008).
412. De La Cochetière, M. F. et al. Resilience of the dominant human fecal microbiota upon short-course antibiotic challenge. *Journal of Clinical Microbiology* 43, 5588–5592 (2005).
413. Pérez-Cobas, A. E. et al. Differential effects of antibiotic therapy on the structure and function of human gut microbiota. *PLoS One* 8, e80201 (2013).
414. Abeles, S. R. et al. Microbial diversity in individuals and their household contacts following typical antibiotic courses. *Microbiome* 4, 39 (2016).
415. Panda, S. et al. Short-Term Effect of Antibiotics on Human Gut Microbiota. *PLoS One* 9, e95476 (2014).
416. Doan, T. et al. Gut Microbial Diversity in Antibiotic-Naive Children After Systemic Antibiotic Exposure: A Randomized Controlled Trial. *Clinical Infectious Diseases* 64, 1147–1153 (2017).
417. Stewardson, A. J. et al. Collateral damage from oral ciprofloxacin versus nitrofurantoin in outpatients with urinary tract infections: a culture-free analysis of gut microbiota. *Clinical Microbiology and Infection* 21, 344.e1–11 (2015).
418. Lankelma, J. M. et al. Antibiotic-induced gut microbiota disruption during human endotoxemia: a randomised controlled study. *Gut* 66, 1623–1630 (2017).
419. Zaura, E. et al. Same Exposure but Two Radically Different Responses to Antibiotics: Resilience of the Salivary Microbiome versus Long-Term Microbial Shifts in Feces. *mBio* 6, e01693-15 (2015).
420. Nord, C. E. & Edlund, C. Impact of antimicrobial agents on human intestinal



- microflora. *Journal of Chemotherapy* 2, 218–237 (1990).
421. Bernhardt, H. & Knoke, M. Anaerobe Darmflora: Einfluss von Antibiotika. *Chemotherapie Journal* 2, 15–18 (1993).
  422. Linzenmeier, G. & Haralambie, E. Aerobe Darmflora: Einfluss von Antibiotika. *Chemotherapie Journal* 2, 11–14 (1993).
  423. Lübbert, C., John, E. & von Müller, L. Clostridium Difficile Infection. *Deutsches Ärzteblatt International* 111, 723–731 (2014).
  424. Buffie, C. G. et al. Precision microbiome reconstitution restores bile acid mediated resistance to Clostridium difficile. *Nature* 517, 205–208 (2015).
  425. Antharam, V. C. et al. Intestinal Dysbiosis and Depletion of Butyrogenic Bacteria in Clostridium difficile Infection and Nosocomial Diarrhea. *Journal of Clinical Microbiology* 51, 2884–2892 (2013).
  426. Hagel, S. et al. S2k-Leitlinie Gastrointestinale Infektionen und Morbus Whipple. *Zeitschrift für Gastroenterologie* 53, 418–459 (2015).
  427. Slimings, C. & Riley, T. V. Antibiotics and hospital-acquired Clostridium difficile infection: update of systematic review and meta-analysis. *Journal of Antimicrobial Chemotherapy* 69, 881–891 (2014).
  428. McFarland, L. V., Ozen, M., Dinleyici, E. C. & Goh, S. Comparison of pediatric and adult antibiotic-associated diarrhea and Clostridium difficile infections. *World Journal of Gastroenterology* 22, 3078 (2016).
  429. Schneider T, Eckmanns T, Ignatius R, Weist K, L. O. Clostridium-difficile-assoziierte Diarrhö. *Deutsches Ärzteblatt* 104, A1588–A1594 (2007).
  430. Schubert, A. M. et al. Microbiome data distinguish patients with Clostridium difficile infection and non-C. difficile-associated diarrhea from healthy controls. *mBio* 5, e01021-14 (2014).
  431. Bakker, G. J. et al. Oral vancomycin treatment does not alter markers of postprandial inflammation in lean and obese subjects. *Physiological Reports* 7, e14199 (2019).
  432. McFarland, L. Evidence-based review of probiotics for antibiotic-associated diarrhea and Clostridium difficile infections. *Anaerobe* 15, 274–280 (2009).
  433. Tanaka, S. et al. Influence of antibiotic exposure in the early postnatal period on the development of intestinal microbiota. *FEMS Immunology and Medical Microbiology* 56, 80–87 (2009).
  434. Marco, F. et al. Comparison of rifloxacin and norfloxacin effects on faecal flora. *Journal of Antimicrobial Chemotherapy* 35, 895–901 (1995).
  435. Ambrose, N. S., Johnson, M., Burdon, D. W. & Keighley, M. R. The influence of single dose intravenous antibiotics on faecal flora and emergence of Clostridium difficile. *Journal of Antimicrobial Chemotherapy* 15, 319–326 (1985).
  436. Burdon, D. W., Ambrose, N. S., Keighley, M. R. & Youngs, D. The effect of a single intravenous dose of cefotaxime on the faecal flora. *Infection* 13 Suppl 1, S134-136 (1985).
  437. Michéa-Hamzehpour, M., Auckenthaler, R., Kunz, J. & Pechère, J. C. Effect of a single dose of cefotaxime or ceftriaxone on human faecal flora. A double-blind study. *Drugs* 35 Suppl 2, 6–11 (1988).
  438. Jernberg, C., Löfmark, S., Edlund, C. & Jansson, J. K. Long-term ecological impacts of antibiotic administration on the human intestinal microbiota. *ISME Journal* 1, 56–66 (2007).
  439. Jakobsson, H. E. et al. Short-Term Antibiotic Treatment Has Differing Long-Term Impacts on the Human Throat and Gut Microbiome. *PLoS One* 5, e9836 (2010).
  440. Wexler, H. M. Bacteroides: the good, the bad, and the nitty-gritty. *Clinical Microbiology Reviews* 20, 593–621 (2007).
  441. Dietrich, C. G. Commercially available probiotic drinks containing Lactobacillus casei DN-114001 reduce antibiotic-associated diarrhea. *World Journal of Gastroenterology* 20, 15837–15844 (2014).
  442. Robert Koch-Institut (RKI). RKI-Ratgeber für Ärzte - Clostridium difficile. (2016).
  443. Cramer, J. P., Burchard, G. D. & Lohse, A. W. Altes und Neues zur antibiotika-assoziierten Diarrhö. *Medizinische Klinik* 103, 325–338 (2008).
  444. Rao, S. S. C., Edwards, C. A., Austen, C. J., Bruce, C. & Read, N. W. Impaired colonic fermentation of carbohydrate after ampicillin. *Gastroenterology* 94, 928–932 (1988).
  445. Clausen, M. R., Bonnén, H., Tvede, M. & Brøbech Mortensen, P. Colonic fermentation to short-chain fatty acids is decreased in antibiotic-associated diarrhea. *Gastroenterology* 101, 1497–1504 (1991).
  446. Högenauer, C., Hammer, H. F., Krejs, G. J. & Reisinger, E. C. Mechanisms and management of antibiotic-associated diarrhea. *Clinical Infectious Diseases* 27, 702–710 (1998).
  447. Ofosu, A. Clostridium difficile infection: a review of current and emerging therapies. *Annals of Gastroenterology* 29, 147–154 (2016).
  448. Czepiel, J. et al. Clostridium difficile infection: review. *European Journal of Clinical Microbiology & Infectious Diseases* 38, 1211–1221 (2019).
  449. Manson, J. M., Rauch, M. & Gilmore, M. S. The commensal microbiology of the gastrointestinal tract. *Advances in Experimental Medicine and Biology* 635, 15–28 (2008).
  450. Hold, G. L., Pryde, S. E., Russell, V. J., Furrie, E. & Flint, H. J. Assessment of microbial diversity in human colonic samples by 16S rDNA sequence analysis. *FMicrobiology Ecology* 39, 33–39 (2002).
  451. Lopetuso, L. R., Scaldaferrri, F., Petito, V. & Gasbarrini, A. Commensal Clostridia: leading players in the maintenance of gut homeostasis. *Gut Pathogens* 5, 23 (2013).
  452. Singh, A., Cresci, G. A. & Kirby, D. F. Proton Pump Inhibitors: Risks and Rewards and Emerging Consequences to the Gut Microbiome. *Nutrition in Clinical Practice* 33, 614–624 (2018).
  453. Minalyan, A., Gabrielyan, L., Scott, D., Jacobs, J. & Piseigna, J. R. The Gastric and Intestinal Microbiome: Role of Proton Pump Inhibitors. *Current Gastroenterology Reports* 19, 42 (2017).
  454. Wang, F. & Roy, S. Gut Homeostasis, Microbial Dysbiosis, and Opioids. *Toxicologic Pathology* 45, 150–156 (2017).
  455. Morgan, A. P. et al. The Antipsychotic Olanzapine Interacts with the Gut Microbiome to Cause Weight Gain in Mouse. *PLoS One* 9, e115225 (2014).
  456. Bahr, S. M. et al. Risperidone-induced weight gain is mediated through shifts in the gut microbiome and suppression of energy expenditure. *EBioMedicine* 2, 1725–1734 (2015).
  457. Davey, K. J. et al. Antipsychotics and the gut microbiome: olanzapine-induced metabolic dysfunction is attenuated by antibiotic administration in the rat. *Translational Psychiatry* 3, e309 (2013).
  458. Aura, A.-M. et al. Drug metabolome of the simvastatin formed by human intestinal microbiota in vitro. *Molecular BioSystems* 7, 437–446 (2011).
  459. Nolan, J. A. et al. The influence of rosuvastatin upon the gastrointestinal microbiota and host gene expression profiles. *American Journal of Physiology Gastrointestinal and Liver Physiology* 312, G488–G497 (2017). doi:10.1152/ajpgi.00149.2016.
  460. Nolan, J. A., Kinsella, M., Hill, C., Joyce, S. A. & Gahan, C. G. M. Analysis of the Impact of Rosuvastatin on Bacterial Mevalonate Production Using a UPLC-Mass Spectrometry Approach. *Current Microbiology* 73, 1–8 (2016).
  461. Catry, E. et al. Ezetimibe and simvastatin modulate gut microbiota and expression of genes related to cholesterol metabolism. *Life Sciences* 132, 77–84 (2015).
  462. Kaddurah-Daouk, R. et al. Enteric Microbiome Metabolites Correlate with Response to Simvastatin Treatment. *PLoS One* 6, e25482 (2011).
  463. Gottlieb, K., Wachter, V., Sliman, J. & Pimentel, M. Review article: inhibition of methanogenic archaea by statins as a targeted management strategy for constipation and related disorders. *Alimentary Pharmacology & Therapeutics* 43, 197–212 (2016).
  464. Forslund, K. et al. Disentangling type 2 diabetes and metformin treatment signatures in the human gut microbiota. *Nature* 528, 262–266 (2015).
  465. la Cuesta-Zuluaga, J. et al. Metformin Is Associated With Higher Relative Abundance of Mucin-Degrading Akkermansia muciniphila and Several Short-Chain Fatty Acid-Producing Microbiota in the Gut. *Diabetes Care* 40, 54–62 (2017).
  466. Kortman, G. A. M. et al. Microbial Metabolism Shifts Towards an Adverse Profile with Supplementary Iron in the TIM-2 In vitro Model of the Human Colon. *Frontiers in Microbiology* 6, 1481 (2016).
  467. Maseda, D. & Ricciotti, E. NSAID-Gut Microbiota Interactions. *Frontiers in Pharmacology* 11, 1153 (2020).
  468. Ruskowski, J. & Witkowski, J. M. Lactulose: Patient- and dose-dependent prebiotic properties in humans. *Anaerobe* 59, 100–106 (2019).
  469. Brechmann, T., Sperlbaum, A. & Schmiegel, W. Levothyroxine therapy and impaired clearance are the strongest contributors to small intestinal bacterial overgrowth: Results of a retrospective cohort study. *World Journal of Gastroenterology* 23, 842–852 (2017).
  470. Statista GmbH. Arzneimittel – Am häufigsten verordnete Wirkstoffgruppen in Deutschland 2012. URL: <https://de.statista.com/statistik/daten/studie/321762/umfrage/am-haeufigsten-verordnete-wirkstoffgruppen-in-deutschland/> (2016).
  471. Bruno, G. et al. Proton pump inhibitors and dysbiosis: Current knowledge and aspects to be clarified. *World Journal of Gastroenterology* 25, 2706–2719 (2019).
  472. Jackson, M. A. et al. Proton pump inhibitors alter the composition of the gut microbiota. *Gut* 65, 749–756 (2016).
  473. Zhang, J., Zhang, J. & Wang, R. Gut microbiota modulates drug pharmacokinetics.

- Drug Metabolism Reviews 50, 357–368 (2018).
474. Zimmermann, M., Zimmermann-Kogadeeva, M., Wegmann, R. & Goodman, A. L. Separating host and microbiome contributions to drug pharmacokinetics and toxicity. *Science* 363, eaat9931 (2019).
  475. Silbergeld, E. K. The Microbiome. *Toxicologic Pathology* 45, 190–194 (2017).
  476. Clarke, G. et al. Gut Reactions: Breaking Down Xenobiotic-Microbiome Interactions. *Pharmacological Reviews* 71, 198–224 (2019).
  477. Tuteja, S. & Ferguson, J. F. Gut Microbiome and Response to Cardiovascular Drugs. *Circulation Genomic and Precision Medicine* 12, 421–429 (2019).
  478. McCreight, L. J., Bailey, C. J. & Pearson, E. R. Metformin and the gastrointestinal tract. *Diabetologia* 59, 426–435 (2016).
  479. Routy, B. et al. Gut microbiome influences efficacy of PD-1-based immunotherapy against epithelial tumors. *Science* 359, 91–97 (2018).
  480. Gopalakrishnan, V. et al. Gut microbiome modulates response to anti-PD-1 immunotherapy in melanoma patients. *Science* 359, 97–103 (2018).
  481. Pierrard, J. & Seront, E. Impact of the gut microbiome on immune checkpoint inhibitor efficacy – a systematic review. *Current Oncology* 26, 395–403 (2019).
  482. FAO/WHO. Joint FAO/WHO Expert Consultation on Evaluation of Health and Nutritional Properties of Probiotics in Food including Powder Milk with Live Lactic Acid Bacteria. (2001).
  483. Khoruts, A., Hoffmann, D. E. & Britton, R. A. Probiotics: Promise, Evidence, and Hope. *Gastroenterology* 159, 409–413 (2020).
  484. Sonnenborn, U. *Escherichia coli* strain Nissle 1917– from bench to bedside and back: history of a special *Escherichia coli* strain with probiotic properties. *FEMS Microbiology Letters* 363, fnw212 (2016). doi: 10.1093/femsle/fnw212.
  485. Eiseman, B., Silen, W., Bascom, G. S. & Kauvar, A. J. Fecal enema as an adjunct in the treatment of pseudomembranous enterocolitis. *Surgery* 44, 854–859 (1958).
  486. Davar, D. et al. Fecal microbiota transplant overcomes resistance to anti-PD-1 therapy in melanoma patients. *Science* 371, 595–602 (2021).
  487. Gareau, M. G., Sherman, P. M. & Walker, W. A. Probiotics and the gut microbiota in intestinal health and disease. *Nature Reviews Gastroenterology & Hepatology* 7, 503–514 (2010).
  488. Gibson, G. R. et al. The International Scientific Association for Probiotics and Prebiotics (ISAPP) consensus statement on the definition and scope of prebiotics. *Nature Reviews Gastroenterology & Hepatology* 14, 491–502 (2017).
  489. Swanson, K. S. et al. The International Scientific Association for Probiotics and Prebiotics (ISAPP) consensus statement on the definition and scope of synbiotics. *Nature Reviews Gastroenterology & Hepatology* 17, 687–701 (2020).
  490. Żółkiewicz, J., Marzec, A., Ruszczyński, M. & Feleszko, W. Postbiotics – A Step Beyond Pre- and Probiotics. *Nutrients* 12, 2189 (2020).
  491. Collado, M. C., Vinderola, G. & Salminen, S. Postbiotics: facts and open questions. A position paper on the need for a consensus definition. *Beneficial Microbes* 10, 711–719 (2019).
  492. Gill, H. S. & Rutherford, K. J. Viability and dose-response studies on the effects of the immunoenhancing lactic acid bacterium *Lactobacillus rhamnosus* in mice. *British Journal of Nutrition* 86, 285–289 (2001).
  493. Minelli, P. E. B. & Benini, A. Relationship between number of bacteria and their probiotic effects. *Microbial Ecology in Health and Disease* 20, 180–183 (2009).
  494. Saxelin, M., Ahokas, M. & Salminen, S. Dose Response on the Faecal Colonisation of *Lactobacillus* Strain GG Administered in Two Different Formulations. *Microbial Ecology in Health and Disease* 6, 119–122 (2009).
  495. Saxelin, M. et al. Persistence of probiotic strains in the gastrointestinal tract when administered as capsules, yoghurt, or cheese. *International Journal of Food Microbiology* 144, 293–300 (2010).
  496. FAO/WHO. Report of a Joint FAO/WHO Working Group. Guidelines for the Evaluation of Probiotics in Food. (2002).
  497. European Food Safety Authority. Qualified presumption of safety (QPS). URL: <https://www.efsa.europa.eu/en/topics/topic/qualified-presumption-safety-qps>.
  498. FDA/Center for Food Safety and Applied Nutrition. Generally Recognized as Safe (GRAS). URL: <https://www.fda.gov/food/food-ingredients-packaging/generally-recognized-safe-gras> (2020).
  499. Bourdichon, F. et al. Food fermentations: Microorganisms with technological beneficial use. *International Journal of Food Microbiology* 154, 87–97 (2012).
  500. Bermudez-Brito, M., Plaza-Díaz, J., Muñoz-Quezada, S., Gómez-Llorente, C. & Gil, A. Probiotic mechanisms of action. *Annals of Nutrition & Metabolism* 61, 160–174 (2012).
  501. Vogt, S. L., Peña-Díaz, J. & Finlay, B. B. Chemical communication in the gut: Effects of microbiota-generated metabolites on gastrointestinal bacterial pathogens. *Anaerobe* 34, 106–115 (2015).
  502. Thompson, J. A., Oliveira, R. A. & Xavier, K. B. Chemical conversations in the gut microbiota. *Gut Microbes* 7, 163–170 (2016).
  503. Nunes-Alves, C. Microbiome: Taking advantage of quorum sensing. *Nature Reviews Microbiology* 13, 252 (2015).
  504. Rakoff-Nahoum, S., Foster, K. R. & Comstock, L. E. The evolution of cooperation within the gut microbiota. *Nature* 533, 255–259 (2016).
  505. Dobson, A., Cotter, P. D., Ross, R. P. & Hill, C. Bacteriocin Production: a Probiotic Trait? *Applied and Environmental Microbiology* 78, 1–6 (2012).
  506. Chung, W. S. F. et al. Modulation of the human gut microbiota by dietary fibres occurs at the species level. *BMC Biology* 14, 3 (2016).
  507. Belenguer, A. et al. Two routes of metabolic cross-feeding between *Bifidobacterium adolescentis* and butyrate-producing anaerobes from the human gut. *Applied and Environmental Microbiology* 72, 3593–3599 (2006).
  508. Duncan, S. H., Louis, P. & Flint, H. J. Lactate-utilizing bacteria, isolated from human feces, that produce butyrate as a major fermentation product. *Applied and Environmental Microbiology* 70, 5810–5817 (2004).
  509. Scott, K. P., Antoine, J.-M., Midtvedt, T. & Hemert, S. Manipulating the gut microbiota to maintain health and treat disease. *Microbial Ecology in Health & Disease* 26, 25877 (2015).
  510. Seth, E. C. & Taga, M. E. Nutrient cross-feeding in the microbial world. *Frontiers in Microbiology* 5, 350 (2014).
  511. Stallmach, A. & Vehreschild, M. J. G. T. *Mikrobiom*. (De Gruyter, 2016).
  512. Day, R. L., Harper, A. J., Woods, R. M., Davies, O. G. & Heaney, L. M. Probiotics: current landscape and future horizons. *Future Science OAS*, FSO391 (2019).
  513. Teame, T. et al. Paraprobiotics and Postbiotics of Probiotic Lactobacilli, Their Positive Effects on the Host and Action Mechanisms: A Review. *Frontiers in Nutrition* 7, 570344 (2020).
  514. Bäuerl, C. et al. *Lactobacillus paracasei* and *Lactobacillus plantarum* strains downregulate proinflammatory genes in an ex vivo system of cultured human colonic mucosa. *Genes & Nutrition* 8, 165–180 (2013).
  515. Yan, F. et al. A *Lactobacillus rhamnosus* GG-derived Soluble Protein, p40, Stimulates Ligand Release from Intestinal Epithelial Cells to Transactivate Epidermal Growth Factor Receptor. *Journal of Biological Chemistry* 288, 30742–30751 (2013).
  516. O’Connell, T. M. The Application of Metabolomics to Probiotic and Prebiotic Interventions in Human Clinical Studies. *Metabolites* 10, 120 (2020).
  517. Weichselbaum, E. Probiotics and health: a review of the evidence. *Nutrition Bulletin* 34, 340–373 (2009).
  518. Chapman, C. M. C., Gibson, G. R. & Rowland, I. In vitro evaluation of single- and multi-strain probiotics: Inter-species inhibition between probiotic strains, and inhibition of pathogens. *Anaerobe* 18, 405–413 (2012).
  519. Hemert, S. & Ormel, G. Influence of the Multispecies Probiotic Ecologic® BARRIER on Parameters of Intestinal Barrier Function. *Food and Nutrition Sciences* 5, 1739–1745 (2014).
  520. Gomes, A. M. P., Malcata, F. X. & Klaver, F. A. M. Growth Enhancement of *Bifidobacterium lactis* Bo and *Lactobacillus acidophilus* Ki by Milk Hydrolyzates. *Journal of Dairy Science* 81, 2817–2825 (1998).
  521. Kailasapathy, K. & Chin, J. Survival and therapeutic potential of probiotic organisms with reference to *Lactobacillus acidophilus* and *Bifidobacterium* spp. *Immunology and Cell Biology* 78, 80–88 (2000).
  522. Bischoff, S. C. *Probiotika, Präbiotika und Synbiotika*. (Georg Thieme Verlag KG, 2009).
  523. Timmerman, H. M., Koning, C. J. M., Mulder, L., Rombouts, F. M. & Beynen, A. C. Monostrain, multistain and multispecies probiotics – A comparison of functionality and efficacy. *International Journal of Food Microbiology* 96, 219–233 (2004).
  524. Chapman, C. M. C., Gibson, G. R. & Rowland, I. Health benefits of probiotics: are mixtures more effective than single strains? *European Journal of Nutrition* 50, 1–17 (2011).
  525. Ducroté, P. Clinical trial: *Lactobacillus plantarum* 299v (DSM 9843) improves symptoms of irritable bowel syndrome. *World Journal of Gastroenterology* 18, 4012–4018 (2012).
  526. Allen, S. J., Martinez, E. G., Gregorio, G. & Dans, L. F. Probiotics for treating acute infectious diarrhoea. *The Cochrane Database of Systematic Reviews* CD003048 (2010). doi:10.1002/14651858.CD003048.pub3.
  527. Ahmadi, E., Alizadeh-Navaei, R. & Rezai, M. S. Efficacy of probiotic use in acute

- rotavirus diarrhea in children: A systematic review and meta-analysis. *Caspian Journal of Internal Medicine* 6, 187–195 (2015).
528. Goldenberg, J. Z. et al. Probiotics for the prevention of pediatric antibiotic-associated diarrhea. *Cochrane Database of Systematic Reviews* CD004827 (2015). doi: 10.1002/14651858.CD004827.pub4.
529. Hempel, S. et al. Probiotics for the prevention and treatment of antibiotic-associated diarrhea: a systematic review and meta-analysis. *Journal of the American Medical Association (JAMA)* 307, 1959–1569 (2012).
530. Videlock, E. J. & Cremonini, F. Meta-analysis: probiotics in antibiotic-associated diarrhoea. *Alimentary Pharmacology & Therapeutics* 35, 1355–1369 (2012).
531. Johnston, B. C. et al. Microbial Preparations (Probiotics) for the Prevention of *Clostridium difficile* Infection in Adults and Children: An Individual Patient Data Meta-analysis of 6,851 Participants. *Infection Control and Hospital Epidemiology* 39, 771–781 (2018).
532. Goldenberg, J. Z. et al. Probiotics for the prevention of *Clostridium difficile*-associated diarrhea in adults and children. *Cochrane Database of Systematic Reviews* CD006095 (2013). doi: 10.1002/14651858.CD006095.pub3.
533. Kotowska, M., Albrecht, P. & Szajewska, H. *Saccharomyces boulardii* in the prevention of antibiotic-associated diarrhoea in children: a randomized double-blind placebo-controlled trial. *Alimentary Pharmacology & Therapeutics* 21, 583–590 (2005).
534. Can, M., Can, M., Avci, I. Y., Beker, C. M. & Pahsa, A. Prophylactic *Saccharomyces boulardii* in the prevention of antibiotic-associated diarrhea: a prospective study. *Medical Science Monitor* 12, P119–P122 (2006).
535. Szajewska, H. & Kołodziej, M. Systematic review with meta-analysis: *Saccharomyces boulardii* in the prevention of antibiotic-associated diarrhoea. *Alimentary Pharmacology & Therapeutics* 42, 793–801 (2015).
536. Goldenberg, J. Z. et al. Probiotics for the prevention of *Clostridium difficile*-associated diarrhea in adults and children. *Cochrane Database of Systematic Reviews* CD006095 (2017). doi: 10.1002/14651858.CD006095.pub4.
537. Lau, C., Ward, A. & Chamberlain, R. Probiotics improve the efficacy of standard triple therapy in the eradication of *Helicobacter pylori*: a meta-analysis. *Infection and Drug Resistance* 9, 275–289 (2016).
538. Zhang, M.-M., Qian, W., Qin, Y.-Y., He, J. & Zhou, Y.-H. Probiotics in *Helicobacter pylori* eradication therapy: a systematic review and meta-analysis. *World Journal of Gastroenterology* 21, 4345–4357 (2015).
539. Zhu, R. et al. Meta-analysis of the efficacy of probiotics in *Helicobacter pylori* eradication therapy. *World Journal of Gastroenterology* 20, 18013–18021 (2014).
540. de Bortoli, N. et al. *Helicobacter pylori* Eradication: A Randomized Prospective Study of Triple Therapy Versus Triple Therapy Plus Lactoferrin and Probiotics. *American Journal of Gastroenterology* 102, 951–956 (2007).
541. Fischbach, W., Malferteiner, P., Lynen Jansen, P. & Bolten, W. S2k-Leitlinie *Helicobacter pylori* und gastroduodenale Ulkuserkrankheit. *Zeitschrift für Gastroenterologie* 54, 327–363 (2016).
542. Cekin, A. H. et al. Use of probiotics as an adjuvant to sequential *H. pylori* eradication therapy: impact on eradication rates, treatment resistance, treatment-related side effects, and patient compliance. *Turkish Journal of Gastroenterology* 28, 3–11 (2017).
543. Azais-Braesco, V., Bresson, J. L., Guarner, F. & Corthier, G. Not all lactic acid bacteria are probiotics, ...but some are. *British Journal of Nutrition* 103, 1079–1081 (2010).
544. Koning, C. J. M. et al. The effect of a multispecies probiotic on the intestinal microbiota and bowel movements in healthy volunteers taking the antibiotic amoxicillin. *American Journal of Gastroenterology* 103, 178–189 (2008).
545. Shen, N. T. et al. Timely use of Probiotics in Hospitalized Adults Prevents *Clostridium difficile* Infection: a Systematic Review with Meta-Regression Analysis. *Gastroenterology* 152, 1889–1900 (2017). doi:10.1053/j.gastro.2017.02.003.
546. Johnston, B. C. et al. Probiotics for the prevention of *Clostridium difficile*-associated diarrhea: a systematic review and meta-analysis. *Annals of Internal Medicine* 157, 878–888 (2012).
547. Tolone, S., Pellino, V., Vitaliti, G., Lanzafame, A. & Tolone, C. Evaluation of *Helicobacter Pylori* eradication in pediatric patients by triple therapy plus lactoferrin and probiotics compared to triple therapy alone. *Italian Journal of Pediatrics* 38, 63 (2012).
548. van Wietmarschen, H. A., Busch, M., van Oostveen, A., Pot, G. & Jong, M. C. Probiotics use for antibiotic-associated diarrhea: a pragmatic participatory evaluation in nursing homes. *BMC Gastroenterology* 20, 151 (2020).
549. Madden, J. A. J. et al. Effect of probiotics on preventing disruption of the intestinal microflora following antibiotic therapy: a double-blind, placebo-controlled pilot study. *International Immunopharmacology* 5, 1091–1097 (2005).
550. McFarland, L. V. Use of probiotics to correct dysbiosis of normal microbiota following disease or disruptive events: a systematic review. *BMJ Open* 4, e005047 (2014).
551. Oh, B., Kim, J. W. & Kim, B.-S. Changes in the Functional Potential of the Gut Microbiome Following Probiotic Supplementation during *Helicobacter Pylori* Treatment. *Helicobacter* 21, 493–503 (2016).
552. Korpela, K. et al. Probiotic supplementation restores normal microbiota composition and function in antibiotic-treated and in caesarean-born infants. *Microbiome* 6, 182 (2018).
553. Engelbrektson, A. et al. Probiotics to minimize the disruption of faecal microbiota in healthy subjects undergoing antibiotic therapy. *Journal of Medical Microbiology* 58, 663–670 (2009).
554. Zoppi, G., Cinquetti, M., Benini, A., Bonamini, E. & Minelli, E. B. Modulation of the intestinal ecosystem by probiotics and lactulose in children during treatment with ceftriaxone. *Current Therapeutic Research* 62, 418–435 (2001).
555. Oh, B. et al. The Effect of Probiotics on Gut Microbiota during the *Helicobacter pylori* Eradication: Randomized Controlled Trial. *Helicobacter* 21, 165–174 (2016).
556. Almeida, C. C., Lorena, S. L. S., Pavan, C. R., Akasaka, H. M. I. & Mesquita, M. A. Beneficial effects of long-term consumption of a probiotic combination of *actobacillus casei* Shirota and *Bifidobacterium breve* Yakult may persist after suspension of therapy in lactose-intolerant patients. *Nutrition in Clinical Practice* 27, 247–251 (2012).
557. Vrese, M. et al. Probiotics—compensation for lactase insufficiency. *American Journal of Clinical Nutrition* 73, 421S–429S (2001).
558. Besseling-van der Vaart, I., Heath, M. D., Guagnini, F. & Kramer, M. F. In vitro evidence for efficacy in food intolerance for the multispecies probiotic formulation Ecologic® Tolerance (Syngut™). *Beneficial Microbes* 1–8 (2015). doi:10.3920/BM2015.0051.
559. Klemenak, M., Dolinšek, J., Langerholc, T., Gioia, D. & Mičetić-Turk, D. Administration of *Bifidobacterium breve* Decreases the Production of TNF- $\alpha$  in Children with Celiac Disease. *Digestive Diseases and Sciences* 60, 3386–3392 (2015).
560. Olivares, M., Castillejo, G., Varea, V. & Sanz, Y. Double-blind, randomised, placebo-controlled intervention trial to evaluate the effects of *Bifidobacterium longum* CECT 7347 in children with newly diagnosed coeliac disease. *British Journal of Nutrition* 112, 30–40 (2014).
561. Smecuol, E. et al. Exploratory, Randomized, Double-blind, Placebo-controlled Study on the Effects of *Bifidobacterium infantis* Natren Life Start Strain Super Strain in Active Celiac Disease. *Journal of Clinical Gastroenterology* 47, 139–147 (2013).
562. Pecora, F. et al. Gut Microbiota in Celiac Disease: Is There Any Role for Probiotics? *Frontiers in Immunology* 11, 957 (2020).
563. Olivares, M., Laparra, M. & Sanz, Y. Influence of *Bifidobacterium longum* CECT 7347 and gliadin peptides on intestinal epithelial cell proteome. *Journal of Agricultural and Food Chemistry* 59, 7666–7671 (2011).
564. Angelis, M. et al. VSL#3 probiotic preparation has the capacity to hydrolyze gliadin polypeptides responsible for Celiac Sprue probiotics and gluten intolerance. *Biochimica et Biophysica Acta* 1762, 80–93 (2006).
565. Strachan, D. P. Hay fever, hygiene, and household size. *BMJ* 299, 1259–1260 (1989).
566. Froidure, A. & Pilette, C. From the hygiene hypothesis to A20: the protective effect of endotoxins against asthma development. *Clinical & Experimental Allergy* 46, 192–193 (2016).
567. Bridgman, S. L. et al. Gut microbiota and allergic disease in children. *Annals of Allergy, Asthma & Immunology* 116, 99–105 (2016).
568. Johnson, C. C. et al. The infant gut bacterial microbiota and risk of pediatric asthma and allergic diseases. *Translational Research* 179, 60–70 (2017).
569. Zhang, G.-Q. et al. Probiotics for Prevention of Atopy and Food Hypersensitivity in Early Childhood: A PRISMA-Compliant Systematic Review and Meta-Analysis of Randomized Controlled Trials. *Medicine* 95, e2562 (2016).
570. Toh, Z. Q., Anzela, A., Tang, M. L. K. & Licciardi, P. V. Probiotic therapy as a novel approach for allergic disease. *Frontiers in Pharmacology* 3, 171 (2012).
571. Güvenc, I. A. et al. Do probiotics have a role in the treatment of allergic rhinitis? A comprehensive systematic review and meta analysis. *American Journal of Rhinology & Allergy* 30, 157–175 (2016). doi:10.2500/ajra.2016.30.4354.
572. Watts, A. M. et al. A Specifically Designed Multispecies Probiotic Supplement

- Relieves Seasonal Allergic Rhinitis Symptoms. *Journal of Alternative and Complementary Medicine* 24, 833–840 (2018).
573. Vliagoftis, H., Kouranos, V. D., Betsi, G. I. & Falagas, M. E. Probiotics for the treatment of allergic rhinitis and asthma: systematic review of randomized controlled trials. *Annals of Allergy, Asthma & Immunology* 101, 570–579 (2008).
574. Lin, T.-Y., Chen, C.-J., Chen, L.-K., Wen, S.-H. & Jan, R.-H. Effect of probiotics on allergic rhinitis in Df, Dp or dust-sensitive children: a randomized double blind controlled trial. *Indian Pediatrics* 50, 209–213 (2013).
575. Jerzynska, J. et al. Effect of *Lactobacillus rhamnosus* GG and vitamin D supplementation on the immunologic effectiveness of grass-specific sublingual immunotherapy in children with allergy. *Allergy and Asthma Proceedings* 37, 324–334 (2016).
576. Cao, L. et al. Long-term effect of early-life supplementation with probiotics on preventing atopic dermatitis: A meta-analysis. *Journal of Dermatological Treatment* 26, 537–540 (2015).
577. Panduru, M., Panduru, N. M., Sălăvăstru, C. M. & Tiplica, G.-S. Probiotics and primary prevention of atopic dermatitis: a meta-analysis of randomized controlled studies. *Journal of the European Academy of Dermatology and Venereology* 29, 232–242 (2015).
578. Zuccotti, G. et al. Probiotics for prevention of atopic diseases in infants: systematic review and meta-analysis. *Allergy* 70, 1356–1371 (2015).
579. Jiang, W. et al. The Role of Probiotics in the Prevention and Treatment of Atopic Dermatitis in Children: An Updated Systematic Review and Meta-Analysis of Randomized Controlled Trials. *Paediatric Drugs* 22, 535–549 (2020). doi:10.1007/s40272-020-00410-6.
580. Rautava, S., Kainonen, E., Salminen, S. & Isolauri, E. Maternal probiotic supplementation during pregnancy and breast-feeding reduces the risk of eczema in the infant. *Journal of Allergy and Clinical Immunology* 130, 1355–1360 (2012).
581. Wang, I.-J. & Wang, J.-Y. Children with atopic dermatitis show clinical improvement after *Lactobacillus* exposure. *Clinical & Experimental Allergy* 45, 779–787 (2015).
582. Fiocchi, A. et al. World Allergy Organization-McMaster University Guidelines for Allergic Disease Prevention (GLAD-PP): Probiotics. *World Allergy Organization Journal* 8, 4 (2015).
583. Messaoudi, M. et al. Assessment of psychotropic-like properties of a probiotic formulation (*Lactobacillus helveticus* R0052 and *Bifidobacterium longum* R0175) in rats and human subjects. *British Journal of Nutrition* 105, 755–764 (2011).
584. Ait-Belgnaoui, A. et al. *Bifidobacterium longum* and *Lactobacillus helveticus* Synergistically Suppress Stress-related Visceral Hypersensitivity Through Hypothalamic-Pituitary-Adrenal Axis Modulation. *Journal of Neurogastroenterology and Motility* 24, 138–146 (2018).
585. Bermúdez-Humarán, L. G. et al. From Probiotics to Psychobiotics: Live Beneficial Bacteria Which Act on the Brain-Gut Axis. *Nutrients* 11, 890 (2019).
586. Cryan, J. F. & Dinan, T. G. Mind-altering microorganisms: the impact of the gut microbiota on brain and behaviour. *Nature Reviews Neuroscience* 13, 701–712 (2012).
587. Sharma, R., Gupta, D., Mehrotra, R. & Mago, P. Psychobiotics: The Next-Generation Probiotics for the Brain. *Current Microbiology* 78, 449–463 (2021).
588. Ait-Belgnaoui, A. et al. Probiotic gut effect prevents the chronic psychological stress-induced brain activity abnormality in mice. *Neurogastroenterology & Motility* 26, 510–520 (2014).
589. Arseneault-Bréard, J. et al. Combination of *Lactobacillus helveticus* R0052 and *Bifidobacterium longum* R0175 reduces post-myocardial infarction depression symptoms and restores intestinal permeability in a rat model. *British Journal of Nutrition* 107, 1793–1799 (2012).
590. Ohland, C. L. et al. Effects of *Lactobacillus helveticus* on murine behavior are dependent on diet and genotype and correlate with alterations in the gut microbiome. *Psychoneuroendocrinology* 38, 1738–1747 (2013).
591. McKean, J., Naug, H., Nikbakht, E., Amiet, B. & Colson, N. Probiotics and Subclinical Psychological Symptoms in Healthy Participants: A Systematic Review and Meta-Analysis. *Journal of Alternative and Complementary Medicine* 23, 249–258 (2017).
592. Drossman, D. A. & Hasler, W. L. Rome IV-Functional GI Disorders: Disorders of Gut-Brain Interaction. *Gastroenterology* 150, 1257–1261 (2016).
593. Quigley, E. The Gut-Brain Axis and the Microbiome: Clues to Pathophysiology and Opportunities for Novel Management Strategies in Irritable Bowel Syndrome (IBS). *Journal of Clinical Medicine* 7, 6 (2018).
594. Devanarayana, N. M. & Rajindrajith, S. Irritable bowel syndrome in children: Current knowledge, challenges and opportunities. *World Journal of Gastroenterology* 24, 2211–2235 (2018).
595. Salonen, A., Vos, W. M. & Palva, A. Gastrointestinal microbiota in irritable bowel syndrome: present state and perspectives. *Microbiology* 156, 3205–3215 (2010).
596. Sundin, J. et al. Altered faecal and mucosal microbial composition in post-infectious irritable bowel syndrome patients correlates with mucosal lymphocyte phenotypes and psychological distress. *Alimentary Pharmacology & Therapeutics* 41, 342–351 (2015).
597. Jalanka-Tuovinen, J. et al. Faecal microbiota composition and host-microbe cross-talk following gastroenteritis and in postinfectious irritable bowel syndrome. *Gut* 63, 1737–1745 (2014).
598. Lee, K. N. & Lee, O. Y. Intestinal microbiota in pathophysiology and management of irritable bowel syndrome. *World Journal of Gastroenterology* 20, 8886–8897 (2014).
599. Niedzielin, K., Kordecki, H. & Birkenfeld, B. A controlled, double-blind, randomized study on the efficacy of *Lactobacillus plantarum* 299V in patients with irritable bowel syndrome. *European Journal of Gastroenterology & Hepatology* 13, 1143–1147 (2001).
600. Nobaek, S., Johansson, M. L., Molin, G., Ahrné, S. & Jeppsson, B. Alteration of intestinal microflora is associated with reduction in abdominal bloating and pain in patients with irritable bowel syndrome. *American Journal of Gastroenterology* 95, 1231–1238 (2000).
601. Hoveyda, N. et al. A systematic review and meta-analysis: probiotics in the treatment of irritable bowel syndrome. *BMC Gastroenterology* 9, 15 (2009).
602. Hungin, A. P. S. et al. Systematic review: probiotics in the management of lower gastrointestinal symptoms - an updated evidence-based international consensus. *Alimentary Pharmacology & Therapeutics* 47, 1054–1070 (2018).
603. Didari, T. Effectiveness of probiotics in irritable bowel syndrome: Updated systematic review with meta-analysis. *World Journal of Gastroenterology* 21, 3072–3084 (2015).
604. Layer, P. et al. Update S3-Leitlinie Reizdarmsyndrom: Definition, Pathophysiologie, Diagnostik und Therapie des Reizdarmsyndroms der Deutschen Gesellschaft für Gastroenterologie, Verdauungs- und Stoffwechselkrankheiten (DGVS) und der Deutschen Gesellschaft für Neurogastroenterologie und Motilität (DGNM). (2021).
605. Zhang, Y. et al. Effects of probiotic type, dose and treatment duration on irritable bowel syndrome diagnosed by Rome III criteria: a meta-analysis. *BMC Gastroenterology* 16, 62 (2016).
606. Mazurak, N., Broelz, E., Storr, M. & Enck, P. Probiotic Therapy of the Irritable Bowel Syndrome: Why Is the Evidence Still Poor and What Can Be Done About It? *Journal of Neurogastroenterology and Motility* 21, 471–485 (2015).
607. Krammer, H., Storr, M., Madisch, A. & Riffel, J. Reizdarmbehandlung mit *Lactobacillus plantarum* 299v: Längere Einnahme verstärkt Behandlungserfolg – Ergebnisse einer nichtinterventionellen Studie. *Zeitschrift für Gastroenterologie* 59, 125–134 (2021).
608. Round, J. L. & Mazmanian, S. K. The gut microbiota shapes intestinal immune responses during health and disease. *Nature Reviews Immunology* 9, 313–323 (2009).
609. Sencio, V., Machado, M. G. & Trottein, F. The lung-gut axis during viral respiratory infections: the impact of gut dysbiosis on secondary disease outcomes. *Mucosal Immunology* 14, 296–304 (2021). doi:10.1038/s41385-020-00361-8.
610. Hao, Q., Dong, B. R. & Wu, T. Probiotics for preventing acute upper respiratory tract infections. *Cochrane Database of Systematic Reviews* CD006895 (2015). doi:10.1002/14651858.CD006895.pub3.
611. King, S., Glanville, J., Sanders, M. E., Fitzgerald, A. & Varley, D. Effectiveness of probiotics on the duration of illness in healthy children and adults who develop common acute respiratory infectious conditions: a systematic review and meta-analysis. *British Journal of Nutrition* 112, 41–54 (2014).
612. Wang, Y. et al. Probiotics for prevention and treatment of respiratory tract infections in children: A systematic review and meta-analysis of randomized controlled trials. *Medicine* 95, e4509 (2016).
613. Li, L. et al. Probiotics for Preventing Upper Respiratory Tract Infections in Adults: A Systematic Review and Meta-Analysis of Randomized Controlled Trials. *Evidence-based Complementary and Alternative Medicine* 2020, 8734140 (2020).
614. Smith, T. J., Rigasio-Radler, D., Denmark, R., Haley, T. & Touger-Decker, R. Effect of *Lactobacillus rhamnosus* LGG and *Bifidobacterium animalis* ssp. *lactis* BB-12 on health-related quality of life in college students affected by upper respiratory infections. *British Journal of Nutrition* 109, 1999–2007 (2013).
615. Meng, H. et al. Consumption of *Bifidobacterium animalis* subsp. *lactis* BB-12

- impacts upper respiratory tract infection and the function of NK and T cells in healthy adults. *Molecular Nutrition & Food Research* 60, 1161–1171 (2016).
616. Dong, H., Rowland, I. & Yaqoob, P. Comparative effects of six probiotic strains on immune function in vitro. *British Journal of Nutrition* 108, 459–470 (2012).
  617. Rizzardini, G. et al. Evaluation of the immune benefits of two probiotic strains *Bifidobacterium animalis* ssp. *lactis*, BB-12<sup>®</sup> and *Lactobacillus paracasei* ssp. *paracasei*, L. casei 431<sup>®</sup> in an influenza vaccination model: a randomised, double-blind, placebo-controlled study. *British Journal of Nutrition* 107, 876–884 (2012).
  618. Pyne, D. B. & Gleeson, M. Effects of intensive exercise training on immunity in athletes. *International Journal of Sports Medicine* 19 Suppl 3, S183-91; discussion S191– S194 (1998).
  619. Gleeson, M. Mucosal immune responses and risk of respiratory illness in elite athletes. *Exercise Immunology Review* 6, 5–42 (2000).
  620. Mackinnon, L. T. Chronic exercise training effects on immune function. *Medicine and Science in Sports and Exercise* 32, S369–S376 (2000).
  621. Gleeson, M. & Pyne, D. B. Respiratory inflammation and infections in high-performance athletes. *Immunology and Cell Biology* 94, 124–131 (2016).
  622. Gleeson, M. & Pyne, D. B. Special feature for the Olympics: effects of exercise on the immune system: exercise effects on mucosal immunity. *Immunology and Cell Biology* 78, 536–544 (2000).
  623. Gleeson, M., Pyne, D. B. & Callister, R. The missing links in exercise effects on mucosal immunity. *Exercise Immunology Review* 10, 107–128 (2004).
  624. Pals, K. L. et al. Effect of running intensity on intestinal permeability. *Journal of Applied Physiology* 82, 571–576 (1997).
  625. Zuhl, M. et al. Exercise regulation of intestinal tight junction proteins. *British Journal of Sports Medicine* 48, 980–986 (2014).
  626. Dokladny, K., Zuhl, M. N. & Moseley, P. L. Intestinal epithelial barrier function and tight junction proteins with heat and exercise. *Journal of Applied Physiology* 120, 692–701 (2016).
  627. Selkirk, G. A., McLellan, T. M., Wright, H. E. & Rhind, S. G. Mild endotoxemia, NF-kappaB translocation, and cytokine increase during exertional heat stress in trained and untrained individuals. *American Journal of Physiology. Regulatory, Integrative and Comparative Physiology* 295, R611–R623 (2008).
  628. Pedersen, B. K. & Toft, A. D. Effects of exercise on lymphocytes and cytokines. *British Journal of Sports Medicine* 34, 246–251 (2000).
  629. Moreira, A., Delgado, L., Moreira, P. & Haahela, T. Does exercise increase the risk of upper respiratory tract infections? *British Medical Bulletin* 90, 111–131 (2009).
  630. Nieman, D. The effect of exercise on immune function. *Bulletin on the Rheumatic Diseases* 43, 5–8 (1995).
  631. Gleeson, M., Bishop, N. C., Oliveira, M. & Tauler, P. Daily probiotics (*Lactobacillus casei* Shirota) reduction of infection incidence in athletes. *International Journal of Sport Nutrition and Exercise Metabolism* 21, 55–64 (2011).
  632. Cox, A. J., Pyne, D. B., Saunders, P. U. & Fricker, P. A. Oral administration of the probiotic *Lactobacillus fermentum* VRI-003 and mucosal immunity in endurance athletes. *British Journal of Sports Medicine* 44, 222–6 (2010).
  633. West, N. P. et al. *Lactobacillus fermentum* (PCC<sup>®</sup>) supplementation and gastro intestinal and respiratory-tract illness symptoms: a randomised control trial in athletes. *Nutrition Journal* 10, 30 (2011).
  634. Petrak, D. & Winzenhöller, P. Darmfloraveränderungen und Infektanfälligkeit durch Stress? *Der Heilpraktiker & Volksheilkunde* (2009).
  635. Marinkovic, D. M. et al. *L. helveticus* Lafti<sup>®</sup> L10 supplementation modulates mucosal and humoral immunity in elite athletes: a randomized double-blinded placebo-controlled trial. *Journal of Strength and Conditioning Research* 31, 62–70 (2016). doi:10.1519/JSC.0000000000001456.
  636. The Australian Institute of Sports/Australian Sports Commission. Supplements and Sports Food. URL: <https://www.ais.gov.au/nutrition/supplements>.
  637. Swiss Sports Nutrition Society (SSNS). Supplementguide. URL: <http://www.ssns.ch/sportsnutrition/supplemente/supplementguide/#a-supp>.
  638. Kölner Liste<sup>®</sup>. Kölner Liste<sup>®</sup> – Doping-Prävention im Sport. URL: <https://www.koelnerliste.com/hintergrund> (2021).
  639. Doron, S. & Snyderman, D. R. Risk and Safety of Probiotics. *Clinical Infectious Diseases* 60, S129–S134 (2015).
  640. Didari, T., Solki, S., Mozaffari, S., Nikfar, S. & Abdollahi, M. A systematic review of the safety of probiotics. *Expert Opinion on Drug Safety* 13, 227–239 (2014).
  641. Durchschein, F., Petritsch, W. & Hammer, H. F. Diet therapy for inflammatory bowel diseases: The established and the new. *World Journal of Gastroenterology* 22, 2179–2194 (2016).
  642. Guandalini, S., Cernat, E. & Moscoso, D. Probiotics and probiotics in irritable bowel syndrome and inflammatory bowel disease in children. *Beneficial Microbes* 6, 209–217 (2015).
  643. Rembacken, B., Snelling, A., Hawkey, P., Chalmers, D. & Axon, A. Non-pathogenic *Escherichia coli* versus mesalazine for the treatment of ulcerative colitis: a randomised trial. *The Lancet* 354, 635–639 (1999).
  644. Kruijs, W. et al. Double-blind comparison of an oral *Escherichia coli* preparation and mesalazine in maintaining remission of ulcerative colitis. *Alimentary Pharmacology and Therapeutics* 11, 853–858 (1997).
  645. Gionchetti, P. et al. Prophylaxis of pouchitis onset with probiotic therapy: a double-blind, placebo-controlled trial. *Gastroenterology* 124, 1202–1209 (2003).
  646. Holubar, S. D., Cima, R. R., Sandborn, W. J. & Pardi, D. S. Treatment and prevention of pouchitis after ileal pouch-anal anastomosis for chronic ulcerative colitis. *Cochrane Database of Systematic Reviews* CD001176. doi: 10.1002/14651858.CD001176.pub2.
  647. Miller, L. E., Zimmermann, A. K. & Ouwehand, A. C. Contemporary meta-analysis of short-term probiotic consumption on gastrointestinal transit. *World Journal of Gastroenterology* 22, 5122–5131 (2016).
  648. Dimidi, E., Christodoulides, S., Fragkos, K. C., Scott, S. M. & Whelan, K. The effect of probiotics on functional constipation in adults: a systematic review and meta-analysis of randomized controlled trials. *American Journal of Clinical Nutrition* 100, 1075–1084 (2014).
  649. Dugoua, J.-J. et al. Probiotic Safety in Pregnancy: A Systematic Review and Meta-analysis of Randomized Controlled Trials of *Lactobacillus*, *Bifidobacterium*, and *Saccharomyces* spp. *Journal of Obstetrics and Gynaecology Canada* 31, 542–552 (2009).
  650. Lamiki, P. et al. Probiotics in diverticular disease of the colon: an open label study. *Journal of Gastrointestinal and Liver Diseases* 19, 31–36 (2010).
  651. Tursi, A., Brandimarte, G., Giorgetti, G. M., Elisei, W. & Aiello, F. Balsalazide and/or high-potency probiotic mixture (VSL#3) in maintaining remission after attack of acute, uncomplicated diverticulitis of the colon. *International Journal of Colorectal Disease* 22, 1103–1108 (2007).
  652. Dryl, R. & Szajewska, H. Probiotics for management of infantile colic: a systematic review of randomized controlled trials. *Archives of Medical Science* 14, 1137–1143 (2018).
  653. He, T. et al. Effects of yogurt and bifidobacteria supplementation on the colonic microbiota in lactose-intolerant subjects. *Journal of Applied Microbiology* 104, 595–604 (2008).
  654. Deshpande, G. C., Rao, S. C., Keil, A. D. & Patole, S. K. Evidence-based guidelines for use of probiotics in preterm neonates. *BMC Medicine* 9, 92 (2011).
  655. Deshpande, G. et al. Probiotics for prevention of necrotizing enterocolitis in preterm neonates with very low birthweight: a systematic review of randomised controlled trials. *The Lancet* 369, 1614–1620 (2007).
  656. Deshpande, G. et al. Updated meta-analysis of probiotics for preventing necrotizing enterocolitis in preterm neonates. *Pediatrics* 125, 921–930 (2010).
  657. Alfaleh, K. & Anabrees, J. Probiotics for prevention of necrotizing enterocolitis in preterm infants. *Evidence-Based Child Health* 9, 584–671 (2014).
  658. Barclay, A. R., Stenson, B., Simpson, J. H., Weaver, L. T. & Wilson, D. C. Probiotics for Necrotizing Enterocolitis: A Systematic Review. *Journal of Pediatric Gastroenterology and Nutrition* 45, 569–576 (2007).
  659. Mihatsch, W. & Pohlandt, F. Probiotika - Eine Routinetherapie für Frühgeborene? Was beweisen die bisherigen Studien? *Kinder- und Jugendmedizin* 10, 21–32 (2010).
  660. Robinson, J. Cochrane in context: Probiotics for prevention of necrotizing enterocolitis in preterm infants. *Evidence-Based Child Health* 9, 672–674 (2014).
  661. Giannetti, E. & Staiano, A. Probiotics for Irritable Bowel Syndrome: Clinical Data in Children. *Journal of Pediatric Gastroenterology and Nutrition* 63 Suppl 1, S25–S26 (2016).
  662. Clarke, G., Cryan, J. F., Dinan, T. G. & Quigley, E. M. Review article: probiotics for the treatment of irritable bowel syndrome-focus on lactic acid bacteria. *Alimentary Pharmacology & Therapeutics* 35, 403–413 (2012).
  663. Ford, A. C. et al. Efficacy of prebiotics, probiotics, and synbiotics in irritable bowel syndrome and chronic idiopathic constipation: systematic review and meta-analysis. *American Journal of Gastroenterology* 109, 1547–1561 (2014).
  664. Moayyedi, P. et al. The efficacy of probiotics in the treatment of irritable bowel

- syndrome: a systematic review. *Gut* 59, 325–332 (2010).
665. Tavakkoli, A. & Green, P. H. Probiotic Therapy for Celiac Disease. *Journal of Clinical Gastroenterology* 47, 101–103 (2013).
666. Sousa Moraes, L. F., Grzeskowiak, L. M., Sales Teixeira, T. F. & Gouveia Peluzio, M. do C. Intestinal microbiota and probiotics in celiac disease. *Clinical Microbiology Reviews* 27, 482–489 (2014).
667. Kramer, M. F. & Heath, M. D. Probiotics in the Treatment of Chronic Rhinoconjunctivitis and Chronic Rhinosinusitis. *Journal of Allergy* 2014, 1–7 (2014).
668. Ng, Q. X. et al. A Systematic Review of the Role of Prebiotics and Probiotics in Autism Spectrum Disorders. *Medicina* 55, 129 (2019).
669. Patusco, R. & Ziegler, J. Role of Probiotics in Managing Gastrointestinal Dysfunction in Children with Autism Spectrum Disorder: An Update for Practitioners. *Advances in Nutrition* 9, 637–650 (2018).
670. Tankou, S. K. et al. A probiotic modulates the microbiome and immunity in multiple sclerosis. *Annals of Neurology* 83, 1147–1161 (2018).
671. Huang, R., Wang, K. & Hu, J. Effect of Probiotics on Depression: A Systematic Review and Meta-Analysis of Randomized Controlled Trials. *Nutrients* 8, 483 (2016).
672. Liu, R. T., Walsh, R. F. L. & Sheehan, A. E. Prebiotics and probiotics for depression and anxiety: A systematic review and meta-analysis of controlled clinical trials. *Neuroscience and Biobehavioral Reviews* 102, 13–23 (2019).
673. Tabrizi, R. et al. The effects of probiotic and synbiotic supplementation on inflammatory markers among patients with diabetes: A systematic review and meta-analysis of randomized controlled trials. *European Journal of Pharmacology* 852, 254–264 (2019).
674. Xu, J. et al. Effects of probiotic therapy on hepatic encephalopathy in patients with liver cirrhosis: an updated meta-analysis of six randomized controlled trials. *Hepatobiliary & Pancreatic Diseases International* 13, 354–360 (2014).
675. Ma, Y.-Y. et al. Effects of probiotics on nonalcoholic fatty liver disease: a meta-analysis. *World Journal of Gastroenterology* 19, 6911–6918 (2013).
676. Gao, X., Zhu, Y., Wen, Y., Liu, G. & Wan, C. Efficacy of probiotics in nonalcoholic fatty liver disease in adult and children: A meta-analysis of randomized controlled trials. *Hepatology Research* 46, 1226–1233 (2016).
677. Zhao, L.-N. et al. Probiotics can improve the clinical outcomes of hepatic encephalopathy: An update meta-analysis. *Clinics and Research in Hepatology and Gastroenterology* 39, 674–682 (2015).
678. Koppe, L. et al. Probiotics and chronic kidney disease. *Kidney International* 88, 958–966 (2015).
679. Taipale, T. et al. Bifidobacterium animalis subsp. lactis BB-12 in reducing the risk of infections in infancy. *British Journal of Nutrition* 105, 409–416 (2011).
680. Taipale, T. J., Pienihäkkinen, K., Isolauri, E., Jokela, J. T. & Söderling, E. M. Bifidobacterium animalis subsp. lactis BB-12 in reducing the risk of infections in early childhood. *Pediatric Research* 79, 65–69 (2016).
681. Zhang, Q., Wu, Y. & Fei, X. Effect of probiotics on body weight and body-mass index: a systematic review and meta-analysis of randomized, controlled trials. *International Journal of Food Sciences and Nutrition* 67, 571–580 (2016).
682. John, G. et al. Dietary Alteration of the Gut Microbiome and Its Impact on Weight and Fat Mass: A Systematic Review and Meta-Analysis. *Genes* 9, 167 (2018).
683. Wang, Y.-H. et al. The efficacy and safety of probiotics for prevention of chemoradiotherapy-induced diarrhea in people with abdominal and pelvic cancer: a systematic review and meta-analysis. *European Journal of Clinical Nutrition* 70, 1246–1253 (2016).
684. Sebillé, Y. Z. A. et al. Management of Mucositis During Chemotherapy: From Pathophysiology to Pragmatic Therapeutics. *Current Oncology Reports* 17, 50 (2015).
685. Toucheffeu, Y. et al. Systematic review: the role of the gut microbiota in chemotherapy- or radiation-induced gastrointestinal mucositis - current evidence and potential clinical applications. *Alimentary Pharmacology & Therapeutics* 40, 409–421 (2014).
686. Ciorba, M. A., Hallemeier, C. L., Stenson, W. F. & Parikh, P. J. Probiotics to prevent gastrointestinal toxicity from cancer therapy: an interpretive review and call to action. *Current Opinion in Supportive and Palliative Care* 9, 157–162 (2015).
687. Qiu, G., Yu, Y., Wang, Y. & Wang, X. The significance of probiotics in preventing radiotherapy-induced diarrhea in patients with cervical cancer: A systematic review and meta-analysis. *International Journal of Surgery* 65, 61–69 (2019).
688. Diop, L., Guillou, S. & Durand, H. Probiotic food supplement reduces stress-induced gastrointestinal symptoms in volunteers: a double-blind, placebo-controlled, randomized trial. *Nutrition Research* 28, 1–5 (2008).
689. Andresen, V. et al. S2k-Leitlinie Chronische Obstipation: Definition, Pathophysiologie, Diagnostik und Therapie. *Zeitschrift für Gastroenterologie* 51, 651–672 (2013).
690. Fischbach, W. et al. S2k-Leitlinie Helicobacter pylori und gastroduodenale Ulkuserkrankheit. *Zeitschrift für Gastroenterologie* 55, 167–206 (2016).
691. Kucharzik, T. et al. Aktualisierte S3-Leitlinie Colitis ulcerosa – Living Guideline: August 2020 – AWMF-Registriernummer: 021-009. *Zeitschrift für Gastroenterologie* 58, e241–e326 (2020).
692. Keller, J. et al. S3-Leitlinie der Deutschen Gesellschaft für Verdauungs- und Stoffwechselkrankheiten (DGVS) und der Deutschen Gesellschaft für Neurogastroenterologie und Motilität (DGNM) zu Definition, Pathophysiologie, Diagnostik und Therapie intestinaler Motilitätsstörungen. *Zeitschrift für Gastroenterologie* 49, 374–390 (2011).
693. Gesellschaft für Neonatologie und Pädiatrische Intensivmedizin et al. Nekrotisierende Enterokolitis - Leitlinie der Gesellschaft für Neonatologie und Pädiatrische Intensivmedizin, der Deutschen Gesellschaft für Kinder- und Jugendmedizin, der Gesellschaft für Pädiatrische Gastroenterologie und Ernährung und der Deutschen Gesellschaft für Kinderchirurgie. AWMF-Leitlinien-Register-Nr. 024/009. (2017).
694. Bischoff, S., Koletzko, B., Lochs, H., Meier, R., & und das DGEM Steering Committee. S3-Leitlinie der Deutschen Gesellschaft für Ernährungsmedizin (DGEM) in Zusammenarbeit mit der Gesellschaft für klinische Ernährung der Schweiz (GESKES), der Österreichischen Arbeitsgemeinschaft für klinische Ernährung (AKE) und der Deutschen Gesellschaft für Gastroenterologie, Verdauungs- und Stoffwechselkrankheiten (DGVS): Klinische Ernährung in der Gastroenterologie (Teil 4) – Chronisch-entzündliche Darmerkrankungen. *Aktuelle Ernährungsmedizin* 39, e72–e98 (2014).
695. Heintze, C., Krüger, K., Gehrke-Beck, S. & Holzinger, F. Husten – DEGAM-Leitlinie Nr. 11. Leitlinie der Deutschen Gesellschaft für Allgemeinmedizin und Familienmedizin. (2014).
696. Posovszky, C. et al. S2k-Leitlinie Akute infektiöse Gastroenteritis im Säuglings-, Kindes- und Jugendalter – AWMF Registernummer 068-003. Leitlinie der Gesellschaft für pädiatrische Gastroenterologie und Ernährung (GPGE) gemeinsam mit der Deutschen Gesellschaft für Kinder- und Jugendmedizin (DGKJ), dem Berufsverband der Kinder- und Jugendärzte (BVKJ), der Deutschen Gesellschaft für pädiatrische Infektiologie (DGPI), der österreichischen Gesellschaft für Kinder- und Jugendheilkunde (ÖGKJ), der Deutschen Gesellschaft für Gastroenterologie, Verdauungs- und Stoffwechselstörungen (DGVS), dem Arbeitskreis „Krankenhaus & Praxishygiene“ der AWMF und der Deutschen Gesellschaft für Pflegewissenschaft e. V. (DGPW). *Zeitschrift für Gastroenterologie* 57, 1077–1118 (2019).
697. Stephen, A. M. et al. Dietary fibre in Europe: current state of knowledge on definitions, sources, recommendations, intakes and relationships to health. *Nutrition Research Reviews* 30, 149–190 (2017).
698. Codex Alimentarius Commission. Report of the 30th session of the Codex Committee on Nutrition and Foods for Special Dietary Uses (ALINORM 09/32/26). (2008).
699. Biesalski, H. K., Pirlich, M., Bischoff, S. C. & Weimann, A. Ernährungsmedizin – Nach dem Curriculum Ernährungsmedizin der Bundesärztekammer. (Thieme Verlag, 2017).
700. Hesecker, H. Ein Mix gesunder Fasern. *Aktuelle Ernährungsmedizin* 39, S2–S4 (2014).
701. Slavin, J. L., Savarino, V., Paredes-Diaz, A. & Fotopoulos, G. A review of the role of soluble fiber in health with specific reference to wheat dextrin. *Journal of International Medical Research* 37, 1–17 (2009).
702. Wisker, E. Präbiotika: Überblick über die Ergebnisse von Studien am Menschen. *ErnährungsUmschau* 49, 468–476 (2002).
703. Lefranc-Millot, C. et al. Impact of a resistant dextrin on intestinal ecology: how altering the digestive ecosystem with NUTRIOSE®, a soluble fibre with prebiotic properties, may be beneficial for health. *Journal of International Medical Research* 40, 211–224 (2012).
704. Deutsche Gesellschaft für Ernährung (DGE), Österreichische Gesellschaft für Ernährung (ÖGE), Schweizerische Gesellschaft für Ernährung (SGE). D-A-CH-Referenzwerte für die Nährstoffzufuhr. (2018).
705. Max Rubner Institut (MRI). Nationale Verzehrs Studie II. (2008).
706. Deutsche Gesellschaft für Ernährung (DGE). Ballaststoffe – kein überflüssiger Ballast. DGE akutell. (2008).
707. Gibson, G. R. & Roberfroid, M. B. Dietary modulation of the human colonic microbiota: introducing the concept of prebiotics. *Journal of Nutrition* 125, 1401–1412 (1995).
708. Biesalski, H. K., Grimm, P. & Nowitzki-Grimm, S. Taschenatlas Ernährung. (Thieme

- Verlag, 2015).
709. Dueñas, M. et al. A Survey of Modulation of Gut Microbiota by Dietary Polyphenols. *BioMed Research International* 2015, 850902 (2015).
  710. Corrêa, T. A. F., Rogero, M. M., Hassimotto, N. M. A. & Lajolo, F. M. The Two-Way Polyphenols-Microbiota Interactions and Their Effects on Obesity and Related Metabolic Diseases. *Frontiers in Nutrition* 6, 188 (2019).
  711. Slavin, J. Fiber and Prebiotics: Mechanisms and Health Benefits. *Nutrients* 5, 1417–1435 (2013).
  712. Hahn, A., Ströhle, A. & Wolters, M. Ernährung: Physiologische Grundlagen, Prävention, Therapie. (Wissenschaftliche Verlagsgesellschaft mbH, 2016).
  713. Bode, L. Human milk oligosaccharides: every baby needs a sugar mama. *Glycobiology* 22, 1147–1162 (2012).
  714. Harmsen, H. J. et al. Analysis of intestinal flora development in breast-fed and formula-fed infants by using molecular identification and detection methods. *Journal of Pediatric Gastroenterology and Nutrition* 30, 61–67 (2000).
  715. Vulevic, J., Drakoularakou, A., Yaqoob, P., Tzortzis, G. & Gibson, G. R. Modulation of the fecal microflora profile and immune function by a novel trans-galacto-oligosaccharide mixture (B-GOS) in healthy elderly volunteers. *American Journal of Clinical Nutrition* 88, 1438–1446 (2008).
  716. Bouhnik, Y. et al. Administration of transgalacto-oligosaccharides increases fecal bifidobacteria and modifies colonic fermentation metabolism in healthy humans. *Journal of Nutrition* 127, 444–448 (1997).
  717. Gibson, G. R. et al. Dietary modulation of the human colonic microbiota: updating the concept of prebiotics. *Nutrition Research Reviews* 17, 259 (2004).
  718. Bornet, F. R. J., Brouns, F., Tashiro, Y. & Duvillier, V. Nutritional aspects of short-chain fructooligosaccharides: natural occurrence, chemistry, physiology and health implications. *Digestive and Liver Disease* 34 Suppl 2, S111–120 (2002).
  719. Lied, G. A. et al. Perceived food hypersensitivity: a review of 10 years of interdisciplinary research at a reference center. *Scandinavian Journal of Gastroenterology* 46, 1169–1178 (2011).
  720. Grabsitske, H. A. & Slavin, J. L. Gastrointestinal Effects of Low-Digestible Carbohydrates. *Critical Reviews in Food Science and Nutrition* 49, 327–360 (2009).
  721. Ternes, W., Täufel, A., Tunger, L. & Zobel, M. Lebensmittel-Lexikon. (Behr's Verlag, 2005).
  722. Costabile, A. et al. A double-blind, placebo-controlled, cross-over study to establish the bifidogenic effect of a very-long-chain inulin extracted from globe artichoke (*Cynara scolymus*) in healthy human subjects. *British Journal of Nutrition* 104, 1007–1017 (2010).
  723. Amnani, P. et al. Prebiotic effect of fruit and vegetable shots containing Jerusalem artichoke inulin: a human intervention study. *British Journal of Nutrition* 104, 233–240 (2010).
  724. Ramirez-Farias, C. et al. Effect of inulin on the human gut microbiota: stimulation of *Bifidobacterium adolescentis* and *Faecalibacterium prausnitzii*. *British Journal of Nutrition* 101, 541–550 (2009).
  725. Wiciński, M., Sawicka, E., Gębalski, J., Kubiak, K. & Malinowski, B. Human Milk Oligosaccharides: Health Benefits, Potential Applications in Infant Formulas, and Pharmacology. *Nutrients* 12, 266 (2020).
  726. Coppa, G. V. et al. Oligosaccharides in human milk during different phases of lactation. *Acta Paediatrica Suppl* 88, 89–94 (1999).
  727. Plaza-Díaz, J., Fontana, L. & Gil, A. Human Milk Oligosaccharides and Immune System Development. *Nutrients* 10, 1038 (2018).
  728. Ninonuevo, M. R. et al. A Strategy for Annotating the Human Milk Glycome. *Journal of Agricultural and Food Chemistry* 54, 7471–7480 (2006).
  729. Elkington, S. G. Lactulose. *Gut* 11, 1043–1048 (1970).
  730. Watson, D. et al. Selective carbohydrate utilization by lactobacilli and bifidobacteria. *Journal of Applied Microbiology* 114, 1132–1146 (2013).
  731. Costabile, A. et al. Prebiotic Potential of a Maize-Based Soluble Fibre and Impact of Dose on the Human Gut Microbiota. *PLoS One* 11, e0144457 (2016).
  732. Maathuis, A., Hoffman, A., Evans, A., Sanders, L. & Venema, K. The effect of the undigested fraction of maize products on the activity and composition of the microbiota determined in a dynamic in vitro model of the human proximal large intestine. *Journal of the American College of Nutrition* 28, 657–666 (2009).
  733. Vester Boler, B. M. et al. Digestive physiological outcomes related to polydextrose and soluble maize fibre consumption by healthy adult men. *British Journal of Nutrition* 106, 1864–1871 (2011).
  734. Timm, D. A., Thomas, W., Boileau, T. W., Williamson-Hughes, P. S. & Slavin, J. L. Polydextrose and Soluble Corn Fiber Increase Five-Day Fecal Wet Weight in Healthy Men and Women. *Journal of Nutrition* 143, 473–478 (2013).
  735. Knapp, B. K. et al. Soluble fiber dextrin and soluble corn fiber supplementation modify indices of health in cecum and colon of Sprague-Dawley rats. *Nutrients* 5, 396–410 (2013).
  736. Barczynska, R., Kapusniak, J., Litwin, M., Slizewska, K. & Szalecki, M. Dextrins from Maize Starch as Substances Activating the Growth of Bacteroidetes and Actinobacteria Simultaneously Inhibiting the Growth of Firmicutes, Responsible for the Occurrence of Obesity. *Plant Foods for Human Nutrition* 71, 190–196 (2016).
  737. Whisner, C. M. et al. Soluble Corn Fiber Increases Calcium Absorption Associated with Shifts in the Gut Microbiome: A Randomized Dose-Response Trial in Free-Living Pubertal Females. *Journal of Nutrition* 146, 1298–1306 (2016).
  738. Whisner, C. M. et al. Soluble maize fibre affects short-term calcium absorption in adolescent boys and girls: a randomised controlled trial using dual stable isotopic tracers. *British Journal of Nutrition* 112, 446–456 (2014).
  739. Jakeman, S. A. et al. Soluble corn fiber increases bone calcium retention in postmenopausal women in a dose-dependent manner: a randomized crossover trial. *American Journal of Clinical Nutrition* 104, 837–843 (2016).
  740. Weaver, C. M., Martin, B. R., Story, J. A., Hutchinson, I. & Sanders, L. Novel fibers increase bone calcium content and strength beyond efficiency of large intestine fermentation. *Journal of Agricultural and Food Chemistry* 58, 8952–8957 (2010).
  741. Knapp, B. K. Select novel carbohydrates affect glycemic and insulinemic response, energy value, and indices of gut health as measured using canine, avian, rodent, and in vitro model systems. (2011).
  742. Konings, E., Schoffelen, P. F., Stegen, J. & Blaak, E. E. Effect of polydextrose and soluble maize fibre on energy metabolism, metabolic profile and appetite control in overweight men and women. *British Journal of Nutrition* 111, 111–121 (2014).
  743. Kendall, C. W. C. et al. Effect of novel maize-based dietary fibers on postprandial glycemia and insulinemia. *Journal of the American College of Nutrition* 27, 711–718 (2008).
  744. Sanders, L. M. et al. A novel maize-based dietary fiber is well tolerated in humans. *FASEB Journal* 22, 761–761 (2008).
  745. Lockyer, S. & Nugent, A. P. Health effects of resistant starch. *Nutrition Bulletin* 42, 10–41 (2017).
  746. Croghan, M. Resistente Stärke als funktioneller Bestandteil von Lebensmitteln. *ErnährungsUmschau* 50, 65–67 (2003).
  747. Sajilata, M. G., Singhal, R. S. & Kulkarni, P. R. Resistant Starch? A Review. *Comprehensive Reviews in Food Science and Food Safety* 5, 1–17 (2006).
  748. Keenan, M. J. et al. Role of resistant starch in improving gut health, adiposity, and insulin resistance. *Advances in Nutrition* 6, 198–205 (2015).
  749. Soares, N. C. & Ford, A. C. Systematic review: the effects of fibre in the management of chronic idiopathic constipation. *Alimentary Pharmacology & Therapeutics* 33, 895–901 (2011).
  750. European Medicines Agency (EMA), Committee on Herbal Medicinal Products (HMPC). Community herbal monograph on *Plantago ovata* Forssk., seminis tegumentum. (2013).
  751. Elli, M., Cattivelli, D., Soldi, S., Bonatti, M. & Morelli, L. Evaluation of prebiotic potential of refined psyllium (*Plantago ovata*) fiber in healthy women. *Journal of Clinical Gastroenterology* 42 Suppl 3, S174–S176 (2008).
  752. European Medicines Agency (EMA), Committee on Herbal Medicinal Products (HMPC). Community herbal monograph on Psyllium seed (*Plantago Afra* et *Plantago Indica*, Semen). (2008).
  753. Khoury, D., Cuda, C., Luhovyy, B. L. & Anderson, G. H. Beta glucan: health benefits in obesity and metabolic syndrome. *Journal of Nutrition and Metabolism* 2012, 851362 (2012).
  754. Jaskari, J. et al. Oat  $\beta$ -glucan and xylan hydrolysates as selective substrates for *Bifidobacterium* and *Lactobacillus* strains. *Applied Microbiology and Biotechnology* 49, 175–181 (1998).
  755. Kontula, P., Wright, A. & Mattila-Sandholm, T. Oat bran  $\beta$ -gluco- and xylo-oligosaccharides as fermentative substrates for lactic acid bacteria. *International Journal of Food Microbiology* 45, 163–169 (1998).
  756. Mitsou, E. K., Panopoulou, N., Turunen, K., Spiliotis, V. & Kyriacou, A. Prebiotic potential of barley derived  $\beta$ -glucan at low intake levels: A randomised, double-blinded, placebo-controlled clinical study. *Food Research International* 43, 1086–1092 (2010).
  757. Chan, G. et al. The effects of  $\beta$ -glucan on human immune and cancer cells. *Journal of*

- Hematology & Oncology 2, 25 (2009).
758. Stier, H. et al. Immune-modulatory effects of dietary Yeast Beta-1,3/1,6-D-glucan. *Nutrition Journal* 13, 38 (2014).
759. Jesenak, M., Urbancikova, I. & Banovcin, P. Respiratory Tract Infections and the Role of Biologically Active Polysaccharides in Their Management and Prevention. *Nutrients* 9, 779 (2017).
760. Nakov, G., Georgieva, D., Ivanova, N., Damyanova, S., Stamatovska, V. & Necinova, L. Prebiotic effects of inulin and acacia gum (review). *Food and Environment Safety* 14, 148-156 (2015).
761. Cherbut, C., Michel, C., Raison, V., Kravtchenko, T. & Severine, M. Acacia Gum is a Bifidogenic Dietary Fibre with High Digestive Tolerance in Healthy Humans. *Microbial Ecology in Health and Disease* 15, 43–50 (2003).
762. Daguet, A., Pinheiro, I., Verhelst, A., Possemiers, S. & Marzorati, M. Acacia gum improves the gut barrier functionality in vitro. *Agro FOOD Industry Hi Tech* 26, 29–33 (2015).
763. Alarifi, S., Bell, A. & Walton, G. In vitro fermentation of gum acacia – impact on the faecal microbiota. *International Journal of Food Sciences and Nutrition* 69, 696–704 (2018).
764. Calame, W., Weseler, A. R., Viebke, C., Flynn, C. & Siemensma, A. D. Gum arabic establishes prebiotic functionality in healthy human volunteers in a dose-dependent manner. *British Journal of Nutrition* 100, 1269–1275 (2008).
765. Min, Y. W. et al. Effect of composite yogurt enriched with acacia fiber and *Bifidobacterium lactis*. *World Journal of Gastroenterology* 18, 4563–4569 (2012).
766. Coxam, V. et al. Inulin-type fructans and bone health: state of the art and perspectives in the management of osteoporosis. *British Journal of Nutrition* 93, S111–S123 (2005).
767. Sherman, P. M. et al. Potential Roles and Clinical Utility of Prebiotics in Newborns, Infants, and Children: Proceedings from a Global Prebiotic Summit Meeting, New York City, June 27–28, 2008. *Journal of Pediatrics* 155, S61–S70 (2009).
768. Tan, J. et al. The role of short-chain fatty acids in health and disease. *Advances in Immunology* 121, 91–119 (2014).
769. Blaak, E. E. et al. Short chain fatty acids in human gut and metabolic health. *Beneficial Microbes* 11, 411–455 (2020).
770. Petrak, D. Einsatz von  $\beta$ -D-Glucanen als spezifische Immunstimulanzen. *Naturheilpraxis* 353–355 (2008).
771. Paineau, D. et al. The effects of regular consumption of short-chain fructo-oligosaccharides on digestive comfort of subjects with minor functional bowel disorders. *British Journal of Nutrition* 99, 311–318 (2008).
772. Guérin-Deremaux, L. et al. The soluble fiber NUTRIOSE induces a dose-dependent beneficial impact on satiety over time in humans. *Nutrition Research* 31, 665–672 (2011).
773. Collado Yurrita, L., San Mauro Martín, I., Ciudad-Cabañas, M. J., Calle-Purón, M. E. & Hernández Cabria, M. Effectiveness of inulin intake on indicators of chronic constipation; a meta-analysis of controlled randomized clinical trials. *Nutrición Hospitalaria* 30, 244–252 (2014).
774. Spiller, R. Review article: probiotics and prebiotics in irritable bowel syndrome. *Alimentary Pharmacology & Therapeutics* 28, 385–396 (2008).
775. Ashraf, W., Park, F., Lof, J. & Quigley, E. M. M. Effects of psyllium therapy on stool characteristics, colon transit and anorectal function in chronic idiopathic constipation. *Alimentary Pharmacology & Therapeutics* 9, 639–647 (1995).
776. Wilson, B., Rossi, M., Dimidi, E. & Whelan, K. Prebiotics in irritable bowel syndrome and other functional bowel disorders in adults: a systematic review and meta-analysis of randomized controlled trials. *American Journal of Clinical Nutrition* 109, 1098–1111 (2019).
777. Micka, A., Siepelmeyer, A., Holz, A., Theis, S. & Schön, C. Effect of consumption of chicory inulin on bowel function in healthy subjects with constipation: a randomized, double-blind, placebo-controlled trial. *International Journal of Food Sciences and Nutrition* 68, 82–89 (2017).
778. Silk, D. B. A., Davis, A., Vulevic, J., Tzortzis, G. & Gibson, G. R. Clinical trial: the effects of a trans-galactooligosaccharide prebiotic on faecal microbiota and symptoms in irritable bowel syndrome. *Alimentary Pharmacology & Therapeutics* 29, 508–518 (2009).
779. Hotz, J. & Plein, K. Effectiveness of plantago seed husks in comparison with wheat bran on stool frequency and manifestations of irritable colon syndrome with constipation. *Medizinische Klinik* 89, 645–651 (1994).
780. Prior, A. & Whorwell, P. J. Double blind study of ispaghula in irritable bowel syndrome. *Gut* 28, 1510–1513 (1987).
781. Dimidi, E. & Whelan, K. Food supplements and diet as treatment options in irritable bowel syndrome. *Neurogastroenterology and Motility* 32, e13951 (2020).
782. Whelan, K., Martin, L. D., Staudacher, H. M. & Lomer, M. C. E. The low FODMAP diet in the management of irritable bowel syndrome: an evidence-based review of FODMAP restriction, reintroduction and personalisation in clinical practice. *Journal of Human Nutrition and Dietetics* 31, 239–255 (2018).
783. Staudacher, H. M. et al. A Diet Low in FODMAPs Reduces Symptoms in Patients With Irritable Bowel Syndrome and A Probiotic Restores Bifidobacterium Species: A Randomized Controlled Trial. *Gastroenterology* 153, 936–947 (2017).
784. van Lanen, A.-S., de Bree, A. & Greyling, A. Efficacy of a low-FODMAP diet in adult irritable bowel syndrome: a systematic review and meta-analysis. *European Journal of Nutrition* (2021). doi:10.1007/s00394-020-02473-0.
785. Leitfeld, L. et al. S2k-Leitlinie Divertikelkrankheit/Divertikulitis – Gemeinsame Leitlinie der Deutschen Gesellschaft für Gastroenterologie, Verdauungs- und Stoffwechselkrankheiten (DGVS) und der Deutschen Gesellschaft für Allgemein- und Viszeralchirurgie (DGAV). *Zeitschrift für Gastroenterologie* 52, 663–710 (2014).
786. Dreher, M. L. Whole Fruits and Fruit Fiber Emerging Health Effects. *Nutrients* 10, 1833 (2018).
787. Wong, C., Harris, P. J. & Ferguson, L. R. Potential Benefits of Dietary Fibre Intervention in Inflammatory Bowel Disease. *International Journal of Molecular Sciences* 17, 919 (2016).
788. Preter, V. et al. Metabolic Profiling of the Impact of Oligofructose-Enriched Inulin in Crohn's Disease Patients: A Double-Blinded Randomized Controlled Trial. *Clinical and Translational Gastroenterology* 4, e30 (2013).
789. Benjamin, J. L. et al. Randomised, double-blind, placebo-controlled trial of fructo-oligosaccharides in active Crohn's disease. *Gut* 60, 923–929 (2011).
790. Joossens, M. et al. Effect of oligofructose-enriched inulin (OF-IN) on bacterial composition and disease activity of patients with Crohn's disease: results from a double-blinded randomised controlled trial. *Gut* 61, 958 (2012).
791. Casellas, F. et al. Oral oligofructose-enriched inulin supplementation in acute ulcerative colitis is well tolerated and associated with lowered faecal calprotectin. *Alimentary Pharmacology & Therapeutics* 25, 1061–1067 (2007).
792. Hallert, C., Kaldma, M. & Petersson, B. G. Ispaghula husk may relieve gastrointestinal symptoms in ulcerative colitis in remission. *Scandinavian Journal of Gastroenterology* 26, 747–750 (1991).
793. Fernández-Bañares, F. et al. Randomized clinical trial of *Plantago ovata* seeds (dietary fiber) as compared with mesalamine in maintaining remission in ulcerative colitis. *American Journal of Gastroenterology* 94, 427–433 (1999).
794. Hallert, C. et al. Increasing fecal butyrate in ulcerative colitis patients by diet: controlled pilot study. *Inflammatory Bowel Diseases* 9, 116–121 (2003).
795. Arnold, J. W., Simpson, J. B., Roach, J., Bruno-Barcena, J. M. & Azcarate-Peril, M. A. Prebiotics for Lactose Intolerance: Variability in Galacto-Oligosaccharide Utilization by Intestinal *Lactobacillus rhamnosus*. *Nutrients* 10, 1517 (2018).
796. Savaiano, D. A. et al. Improving lactose digestion and symptoms of lactose intolerance with a novel galacto-oligosaccharide (RP-G28): a randomized, double-blind clinical trial. *Nutrition Journal* 12, 160 (2013).
797. McRorie, J. W. & Jr. Evidence-Based Approach to Fiber Supplements and Clinically Meaningful Health Benefits, Part 2: What to Look for and How to Recommend an Effective Fiber Therapy. *Nutrition Today* 50, 90–97 (2015).
798. Jenkins, A. L., Jenkins, D. J. A., Zdravkovic, U., Würsch, P. & Vuksan, V. Depression of the glycemic index by high levels of  $\beta$ -glucan fiber in two functional foods tested in type 2 diabetes. *European Journal of Clinical Nutrition* 56, 622–628 (2002).
799. Regand, A., Chowdhury, Z., Tosh, S. M., Wolever, T. M. S. & Wood, P. The molecular weight, solubility and viscosity of oat beta-glucan affect human glycemic response by modifying starch digestibility. *Food Chemistry* 129, 297–304 (2011).
800. Cavallero, A., Empilli, S., Brighenti, F. & Stanca, A. M. High (1→3,1→4)- $\beta$ -Glucan Barley Fractions in Bread Making and their Effects on Human Glycemic Response. *Journal of Cereal Science* 36, 59–66 (2002).
801. Mäkeläinen, H. et al. The effect of  $\beta$ -glucan on the glycemic and insulin index. *European Journal of Clinical Nutrition* 61, 779–785 (2007).
802. Backhed, F. et al. The gut microbiota as an environmental factor that regulates fat storage. *Proceedings of the National Academy of Sciences* 101, 15718–15723 (2004).
803. Bell, D. S. H. Changes seen in gut bacteria content and distribution with obesity: causation or association? *Postgraduate Medicine* 127, 863–868 (2015).



804. Denou, E., Marcinko, K., Surette, M. G., Steinberg, G. R. & Schertzer, J. D. High-intensity exercise training increases the diversity and metabolic capacity of the mouse distal gut microbiota during diet-induced obesity. *American journal of physiology. Endocrinology and Metabolism* 310, E982–E993 (2016).
805. Oh, B., Kim, J. S., Kweon, M., Kim, B.-S. & Huh, I. S. Six-week Diet Correction for Body Weight Reduction and Its Subsequent Changes of Gut Microbiota: A Case Report. *Clinical Nutrition Research* 5, 137–140 (2016).
806. Arslanoglu, S. et al. Early neutral prebiotic oligosaccharide supplementation reduces the incidence of some allergic manifestations in the first 5 years of life. *Journal of Biological Regulators and Homeostatic Agents* 26, 49–59 (2012).
807. Arslanoglu, S. et al. Early dietary intervention with a mixture of prebiotic oligosaccharides reduces the incidence of allergic manifestations and infections during the first two years of life. *Journal of Nutrition* 138, 1091–1095 (2008).
808. Osborn, D. A. & Sinn, J. K. H. Prebiotics in infants for prevention of allergy. *Cochrane Database for Systematic Reviews* CD006474 (2013). doi:10.1002/14651858.CD006474.pub3.
809. Cuello-Garcia, C. A. et al. World Allergy Organization-McMaster University Guidelines for Allergic Disease Prevention (GLAD-P): Prebiotics. *World Allergy Organization Journal* 9, 10 (2016). doi: 10.1186/s40413-015-0055-2.
810. Talbott, S. & Talbott, J. Effect of BETA 1, 3/1, 6 GLUCAN on Upper Respiratory Tract Infection Symptoms and Mood State in Marathon Athletes. *Journal of Sports Science & Medicine* 8, 509–515 (2009).
811. Talbott, S. M. & Talbott, J. A. Baker's yeast beta-glucan supplement reduces upper respiratory symptoms and improves mood state in stressed women. *Journal of the American College of Nutrition* 31, 295–300 (2012).
812. Graubaum, H.-J., Busch, R., Stier, H. & Gruenwald, J. A Double-Blind, Randomized, Placebo-Controlled Nutritional Study Using an Insoluble Yeast Beta-Glucan to Improve the Immune Defense System. *Food and Nutrition Sciences* 03, 738–746 (2012).
813. Aunger, A., Riede, L., Bothe, G., Busch, R. & Gruenwald, J. Yeast (1,3)-(1,6)-beta-glucan helps to maintain the body's defence against pathogens: a double-blind, randomized, placebo-controlled, multicentric study in healthy subjects. *European Journal of Nutrition* 52, 1913–1918 (2013).
814. Feldman, S. et al. Randomized phase II clinical trials of wellmune WGP[R] for immune support during cold and flu season. *Journal of Applied Research* 9, 30–42 (2009).
815. McFarlin, B. K., Carpenter, K. C., Davidson, T. & McFarlin, M. A. Baker's yeast beta glucan supplementation increases salivary IgA and decreases cold/flu symptomatic days after intense exercise. *Journal of Dietary Supplements* 10, 171–183 (2013).
816. Bergendiova, K., Tibenska, E. & Majtan, J. Pleuran ( $\beta$ -glucan from *Pleurotus ostreatus*) supplementation, cellular immune response and respiratory tract infections in athletes. *European Journal of Applied Physiology* 111, 2033–2040 (2011).
817. Castro, E. D. M., Calder, P. C. & Roche, H. M.  $\beta$ -1,3/1,6-Glucans and Immunity: State of the Art and Future Directions. *Molecular Nutrition & Food Research*, 1901071 (2021).
818. Druml, W. et al. S1-Leitlinie der Deutschen Gesellschaft für Ernährungsmedizin (DGEM) in Zusammenarbeit mit der AKE, der GESKES und der DGFN – Enterale und parenterale Ernährung von Patienten mit Niereninsuffizienz. *Aktuelle Ernährungsmedizin* 40, 21–37 (2015).
819. Bundesärztekammer (BÄK), Kassenärztliche Bundesvereinigung (KBV), Arbeitsgemeinschaft der Wissenschaftlichen Medizinischen Fachgesellschaften (AWMF). Nationale VersorgungsLeitlinie Neuropathie bei Diabetes im Erwachsenenalter – Langfassung, 1. Auflage, Version 5 (2011). doi: 10.6101/AZQ/000302.
820. Wirth, R. et al. Leitlinie der Deutschen Gesellschaft für Ernährungsmedizin (DGEM) in Zusammenarbeit mit der GESKES, der AKE, der DGN und der DGG. *Aktuelle Ernährungsmedizin* 38, e49–e89 (2013).
821. Leitlinienprogramm Onkologie (Deutsche Krebsgesellschaft, Deutsche Krebshilfe, AWMF): S3-Leitlinie Kolorektales Karzinom, Langversion 2.1, 2019, AWMF Registrierungsnummer: 021/0070L.
822. Biesalski, H. K. Vitamine, Spurenelemente und Minerale: Indikation, Diagnostik, Therapie. (Georg Thieme Verlag, 2019). doi:10.1055/b-006-166047.
823. World Health Organization (WHO). Micronutrients. URL: <https://www.who.int/westernpacific/health-topics/micronutrients> (2021).
824. Rabenberg, M. et al. Vitamin D status among adults in Germany-results from the German Health Interview and Examination Survey for Adults (DEGS1). *BMC Public Health* 15, 641 (2015).
825. Deutsche Gesellschaft für Ernährung (DGE). Referenzwerte für die Nährstoffzufuhr. URL: <https://www.dge.de/wissenschaft/referenzwerte/?L=0> (2021).
826. Deutsche Gesellschaft für Ernährung (DGE). FAQs - Häufig gestellte Fragen zu ausgewählten Themenbereichen. URL: <https://www.dge.de/wissenschaft/weitere-publikationen/faqs/?limit=all> (2021).
827. Robert Koch-Institut (RKI). Gesundheit in Deutschland. Gesundheitsberichterstattung des Bundes. (2015).
828. Deutsche Gesellschaft für Ernährung (DGE). Ausgewählte Fragen und Antworten zu Vitamin D. URL: <https://www.dge.de/wissenschaft/weitere-publikationen/faqs/vitamin-d/#suppl> (2012).
829. Bundesinstitut für Risikobewertung (BfR). Jodversorgung in Deutschland wieder rückläufig – Tipps für eine gute Jodversorgung (2021).
830. Deutsche Gesellschaft für Ernährung (DGE). Einheitliche Handlungsempfehlungen für die Schwangerschaft (aktualisiert und erweitert). URL: <https://www.dge.de/ernaehrungspraxis/bevoelkerungsgruppen/schwangere-stillende/handlungsempfehlungen-zur-ernaehrung-in-der-schwangerschaft/?L=0> (2018).
831. IN FORM. Fit im Alter: Die Nährstoffe. URL: <https://www.fitimalter-dge.de/fachinformationen/ernaehrung-im-alter/besondere-anforderungen-kritische-naehrstoffe/mangelernaehrung/kritische-naehrstoffe/> (2019).
832. Deutsche Gesellschaft für Ernährung (DGE). Position der Deutschen Gesellschaft für Ernährung – Vegane Ernährung. URL: <https://www.dge.de/wissenschaft/weitere-publikationen/dge-position/vegane-ernaehrung/> (2016).
833. Deutscher Olympischer Sportbund (DOSB). Nahrungsergänzungsmittel (2014).
834. Hsu, J. M. & Anthony, W. L. Zinc deficiency and urinary excretion of taurine-35S and inorganic sulfate-35S following cystine-35S injection in rats. *Journal of Nutrition* 100, 1189–1195 (1970).
835. Bendich, A., Machlin, L. J., Scandurra, O., Burton, G. W. & Wayner, D. D. M. The antioxidant role of vitamin C. *Advances in Free Radical Biology & Medicine* 2, 419–444 (1986).
836. Jeng, K. C. et al. Supplementation with vitamins C and E enhances cytokine production by peripheral blood mononuclear cells in healthy adults. *American Journal of Clinical Nutrition* 64, 960–965 (1996).
837. Scott, J. M. et al. Folate and vitamin B12. *Proceedings of the Nutrition Society* 58, 441–448 (1999).
838. Wierdsma, N., Bokhorst-de van der Schueren, M., Berkenpas, M., Mulder, C. & Bodegraven, A. Vitamin and Mineral Deficiencies Are Highly Prevalent in Newly Diagnosed Celiac Disease Patients. *Nutrients* 5, 3975–3992 (2013).
839. Felber, J. et al. S2k-Leitlinie Zöliakie: Ergebnisse einer S2k-Konsensuskonferenz der Deutschen Gesellschaft für Gastroenterologie, Verdauungs- und Stoffwechselerkrankungen (DGVS) gemeinsam mit der Deutschen Zöliakie-Gesellschaft (DZG e. V.) zur Zöliakie, Weizenallergie und Weizensensitivität (2014).
840. James, S. C., Fraser, K., Young, W., McNabb, W. C. & Roy, N. C. Gut Microbial Metabolites and Biochemical Pathways Involved in Irritable Bowel Syndrome: Effects of Diet and Nutrition on the Microbiome. *Journal of Nutrition* 150, 1012–1021 (2020).
841. Abbaszadeh, A. et al. Association of Serum Vitamin D Concentration With Clinical Symptoms and Quality of Life in Patients With Irritable Bowel Syndrome. *Journal of the American College of Nutrition* 38, 327–333 (2019).
842. Torres, M. J. et al. Food consumption and dietary intakes in 36,448 adults and their association with irritable bowel syndrome: Nutrinet-Santé study. *Therapeutic Advances in Gastroenterology* 11, 1756283X1774662 (2018).
843. Böhn, L., Störsrud, S. & Simrén, M. Nutrient intake in patients with irritable bowel syndrome compared with the general population: Nutrient intake in IBS. *Neurogastroenterology & Motility* 25, 23–e1 (2013).
844. Biesalski, H. K. Nutrition meets the microbiome: micronutrients and the microbiota. *Annals of the New York Academy of Sciences* 1372, 53–64 (2016).
845. Subramanian, S. et al. Persistent gut microbiota immaturity in malnourished Bangladeshi children. *Nature* 510, 417–421 (2014).
846. Million, M., Diallo, A. & Raoult, D. Gut microbiota and malnutrition. *Microbial Pathogenesis* 106, 127–138 (2017).
847. Hibberd, M. C. et al. The effects of micronutrient deficiencies on bacterial species from the human gut microbiota. *Science Translational Medicine* 9, eaal4069 (2017). doi: 10.1126/scitranslmed.aal4069.
848. Kau, A. L., Ahern, P. P., Griffin, N. W., Goodman, A. L. & Gordon, J. I. Human nutrition, the gut microbiome, and immune system: envisioning the future. *Nature*

- 474, 327–336 (2011).
849. Rodionov, D. A. et al. Micronutrient Requirements and Sharing Capabilities of the Human Gut Microbiome. *Frontiers in Microbiology* 10, 1316 (2019). doi: 10.3389/fmicb.2019.01316.
850. Gombart, A. F., Pierre, A. & Maggini, S. A Review of Micronutrients and the Immune System – Working in Harmony to Reduce the Risk of Infection. *Nutrients* 12, 236 (2020). doi: 10.3390/nu12010236.
851. Farré, R., Fiorani, M., Abdu Rahiman, S. & Matteoli, G. Intestinal Permeability, Inflammation and the Role of Nutrients. *Nutrients* 12, 1185 (2020). doi: 10.3390/nu12041185.
852. Khoshbin, K. & Camilleri, M. Effects of Dietary Components on Intestinal Permeability in Health and Disease. *American Journal of Physiology-Gastrointestinal and Liver Physiology* (2020). doi:10.1152/ajpgi.00245.2020.
853. Rao, R. & Samak, G. Role of Glutamine in Protection of Intestinal Epithelial Tight Junctions. *Journal of Epithelial Biology & Pharmacology* 5, 47–54 (2012).
854. Lan, A. et al. Mucosal healing in inflammatory bowel diseases: is there a place for nutritional supplementation? *Inflammatory Bowel Diseases* 21, 198–207 (2015).
855. Duée, P. H., Darcy-Vrillon, B., Blachier, F. & Morel, M. T. Fuel selection in intestinal cells. *Proceedings of the Nutrition Society* 54, 83–94 (1995).
856. Hulst, R. R., Meyenfeldt, M. F. & Soeters, P. B. Glutamine: an essential amino acid for the gut. *Nutrition* 12, 578–581 (1996).
857. Rapin, J. R. & Wiernsperger, N. Possible links between intestinal permeability and food processing: A potential therapeutic niche for glutamine. *Clinics* 65, 635–643 (2010).
858. Wang, B. et al. Glutamine and intestinal barrier function. *Amino Acids* 47, 2143–2154 (2015).
859. Hulsewe, K. et al. Inflammation rather than nutritional depletion determines glutamine concentrations and intestinal permeability. *Clinical Nutrition* 23, 1209–1216 (2004).
860. Quan, Z.-F., Yang, C., Li, N. & Li, J.-S. Effect of glutamine on change in early post operative intestinal permeability and its relation to systemic inflammatory response. *World Journal of Gastroenterology* 10, 1992–1994 (2004).
861. Zhou, Y.-P. et al. The effect of supplemental enteral glutamine on plasma levels, gut function, and outcome in severe burns: a randomized, double-blind, controlled clinical trial. *Journal of Parenteral and Enteral Nutrition* 27, 241–245 (2003).
862. Yoshida, S. et al. Effects of glutamine supplements and radiochemotherapy on systemic immune and gut barrier function in patients with advanced esophageal cancer. *Annals of Surgery* 227, 485–491 (1998).
863. Stechmiller, J. K., Treloar, D. & Allen, N. Gut dysfunction in critically ill patients: a review of the literature. *American journal of critical care : an official publication, American Association of Critical-Care Nurses* 6, 204–209 (1997).
864. De-Souza, D. A. & Greene, L. J. Intestinal permeability and systemic infections in critically ill patients: effect of glutamine. *Critical Care Medicine* 33, 1125–1135 (2005).
865. Li, Y. et al. Oral glutamine ameliorates chemotherapy-induced changes of intestinal permeability and does not interfere with the antitumor effect of chemotherapy in patients with breast cancer: a prospective randomized trial. *Tumori* 92, 396–401 (2008).
866. Sevastiadou, S. et al. The impact of oral glutamine supplementation on the intestinal permeability and incidence of necrotizing enterocolitis/septicemia in premature neonates. *Journal of Maternal-Fetal & Neonatal Medicine* 24, 1294–1300 (2011).
867. Kim, M.-H. & Kim, H. The Roles of Glutamine in the Intestine and Its Implication in Intestinal Diseases. *International Journal of Molecular Sciences* 18, 1051 (2017). doi: 10.3390/ijms18051051.
868. O'Flaherty, L., Stapleton, P. P., Redmond, H. P. & Bouchier-Hayes, D. J. Intestinal taurine transport: a review. *European Journal of Clinical Investigation* 27, 873–880 (1997).
869. Laidlaw, S., Grosvenor, M. & Kopple, J. The taurine content of common foodstuffs. *Journal of Parenteral and Enteral Nutrition* 14, 183–188 (1990).
870. Huxtable, R. J. Physiological actions of taurine. *Physiological Reviews* 72, 101–163 (1992).
871. Barbeau, A., Inoue, N., Tsukada, Y. & Butterworth, R. F. The neuropharmacology of taurine. *Life Sciences* 17, 669–677 (1975).
872. Kendler, B. S. Taurine: An overview of its role in preventive medicine. *Preventive Medicine* 18, 79–100 (1989).
873. Dai, B. et al. The role of Ca(2+) mediated signaling pathways on the effect of taurine against *Streptococcus uberis* infection. *Veterinary Microbiology* 192, 26–33 (2016).
874. Ginguay, A., Bandt, J.-P. & Cynober, L. Indications and contraindications for infusing specific amino acids (leucine, glutamine, arginine, citrulline, and taurine) in critical illness. *Current opinion in clinical nutrition and metabolic care* 19, 161–169 (2016).
875. Sukhotnik, I. et al. Effect of taurine on intestinal recovery following intestinal ischemia-reperfusion injury in a rat. *Pediatric Surgery International* 32, 161–168 (2016).
876. Ahmad, M. K., Khan, A. A., Ali, S. N. & Mahmood, R. Chemoprotective effect of taurine on potassium bromate-induced DNA damage, DNA-protein cross-linking and oxidative stress in rat intestine. *PLoS One* 10, e0119137 (2015).
877. Katakawa, M. et al. Taurine and magnesium supplementation enhances the function of endothelial progenitor cells through antioxidation in healthy men and spontaneously hypertensive rats. *Hypertension Research* (2016). doi:10.1038/hr.2016.86.
878. Rahmeier, F. L. et al. The effect of taurine and enriched environment on behaviour, memory and hippocampus of diabetic rats. *Neuroscience Letters* 630, 84–92 (2016).
879. Chowdhury, S., Sinha, K., Banerjee, S. & Sil, P. C. Taurine protects cisplatin induced cardiotoxicity by modulating inflammatory and endoplasmic reticulum stress responses. *BioFactors* (2016). doi:10.1002/biof.1301.
880. Al-Asmari, A. K., Al-Zahrani, A. M., Khan, A. Q., Al-Shahrani, H. M. & Ali Al Amri, M. Taurine ameliorates 5-fluorouracil-induced intestinal mucositis, hepatorenal and reproductive organ damage in Wistar rats: A biochemical and histological study. *Human & Experimental Toxicology* 35, 10–20 (2016).
881. Fang, H. et al. Effect of Taurine on Intestinal Microbiota and Immune Cells in Peyer's Patches of Immunosuppressive Mice. *Taurine*, 11 13–24 (2019). doi:10.1007/978-981-13-8023-5\_2.
882. Ahlman, B., Leijonmarck, C.-E. & Wernerman, J. The content of free amino acids in the human duodenal mucosa. *Clinical Nutrition* 12, 266–271 (1993).
883. Jarocki, P., Podleśny, M., Glibowski, P. & Targoński, Z. A new insight into the physiological role of bile salt hydrolase among intestinal bacteria from the genus *Bifidobacterium*. *PLoS One* 9, e114379 (2014).
884. Joyce, S. A., Shanahan, F., Hill, C. & Gahan, C. G. M. Bacterial bile salt hydrolase in host metabolism: Potential for influencing gastrointestinal microbe-host crosstalk. *Gut Microbes* 5, 669–674 (2014).
885. Jones, M. L. et al. The gut microbiome, probiotics, bile acids axis, and human health. *Trends in Microbiology* 22, 306–308 (2014).
886. Włodarska, M. et al. NLRP6 inflammasome orchestrates the colonic host-microbial interface by regulating goblet cell mucus secretion. *Cell* 156, 1045–1059 (2014).
887. Levy, M. et al. Microbiota-Modulated Metabolites Shape the Intestinal Micro-environment by Regulating NLRP6 Inflammasome Signaling. *Cell* 163, 1428–1443 (2015).
888. Maggini, S., Wintergerst, E., Beveridge, S. & Hornig, D. Selected vitamins and trace elements support immune function by strengthening epithelial barriers and cellular and humoral immune responses. *British Journal of Nutrition* 98, S29–S35 (2007).
889. Ferencik, M. & Ebringer, L. Modulatory effects of selenium and zinc on the immune system. *Folia Microbiologica* 48, 417–426 (2003).
890. Prasad, A. S. Zinc in human health: effect of zinc on immune cells. *Molecular Medicine* 14, 353–357 (2008).
891. Bonaventura, P., Benedetti, G., Albarède, F. & Miossec, P. Zinc and its role in immunity and inflammation. *Autoimmunity Reviews* 14, 277–285 (2015).
892. Roy, S. K. et al. Impact of zinc supplementation on intestinal permeability in Bangladeshi children with acute diarrhoea and persistent diarrhoea syndrome. *Journal of Pediatric Gastroenterology and Nutrition* 15, 289–296 (1992).
893. Lazzarini, M. & Wanzira, H. Oral zinc for treating diarrhoea in children. *Cochrane Database for Systematic Reviews*, CD005436 (2016). doi: 10.1002/14651858.CD005436.pub5.
894. Sturniolo, G. C., Leo, V., Ferronato, A., D'Odorico, A. & D'Inca, R. Zinc supplementation tightens leaky gut in Crohn's disease. *Inflammatory Bowel Diseases* 7, 94–98 (2001).
895. Ananthakrishnan, A. N. et al. Zinc intake and risk of Crohn's disease and ulcerative colitis: a prospective cohort study. *International Journal of Epidemiology* 44, 1995–2005 (2015).
896. World Health Organization (WHO). WHO | Zinc supplementation in the management of diarrhoea. URL: [http://www.who.int/elena/titles/zinc\\_diarrhoea/en/](http://www.who.int/elena/titles/zinc_diarrhoea/en/) (2019).
897. Chen, P. et al. Association of vitamin A and zinc status with altered intestinal permeability: Analyses of cohort data from northeastern Brazil. *Journal of Health, Population and Nutrition* 21, 309–315 (2003).

898. Pearce, S. C. et al. Dietary organic zinc attenuates heat stress-induced changes in pig intestinal integrity and metabolism. *Journal of Animal Science* 93, 4702–4713 (2015).
899. Zhang, B. & Guo, Y. Supplemental zinc reduced intestinal permeability by enhancing occludin and zonula occludens protein-1 (ZO-1) expression in weaning piglets. *British Journal of Nutrition* 102, 687–693 (2009).
900. Sturniolo, G. C. et al. Effect of zinc supplementation on intestinal permeability in experimental colitis. *Journal of Laboratory and Clinical Medicine* 139, 311–315 (2002).
901. Amasheh, M., Andres, S., Amasheh, S., Fromm, M. & Schulzke, J.-D. Barrier Effects of Nutritional Factors. *Annals of the New York Academy of Sciences* 1165, 267–273 (2009).
902. Ranaldi, G., Caprini, V., Sambuy, Y., Perozzi, G. & Murgia, C. Intracellular zinc stores protect the intestinal epithelium from Ochratoxin A toxicity. *Toxicology in Vitro* 23, 1516–1521 (2009).
903. Zhong, W., McClain, C. J., Cave, M., Kang, Y. J. & Zhou, Z. The role of zinc deficiency in alcohol-induced intestinal barrier dysfunction. *American Journal of Physiology. Gastrointestinal and Liver Physiology* 298, G625–G633 (2010).
904. Sanz Fernandez, M. et al. Effects of supplemental zinc amino acid complex on gut integrity in heat-stressed growing pigs. *Animal* 8, 43–50 (2014).
905. Speckmann, B. & Steinbrenner, H. Selenium and selenoproteins in inflammatory bowel diseases and experimental colitis. *Inflammatory Bowel Diseases* 20, 1110–1119 (2014).
906. Kudva, A. K., Shay, A. E. & Prabhu, K. S. Selenium and inflammatory bowel disease. *American Journal of Physiology. Gastrointestinal and Liver Physiology* 309, G71–G77 (2015).
907. Geerling, B. J., Badart-Smook, A., Stockbrügger, R. W. & Brummer, R. J. Comprehensive nutritional status in recently diagnosed patients with inflammatory bowel disease compared with population controls. *European Journal of Clinical Nutrition* 54, 514–521 (2000).
908. Weisshof, R. & Chermesh, I. Micronutrient deficiencies in inflammatory bowel disease. *Current Opinion in Clinical Nutrition and Metabolic Care* 18, 576–581 (2015).
909. Ojuawo, A. & Keith, L. The serum concentrations of zinc, copper and selenium in children with inflammatory bowel disease. *Central African Journal of Medicine* 48, 116–119 (2002).
910. Rannem, T., Ladefoged, K., Hylander, E., Hegnhøj, J. & Jarnum, S. Selenium status in patients with Crohn's disease. *American Journal of Clinical Nutrition* 56, 933–937 (1992).
911. Andoh, A. et al. Serum selenoprotein-P levels in patients with inflammatory bowel disease. *Nutrition* 21, 574–579 (2005).
912. Speckmann, B. et al. Proinflammatory cytokines down-regulate intestinal seleno protein P biosynthesis via NOS2 induction. *Free Radical Biology & Medicine* 49, 777–785 (2010).
913. Narayan, V. et al. Epigenetic regulation of inflammatory gene expression in macrophages by selenium. *Journal of Nutritional Biochemistry* 26, 138–145 (2015).
914. Kaushal, N. et al. Crucial role of macrophage selenoproteins in experimental colitis. *Journal of Immunology* 193, 3683–3692 (2014).
915. Gandhi, U. H. et al. Selenoprotein-dependent Up-regulation of Hematopoietic Prostaglandin D2 Synthase in Macrophages Is Mediated through the Activation of Peroxisome Proliferator-activated Receptor (PPAR). *Journal of Biological Chemistry* 286, 27471–27482 (2011).
916. Hrdina, J. et al. The gastrointestinal microbiota affects the selenium status and selenoprotein expression in mice. *Journal of Nutritional Biochemistry* 20, 638–648 (2009).
917. Kasaikina, M. et al. Dietary selenium affects host selenoproteome expression by influencing the gut microbiota. *FASEB Journal* 25, 2492–2499 (2011).
918. Meeker, S., Seamons, A., Maggio-Price, L. & Paik, J. Protective links between vitamin D, inflammatory bowel disease and colon cancer. *World Journal of Gastroenterology* 22, 933–948 (2016).
919. Ananthakrishnan, A. N. et al. Higher Predicted Vitamin D Status Is Associated With Reduced Risk of Crohn's Disease. *Gastroenterology* 142, 482–489 (2012).
920. Gorham, E. D. et al. Optimal Vitamin D Status for Colorectal Cancer Prevention: A Quantitative Meta Analysis. *American Journal of Preventive Medicine* 32, 210–216 (2007).
921. Guillot, X., Semerano, L., Saidenberg-Kermanach, N., Falgarone, G. & Boissier, M.-C. Vitamin D and inflammation. *Joint Bone Spine* 77, 552–557 (2010).
922. Deeb, K. K., Trump, D. L. & Johnson, C. S. Vitamin D signalling pathways in cancer: potential for anticancer therapeutics. *Nature Reviews Cancer* 7, 684–700 (2007).
923. Garland, C. F. & Garland, F. C. Do Sunlight and Vitamin D Reduce the Likelihood of Colon Cancer? *International Journal of Epidemiology* 9, 227–231 (1980).
924. Mouli, V. P. & Ananthakrishnan, A. N. Review article: vitamin D and inflammatory bowel diseases. *Alimentary Pharmacology & Therapeutics* 39, 125–136 (2014).
925. Ananthakrishnan, A. N. et al. Association Between Reduced Plasma 25-Hydroxy Vitamin D and Increased Risk of Cancer in Patients With Inflammatory Bowel Diseases. *Clinical Gastroenterology and Hepatology* 12, 821–827 (2014).
926. Cross, H. S., Nitte, T. & Kallay, E. Colonic vitamin D metabolism: implications for the pathogenesis of inflammatory bowel disease and colorectal cancer. *Molecular and Cellular Endocrinology* 347, 70–79 (2011).
927. Martinesi, M. et al. Role of vitamin D derivatives in intestinal tissue of patients with inflammatory bowel diseases. *Journal of Crohn's & Colitis* 8, 1062–1071 (2014).
928. Blanck, S. & Aberra, F. Vitamin D Deficiency Is Associated with Ulcerative Colitis Disease Activity. *Digestive Diseases and Sciences* 58, 1698–1702 (2013).
929. Jørgensen, S. P. et al. Active Crohn's disease is associated with low vitamin D levels. *Journal of Crohn's and Colitis* 7, e407–e413 (2013).
930. Ulitsky, A. et al. Vitamin D Deficiency in Patients With Inflammatory Bowel Disease: Association With Disease Activity and Quality of Life. *Journal of Parenteral and Enteral Nutrition* 35, 308–316 (2011).
931. Basson, A. Vitamin D and Crohn's Disease in the Adult Patient: A Review. *Journal of Parenteral and Enteral Nutrition* 38, 438–458 (2014).
932. Zhang, Y. et al. Tight junction CLDN2 gene is a direct target of the vitamin D receptor. *Scientific Reports* 5, 10642 (2015).
933. Kong, J. et al. Novel role of the vitamin D receptor in maintaining the integrity of the intestinal mucosal barrier. *American Journal of Physiology Gastrointestinal and Liver Physiology* 294, G208–G216 (2008).
934. Kühne, H. et al. Vitamin D receptor regulates intestinal proteins involved in cell proliferation, migration and stress response. *Lipids in Health and Disease* 13, 51 (2014).
935. Chen, S. et al. 1,25-Dihydroxyvitamin D3 preserves intestinal epithelial barrier function from TNF- $\alpha$  induced injury via suppression of NF- $\kappa$ B p65 mediated MLCK-P-MLC signaling pathway. *Biochemical and Biophysical Research Communications* 460, 873–878 (2015).
936. Hidaka, M., Wakabayashi, I., Takeda, Y. & Fukuzawa, K. Vitamin D derivatives increase soluble CD14 release through ERK1/2 activation and decrease IL-8 production in intestinal epithelial cells. *European Journal of Pharmacology* 721, 305–312 (2013).
937. Zhang, H. et al. 1,25-dihydroxyvitamin D3 regulates the development of chronic colitis by modulating both T helper (Th)1 and Th17 activation. *Acta Pathologica, Microbiologica, et Immunologica Scandinavica* 123, 490–501 (2015).
938. Assa, A. et al. Vitamin D deficiency promotes epithelial barrier dysfunction and intestinal inflammation. *Journal of Infectious Diseases* 210, 1296–1305 (2014).
939. Cantorna, M. T., Munsick, C., Bemiss, C. & Mahon, B. D. 1,25-Dihydroxycholecalciferol prevents and ameliorates symptoms of experimental murine inflammatory bowel disease. *Journal of Nutrition* 130, 2648–2652 (2000).
940. Zhu, T., Liu, T.-J., Shi, Y.-Y. & Zhao, Q. Vitamin D/VDR signaling pathway ameliorates 2,4,6-trinitrobenzene sulfonic acid-induced colitis by inhibiting intestinal epithelial apoptosis. *International Journal of Molecular Medicine* 35, 1213–1218 (2015).
941. Ooi, J. H., Li, Y., Rogers, C. J. & Cantorna, M. T. Vitamin D regulates the gut microbiome and protects mice from dextran sodium sulfate-induced colitis. *Journal of Nutrition* 143, 1679–1686 (2013).
942. Jin, D. et al. Lack of Vitamin D Receptor Causes Dysbiosis and Changes the Functions of the Murine Intestinal Microbiome. *Clinical Therapeutics* 37, 996–1009.e7 (2015).
943. Assa, A. et al. Vitamin D deficiency predisposes to adherent-invasive *Escherichia coli*-induced barrier dysfunction and experimental colonic injury. *Inflammatory Bowel Diseases* 21, 297–306 (2015).
944. Bono, M. R. et al. Retinoic Acid as a Modulator of T Cell Immunity. *Nutrients* 8, 349 (2016). doi: 10.3390/nu8060349.
945. Kubota, H. et al. Retinoid X receptor alpha and retinoic acid receptor gamma mediate expression of genes encoding tight-junction proteins and barrier function in F9 cells during visceral endodermal differentiation. *Experimental Cell Research* 263, 163–172 (2001).
946. Kunisawa, J. & Kiyono, H. Vitamin-mediated regulation of intestinal immunity. *Frontiers in Immunology* 4, 189 (2013).

947. Sirisinha, S. The pleiotropic role of vitamin A in regulating mucosal immunity. *Asian Pacific Journal of Allergy and Immunology* 33, 71–89 (2015).
948. Chen, X. & Mayne, C. G. The Role of Micronutrients in Graft-VS.-Host Disease: Immunomodulatory Effects of Vitamins A and D. *Frontiers in Immunology* 9, 2853 (2018).
949. Hall, J. A., Grainger, J. R., Spencer, S. P. & Belkaid, Y. The role of retinoic acid in tolerance and immunity. *Immunity* 35, 13–22 (2011).
950. Cassani, B., Villablanca, E. J., De Calisto, J., Wang, S. & Mora, J. R. Vitamin A and immune regulation: role of retinoic acid in gut-associated dendritic cell education, immune protection and tolerance. *Molecular Aspects of Medicine* 33, 63–76 (2012).
951. Xiao, L. et al. Vitamin A supplementation improves the intestinal mucosal barrier and facilitates the expression of tight junction proteins in rats with diarrhea. *Nutrition* 57, 97–108 (2019).
952. Padayatty, S. J. et al. Vitamin C as an Antioxidant: Evaluation of Its Role in Disease Prevention. *Journal of the American College of Nutrition* 22, 18–35 (2003).
953. Szymańska, R., Nowicka, B. & Kruk, J. Vitamin E - Occurrence, Biosynthesis by Plants and Functions in Human Nutrition. *Mini Reviews in Medicinal Chemistry* 16, 1039–1052 (2016).
954. Traber, M. G. & Stevens, J. F. Vitamins C and E: beneficial effects from a mechanistic perspective. *Free Radical Biology & Medicine* 51, 1000–1013 (2011).
955. Anwar, M., Nanda, N., Bhatia, A., Akhtar, R. & Mahmood, S. Effect of antioxidant supplementation on digestive enzymes in radiation induced intestinal damage in rats. *International Journal of Radiation Biology* 89, 1061–1070 (2013).
956. Liu, F. et al. Selenium and vitamin E together improve intestinal epithelial barrier function and alleviate oxidative stress in heat-stressed pigs. *Experimental Physiology* 101, 801–810 (2016).
957. Nakano, E. et al. Riboflavin depletion impairs cell proliferation in adult human duodenum: identification of potential effectors. *Digestive Diseases and Sciences* 56, 1007–1019 (2011).
958. Bodiga, V. L. et al. Effect of vitamin supplementation on cisplatin-induced intestinal epithelial cell apoptosis in Wistar/NIN rats. *Nutrition* 28, 572–80 (2012).
959. Fenech, M. Micronutrients and genomic stability: a new paradigm for recommended dietary allowances (RDAs). *Food and Chemical Toxicology* 40, 1113–1117 (2002).
960. Lee, D. H., Keum, N. & Giovannucci, E. L. Colorectal Cancer Epidemiology in the Nurses' Health Study. *American Journal of Public Health* 106, 1599–1607 (2016).
961. Okazaki, Y. et al. Consumption of vitamin B(6) reduces fecal ratio of lithocholic acid to deoxycholic acid, a risk factor for colon cancer, in rats fed a high-fat diet. *Journal of Nutritional Science and Vitaminology* 58, 366–370 (2012).
962. Varella Morandi Junqueira-Franco, M. et al. Intestinal permeability and oxidative stress in patients with alcoholic pellagra. *Clinical Nutrition* 25, 977–983 (2006).
963. Degnan, P. H., Taga, M. E. & Goodman, A. L. Vitamin B12 as a modulator of gut microbial ecology. *Cell Metabolism* 20, 769–778 (2014).
964. Cordonnier, C. et al. Vitamin B12 Uptake by the Gut Commensal Bacteria *Bacteroides thetaiotaomicron* Limits the Production of Shiga Toxin by Enterohemorrhagic *Escherichia coli*. *Toxins* 8 (2016).
965. Fraker, P. J., King, L. E., Laakko, T. & Vollmer, T. L. The dynamic link between the integrity of the immune system and zinc status. *Journal of Nutrition* 130, 1399S–1406S (2000).
966. King, L. E. & Fraker, P. J. Variations in the Cell Cycle Status of Lymphopoietic and Myelopoietic Cells Created by Zinc Deficiency. *Journal of Infectious Diseases* 182, S16–S22 (2000).
967. Blomhoff, H. K. et al. Vitamin A is a key regulator for cell growth, cytokine production, and differentiation in normal B cells. *Journal of Biological Chemistry* 267, 23988–23992 (1992).
968. Ertesvag, A., Aasheim, H.-C., Naderi, S. & Blomhoff, H. K. Vitamin A potentiates CpG-mediated memory B-cell proliferation and differentiation: involvement of early activation of p38MAPK. *Blood* 109 (2007).
969. Aranow, C. Vitamin D and the immune system. *Journal of Investigative Medicine* 59, 881–886 (2011).
970. Kahmann, L. et al. Zinc supplementation in the elderly reduces spontaneous inflammatory cytokine release and restores T cell functions. *Rejuvenation Research* 11, 227–237 (2008).
971. Varin, A. et al. In vitro and in vivo effects of zinc on cytokine signalling in human T cells. *Experimental Gerontology* 43, 472–482 (2008).
972. Huang, Z., Rose, A. H. & Hoffmann, P. R. The Role of Selenium in Inflammation and Immunity: From Molecular Mechanisms to Therapeutic Opportunities. *Antioxidants & Redox Signaling* (2012). doi:10.1089/ARS.2011.4145.
973. Hall, J. A. et al. Essential Role for Retinoic Acid in the Promotion of CD4+ T Cell Effector Responses via Retinoic Acid Receptor Alpha. *Immunity* 34, 435–447 (2010).
974. Wintergerst, E. S., Maggini, S. & Hornig, D. H. Immune-enhancing role of vitamin C and zinc and effect on clinical conditions. *Annals of Nutrition & Metabolism* 50, 85–94 (2006).
975. Meydani, S. N., Han, S. N. & Wu, D. Vitamin E and immune response in the aged: molecular mechanisms and clinical implications. *Immunological Reviews* 205, 269–284 (2005).
976. Chandra, R. K. & Sudhakaran, L. Regulation of immune responses by vitamin B6. *Annals of the New York Academy of Sciences* 585, 404–423 (1990).
977. Rall, L. C. & Meydani, S. N. Vitamin B6 and immune competence. *Nutrition Reviews* 51, 217–225 (1993).
978. Trakatellis, A., Dimitriadou, A. & Trakatelli, M. Pyridoxine deficiency: new approaches in immunosuppression and chemotherapy. *Postgraduate Medical Journal* 73, 617–622 (1997).
979. Miller, L. T. & Kerkvliet, N. I. Effect of Vitamin B 6 on Immunocompetence in the Elderly. *Annals of the New York Academy of Sciences* 587, 49–54 (1990).
980. Tamura, J. et al. Immunomodulation by vitamin B12: augmentation of CD8+ T lymphocytes and natural killer (NK) cell activity in vitamin B12-deficient patients by methyl-B12 treatment. *Clinical and Experimental Immunology* 116, 28–32 (1999).
981. Courtemanche, C., Elson-Schwab, L., Mashiyama, S. T., Kerry, N. & Ames, B. N. Folate deficiency inhibits the proliferation of primary human CD8+ T lymphocytes in vitro. *Journal of Immunology* 173, 3186–3192 (2004).
982. Dhur, A., Galan, P. & Hercberg, S. Folate status and the immune system. *Progress in Food & Nutrition Science* 15, 43–60 (1991).
983. Adorini, L. Intervention in autoimmunity: the potential of vitamin D receptor agonists. *Cellular Immunology* 233, 115–124 (2005).
984. Cantorna, M. T., Snyder, L., Lin, Y.-D. & Yang, L. Vitamin D and 1,25(OH)2D regulation of T cells. *Nutrients* 7, 3011–3021 (2015).
985. Kahmann, L. et al. Effect of improved zinc status on T helper cell activation and TH1/TH2 ratio in healthy elderly individuals. *Biogerontology* 7, 429–435 (2006).
986. Maywald, M. & Rink, L. Zinc homeostasis and immunosenescence. *Journal of Trace Elements in Medicine and Biology* 29, 24–30 (2015).
987. Uciechowski, P. et al. TH1 and TH2 cell polarization increases with aging and is modulated by zinc supplementation. *Experimental Gerontology* 43, 493–498 (2008).
988. Rosenkranz, E. et al. Zinc enhances the number of regulatory T cells in allergen-stimulated cells from atopic subjects. *European Journal of Nutrition* (2015). doi:10.1007/s00394-015-1100-1.
989. Schambach, F., Schupp, M., Lazar, M. A. & Reiner, S. L. Activation of retinoic acid receptor- $\alpha$  favours regulatory T cell induction at the expense of IL-17-secreting T helper cell differentiation. *European Journal of Immunology* 37, 2396–2399 (2007).
990. Kang, S. G., Lim, H. W., Andrisani, O. M., Broxmeyer, H. E. & Kim, C. H. Vitamin A Metabolites Induce Gut-Homing FoxP3+ Regulatory T Cells. *Journal of Immunology* 179, 3724–3733 (2007).
991. Sun, C.-M. et al. Small intestine lamina propria dendritic cells promote de novo generation of Foxp3 T reg cells via retinoic acid. *Journal of Experimental Medicine* 204, 1775–1785 (2007).
992. Iwata, M. et al. Retinoic Acid Imprints Gut-Homing Specificity on T Cells. *Immunity* 21, 527–538 (2004).
993. Wintergerst, E., Maggini, S. & Hornig, D. Contribution of Selected Vitamins and Trace Elements to Immune Function. *Annals of Nutrition and Metabolism* 51, 301–323 (2007).
994. Long, K. Z. & Santos, J. I. Vitamins and the regulation of the immune response. *Pediatric Infectious Disease Journal* 18, 283–290 (1999).
995. Linus Pauling Institute. *Immunity In Depth*. URL: <https://lpi.oregonstate.edu/mic/health-disease/immunity> (2016).
996. Haryanto, B., Suksmasari, T., Wintergerst, E., Maggini, S., & Bayer. Multivitamin Supplementation Supports Immune Function and Ameliorates Conditions Triggered By Reduced Air Quality. *Vitamins and Minerals* 4, 128 (2015). doi:10.4172/2376-1318.1000128.
997. Maggini, S. Feeding the immune system: the role of micronutrients in restoring resistance to infections. *CAB Reviews* 3 (2008). doi:10.1079/PAVSNNR20083098.
998. DeCicco, K. L., Youngdahl, J. D. & Ross, A. C. All-trans-retinoic acid and polyribonucleosinic: polyribocytidylic acid in combination potentiate specific antibody

- production and cell-mediated immunity. *Immunology* 104, 341 (2001).
999. Ross, A. C., Chen, Q. & Ma, Y. Vitamin A and Retinoic Acid in the Regulation of B-Cell Development and Antibody Production. *Vitamins and Hormones* 86, 103 (2011).
  1000. Meydani, S. N. et al. Vitamin E Supplementation and In Vivo Immune Response in Healthy Elderly Subjects. *JAMA* 277, 1380 (1997).
  1001. Fata, F. T., Herzlich, B. C., Schiffman, G. & Ast, A. L. Impaired Antibody Responses to Pneumococcal Polysaccharide in Elderly Patients with Low Serum Vitamin B12 Levels. *Annals of Internal Medicine* 124, 299 (1996).
  1002. Geissmann, F. et al. Retinoids Regulate Survival and Antigen Presentation by Immature Dendritic Cells. *Journal of Experimental Medicine* 198 (2003).
  1003. Vanherwegen, A.-S., Gysemans, C. & Overbergh, L. Dendritic cell metabolism: immunity and tolerance. *Oncotarget* 6, 34039–34040 (2015).
  1004. Sheikh, A. et al. Zinc influences innate immune responses in children with enterotoxigenic *Escherichia coli*-induced diarrhea. *Journal of Nutrition* 140, 1049–1056 (2010).
  1005. Meksawan, K., Sermis, U. & Chanvorachote, P. Zinc supplementation improves anticancer activity of monocytes in type-2 diabetic patients with metabolic syndrome. *Anticancer Research* 34, 295–299 (2014).
  1006. Ibs, K.-H. & Rink, L. Zinc-altered immune function. *Journal of Nutrition* 133, 1452S–1256S (2003).
  1007. Stephensen, C. B. Vitamin A, Infection, and Immune Function. *Annual Review of Nutrition* 21, 167–192 (2001).
  1008. Miller, S. & Kearney, S. Effect of in vivo administration of all trans-retinoic acid on the hemopoietic cell populations of the spleen and bone marrow: profound strain differences between A/J and C57BL/6J mice. *Laboratory Animal Science* 48, 74–80 (1998).
  1009. Twining, S. S., Schulte, D. P., Wilson, P. M., Fish, B. L. & Moulder, J. E. Vitamin A Deficiency Alters Rat Neutrophil Function. *Journal of Nutrition* 127, 558–565 (1997).
  1010. Anderson, R., Oosthuizen, R., Maritz, R., Theron, A. & Rensburg, A. J. The effects of increasing weekly doses of ascorbate on certain cellular and humoral immune functions in normal volunteers. *American Journal of Clinical Nutrition* 33, 71–76 (1980).
  1011. Chun, R. F., Liu, P. T., Modlin, R. L., Adams, J. S. & Hewison, M. Impact of vitamin D on immune function: lessons learned from genome-wide analysis. *Frontiers in Physiology* 5, 151 (2014).
  1012. Gao, H., Dai, W., Zhao, L., Min, J. & Wang, F. The Role of Zinc and Zinc Homeostasis in Macrophage Function. *Journal of Immunology Research* 2018, e6872621 (2018).
  1013. Carr, A. C. & Maggini, S. Vitamin C and Immune Function. *Nutrients* 9 (2017).
  1014. Wishart, K. Increased Micronutrient Requirements during Physiologically Demanding Situations: Review of the Current Evidence. *Vitamins & Minerals* 06 (2017).
  1015. Sly, L. M., Lopez, M., Nauseef, W. M. & Reiner, N. E. 1 $\alpha$ ,25-Dihydroxyvitamin D<sub>3</sub>-induced monocyte antimicrobial activity is regulated by phosphatidylinositol 3-kinase and mediated by the NADPH-dependent phagocyte oxidase. *Journal of Biological Chemistry* 276, 35482–35493 (2001).
  1016. Tanaka, H. et al. Disassociation of the macrophage-maturational effects of vitamin D from respiratory burst priming. *Journal of Biological Chemistry* 266, 10888–10892 (1991).
  1017. Lin, Z. & Li, W. The Roles of Vitamin D and Its Analogs in Inflammatory Diseases. *Current Topics in Medicinal Chemistry* 16, 1242–1261 (2016).
  1018. Zhang, Y. et al. Vitamin D Inhibits Monocyte/Macrophage Proinflammatory Cytokine Production by Targeting MAPK Phosphatase-1. *Journal of Immunology* 188, 2127–2135 (2012).
  1019. Topilski, I. et al. The anti-inflammatory effects of 1,25-dihydroxyvitamin D<sub>3</sub> on Th<sub>2</sub> cells in vivo are due in part to the control of integrin-mediated T lymphocyte homing. *European Journal of Immunology* 34, 1068–1076 (2004).
  1020. Mariani, E. et al. Effect of zinc supplementation on plasma IL-6 and MCP-1 production and NK cell function in healthy elderly: interactive influence of +647 MT1a and -174 IL-6 polymorphic alleles. *Experimental Gerontology* 43, 462–471 (2008).
  1021. Ross, A. & Stephensen, C. Vitamin A and retinoids in antiviral responses. *FASEB Journal* 10, 979–985 (1996).
  1022. Ahmad, S. M., Haskell, M. J., Raqib, R. & Stephensen, C. B. Markers of Innate Immune Function Are Associated with Vitamin A Stores in Men. *Journal of Nutrition* 139, 377–385 (2009).
  1023. Troen, A. M. et al. Unmetabolized folic acid in plasma is associated with reduced natural killer cell cytotoxicity among postmenopausal women. *Journal of Nutrition* 136, 189–194 (2006).
  1024. Bunout, D. et al. Effects of a nutritional supplement on the immune response and cytokine production in free-living Chilean elderly. *JPEN. Journal of Parenteral and Enteral Nutrition* 28, 348–354 (2004).
  1025. Dardenne, M. Zinc and immune function. *European Journal of Clinical Nutrition* 3, S20–S23 (2002).
  1026. Ma, Y., Chen, Q. & Ross, A. C. Retinoic Acid and Polyriboinosinic:Polyribocytidylic Acid Stimulate Robust Anti-Tetanus Antibody Production while Differentially Regulating Type 1/Type 2 Cytokines and Lymphocyte Populations. *Journal of Immunology* 174, 7961–7969 (2005).
  1027. Kloubert, V. & Rink, L. Zinc as a micronutrient and its preventive role of oxidative damage in cells. *Food & Function* 6, 3195–3204 (2015).
  1028. Guo, C.-H. & Wang, C.-L. Effects of zinc supplementation on plasma copper/zinc ratios, oxidative stress, and immunological status in hemodialysis patients. *International Journal of Medical Sciences* 10, 79–89 (2013).
  1029. Prasad, A. S. Zinc: role in immunity, oxidative stress and chronic inflammation. *Current Opinion in Clinical Nutrition and Metabolic Care* 12, 646–652 (2009).
  1030. Cabreiro, F. et al. Zinc supplementation in the elderly subjects: effect on oxidized protein degradation and repair systems in peripheral blood lymphocytes. *Experimental Gerontology* 43, 483–487 (2008).
  1031. Fukada, T., Yamasaki, S., Nishida, K., Murakami, M. & Hirano, T. Zinc homeostasis and signaling in health and diseases: Zinc signaling. *Journal of Biological Inorganic Chemistry* 16, 1123–1134 (2011).
  1032. Barnett, J. B. et al. Effect of zinc supplementation on serum zinc concentration and T cell proliferation in nursing home elderly: a randomized, double-blind, placebo-controlled trial. *American Journal of Clinical Nutrition* 103, 942–951 (2016).
  1033. Aggarwal, R., Sentz, J. & Miller, M. A. Role of Zinc Administration in Prevention of Childhood Diarrhea and Respiratory Illnesses: A Meta-analysis. *Pediatrics* 119 (2007). doi:10.1542/peds.2006-3481.
  1034. Mahalanabis, D. et al. Randomized, double-blind, placebo-controlled clinical trial of the efficacy of treatment with zinc or vitamin A in infants and young children with severe acute lower respiratory infection. *American Journal of Clinical Nutrition* 79, 430–436 (2004).
  1035. Raqib, R. et al. Effect of zinc supplementation on immune and inflammatory responses in pediatric patients with shigellosis. *American Journal of Clinical Nutrition* 79, 444–450 (2004).
  1036. Rahman, M. J. et al. Effects of zinc supplementation as adjunct therapy on the systemic immune responses in shigellosis. *American Journal of Clinical Nutrition* 81, 495–502 (2005).
  1037. Hemilä, H. Zinc Lozenges May Shorten the Duration of Colds: A Systematic Review. *Open Respiratory Medicine Journal* 5, 51 (2011).
  1038. Bosschaerts, T. et al. Alternatively Activated Myeloid Cells Limit Pathogenicity Associated with African Trypanosomiasis through the IL-10 Inducible Gene Selenoprotein P. *Journal of Immunology* 180, 6168–6175 (2008).
  1039. Bhalla, A. K., Amento, E. P., Clemens, T. L., Holick, M. F. & Krane, S. M. Specific high-affinity receptors for 1,25-dihydroxyvitamin D<sub>3</sub> in human peripheral blood mononuclear cells: presence in monocytes and induction in T lymphocytes following activation. *Journal of Clinical Endocrinology & Metabolism* 57, 1308–1310 (1983).
  1040. Prowedini, D., Tsoukas, C., Deftos, L. & Manolagas, S. 1,25-dihydroxyvitamin D<sub>3</sub> receptors in human leukocytes. *Science* 221 (1983). doi: 10.1126/science.6310748.
  1041. Veldman, C. M., Cantorna, M. T. & DeLuca, H. F. Expression of 1,25-Dihydroxyvitamin D<sub>3</sub> Receptor in the Immune System. *Archives of Biochemistry and Biophysics* 374, 334–338 (2000).
  1042. Wei, R. & Christakos, S. Mechanisms Underlying the Regulation of Innate and Adaptive Immunity by Vitamin D. *Nutrients* 7, 8251–8260 (2015).
  1043. Froicu, M. & Cantorna, M. T. Vitamin D and the vitamin D receptor are critical for control of the innate immune response to colonic injury. *BMC Immunology* 8, 5 (2007).
  1044. Rolf, L., Muris, A.-H., Hupperts, R. & Damoiseaux, J. Illuminating vitamin D effects on B-cells - the multiple sclerosis perspective. *Immunology* (2016). doi:10.1111/imm.12577.
  1045. Muris, A.-H. et al. A low vitamin D status at diagnosis is associated with an early conversion to secondary progressive multiple sclerosis. *Journal of Steroid Biochemistry and Molecular Biology* (2015). doi:10.1016/j.jsbmb.2015.11.009.
  1046. Alharbi, F. M. Update in vitamin D and multiple sclerosis. *Neurosciences* 20, 329–335 (2015).
  1047. Lucas, R. M., Byrne, S. N., Correale, J., Ilshner, S. & Hart, P. H. Ultraviolet radiation,

- vitamin D and multiple sclerosis. *Neurodegenerative Disease Management* 5, 413–424 (2015).
1048. Ishikawa, L. L. W. et al. Vitamin D Deficiency and Rheumatoid Arthritis. *Clinical Reviews in Allergy & Immunology* (2016). doi:10.1007/s12016-016-8577-0.
1049. Cebeý-López, M. et al. Role of Vitamin D in Hospitalized Children With Lower Tract Acute Respiratory Infections. *Journal of Pediatric Gastroenterology and Nutrition* 62, 479–485 (2016).
1050. Kurtaran, B. et al. The relationship between brucellosis and vitamin D. *Journal of Infection in Developing Countries* 10, 176–182 (2016).
1051. Liu, P. T., Stenger, S., Tang, D. H. & Modlin, R. L. Cutting edge: vitamin D-mediated human antimicrobial activity against *Mycobacterium tuberculosis* is dependent on the induction of cathelicidin. *Journal of Immunology* 179, 2060–2063 (2007).
1052. Cubillos, S., Krieg, N. & Norgauer, J. Effect of Vitamin D on Peripheral Blood Mononuclear Cells from Patients with Psoriasis Vulgaris and Psoriatic Arthritis. *PLoS One* 11, e0153094 (2016).
1053. Hendaus, M. A., Jomha, F. A. & Ehlayel, M. Allergic diseases among children: nutritional prevention and intervention. *Therapeutics and Clinical Risk Management* 12, 361–372 (2016).
1054. Martineau, A. R. et al. Vitamin D for the management of asthma. *Cochrane Database for Systematic Reviews* 9, CD011511 (2016).
1055. Ismail, A. M., Aly, S. S., Fayed, H. M. & Ahmed, S. S. Serum 25-hydroxyvitamin D and CD4+CD25+(high) FoxP3+ Regulatory T cell as Predictors of Severity of Bronchial Asthma in Children. *Egyptian Journal of Immunology* 22, 9–18 (2015).
1056. Lin, R. Crosstalk between Vitamin D Metabolism, VDR Signalling, and Innate Immunity. *BioMed Research International* 2016, 1375858 (2016).
1057. White, J. H. Vitamin D metabolism and signaling in the immune system. *Reviews in Endocrine & Metabolic Disorders* 13, 21–29 (2012).
1058. Mora, J. R. et al. Generation of Gut-Homing IgA-Secreting B Cells by Intestinal Dendritic Cells. *Science* 314, 1157–1160 (2006). doi: 10.1126/science.1132742.
1059. Meydani, S. N. et al. Vitamin E and respiratory tract infections in elderly nursing home residents: a randomized controlled trial. *JAMA* 292, 828–836 (2004).
1060. Wu, D., Hayek, M. G. & Meydani, S. Vitamin E and macrophage cyclooxygenase regulation in the aged. *Journal of Nutrition* 131, 382S–388S (2001).
1061. Wu, D. et al. Age-associated increase in PGE2 synthesis and COX activity in murine macrophages is reversed by vitamin E. *American Journal of Physiology – Cell Physiology* 275, C661–C668 (1998).
1062. Hume, R. & Weyers, E. Changes in Leucocyte Ascorbic Acid during the Common Cold. *Scottish Medical Journal* 18, 3–7 (1973).
1063. Hemilä, H. & Chalker, E. Vitamin C for preventing and treating the common cold. *Cochrane Database for Systematic Reviews* (2013). doi:10.1002/14651858.CD000980.pub4.
1064. Hemilä, H. Vitamin C and common cold-induced asthma: a systematic review and statistical analysis. *Allergy, Asthma, and Clinical Immunology* 9, 46 (2013).
1065. Prentice, S. They Are What You Eat: Can Nutritional Factors during Gestation and Early Infancy Modulate the Neonatal Immune Response? *Frontiers in Immunology* 8, 1641 (2017).
1066. Hemilä, H. Vitamin C and Infections. *Nutrients* 9, 339 (2017).
1067. Ueland, P. M., McCann, A., Midttun, Ø. & Ulvik, A. Inflammation, vitamin B6 and related pathways. *Molecular Aspects of Medicine* (2016). doi:10.1016/j.mam.2016.08.001.
1068. Matsui, E. C. & Matsui, W. Higher serum folate levels are associated with a lower risk of atopy and wheeze. *Journal of Allergy and Clinical Immunology* 123, 1253–1259.e2 (2009).
1069. Tardy, A.-L., Pouteau, E., Marquez, D., Yilmaz, C. & Scholey, A. Vitamins and Minerals for Energy, Fatigue and Cognition: A Narrative Review of the Biochemical and Clinical Evidence. *Nutrients* 12 (2020). doi: 10.3390/nu12010228.
1070. Nguyen, B., Ding, D. & Mirshahi, S. Fruit and vegetable consumption and psychological distress: cross-sectional and longitudinal analyses based on a large Australian sample. *BMJ Open* 7, e014201 (2017).
1071. Hermes, G., Fogelman, N., Seo, D. & Sinha, R. Differential effects of recent versus past traumas on mood, social support, binge drinking, emotional eating and BMI, and on neural responses to acute stress. *Stress* (2021). doi: 10.1080/10253890.2021.1877271.
1072. Rodrigues, R. et al. Job strain is prospectively associated with a lower frequency of fruit consumption in schoolteachers. *Public Health Nutrition* 24, 1678–1686 (2021).
1073. Cummings, J. R., Ackerman, J. M., Wolfson, J. A. & Gearhardt, A. N. COVID-19 stress and eating and drinking behaviors in the United States during the early stages of the pandemic. *Appetite* 162, 105163 (2021).
1074. Burgerstein, U. P., Schurgast, H. & Zimmermann, M. B. *Handbuch Nährstoffe: Vorbeugen und heilen durch ausgewogene Ernährung: Alles über Vitamine, Mineralstoffe und Spurenelemente.* (TRIAS, 2018).
1075. Glaser, R. & Kiecolt-Glaser, J. K. Stress-induced immune dysfunction: implications for health. *Nature Reviews Immunology* 5, 243–251 (2005).
1076. Martineau, A. R. et al. Vitamin D supplementation to prevent acute respiratory tract infections: systematic review and meta-analysis of individual participant data. *BMJ* 356, i6583 (2017).
1077. Gammoh, N. Z. & Rink, L. Zinc in Infection and Inflammation. *Nutrients* 9, 624 (2017).
1078. Sundaram, M. E. & Coleman, L. A. Vitamin D and Influenza. *Advances in Nutrition* 3, 517–525 (2012).
1079. Kennedy, D. O. B Vitamins and the Brain: Mechanisms, Dose and Efficacy – A Review. *Nutrients* 8, 68 (2016). doi: 10.3390/nu8020068.
1080. Rudzki, L. et al. Gut microbiota-derived vitamins – underrated powers of a multi-potent ally in psychiatric health and disease. *Progress in Neuro-Psychopharmacology and Biological Psychiatry* 107, 110240 (2021).
1081. Huang, F. & Wu, X. Brain Neurotransmitter Modulation by Gut Microbiota in Anxiety and Depression. *Frontiers in Cell and Developmental Biology* 9, 649103 (2021).
1082. Vink, R. & Nechifor, M. (eds). *Magnesium in the Central Nervous System.* (University of Adelaide Press, 2011).
1083. Schuchardt, J. P. & Hahn, A. Intestinal Absorption and Factors Influencing Bioavailability of Magnesium- An Update. *Current Nutrition and Food Science* 13 (2017).
1084. Feng, J. et al. Role of Magnesium in Type 2 Diabetes Mellitus. *Biological Trace Element Research* 196, 74–85 (2020).
1085. Boyle, N. B., Lawton, C. & Dye, L. The Effects of Magnesium Supplementation on Subjective Anxiety and Stress – A Systematic Review. *Nutrients* 9, 429 (2017).
1086. Abbasi, B. et al. The effect of magnesium supplementation on primary insomnia in elderly: A double-blind placebo-controlled clinical trial. *Journal of Research in Medical Sciences* 17, 1161–1169 (2012).
1087. Ford, T. et al. The Effect of a High-Dose Vitamin B Multivitamin Supplement on the Relationship between Brain Metabolism and Blood Biomarkers of Oxidative Stress: A Randomized Control Trial. *Nutrients* 10, 1860 (2018).
1088. Grima, N. A., Pase, M. P., Macpherson, H. & Pipingas, A. The effects of multivitamins on cognitive performance: a systematic review and meta-analysis. *Journal of Alzheimer's Disease* 29, 561–569 (2012).
1089. Haskell, C. F. et al. Effects of a multi-vitamin/mineral supplement on cognitive function and fatigue during extended multi-tasking. *Human Psychopharmacology* 25, 448–461 (2010).
1090. White, D. J., Cox, K. H. M., Peters, R., Pipingas, A. & Scholey, A. B. Effects of Four-Week Supplementation with a Multi-Vitamin/Mineral Preparation on Mood and Blood Biomarkers in Young Adults: A Randomised, Double-Blind, Placebo-Controlled Trial. *Nutrients* 7, 9005–9017 (2015).
1091. Stough, C. et al. The effect of 90 day administration of a high dose vitamin B-complex on work stress. *Human Psychopharmacology: Clinical and Experimental* 26, 470–476 (2011).
1092. Kennedy, D. O. et al. Effects of high-dose B vitamin complex with vitamin C and minerals on subjective mood and performance in healthy males. *Psychopharmacology* 211, 55–68 (2010).
1093. Long, S.-J. & Benton, D. Effects of Vitamin and Mineral Supplementation on Stress, Mild Psychiatric Symptoms, and Mood in Nonclinical Samples: A Meta-Analysis. *Psychosomatic Medicine* 75, 144–153 (2013).
1094. Erdman, K. A., Jones, K. W., Madden, R. F., Gammack, N. & Parnell, J. A. Dietary Patterns in Runners with Gastrointestinal Disorders. *Nutrients* 13, 448 (2021).
1095. Khayyat, Y. & Attar, S. Vitamin D Deficiency in Patients with Irritable Bowel Syndrome: Does it Exist? *Oman Medical Journal* 30, 115–118 (2015).
1096. Nwosu, B. U., Maranda, L. & Candela, N. Vitamin D status in pediatric irritable bowel syndrome. *PLoS One* 12, e0172183 (2017).
1097. Yarandi, S. & Christie, J. The prevalence of vitamin D deficiency in patients with irritable bowel syndrome. *American Journal of Gastroenterology* S565 (2013).
1098. Jalili, M., Vahedi, H., Poustchi, H. & Hekmatdoost, A. Effects of Vitamin D Supplementation in Patients with Irritable Bowel Syndrome: A Randomized, Double-Blind, Placebo-Controlled Clinical Trial. *International Journal of Preventive Medicine* 10, 16 (2019).

1099. Jalili, M. et al. Co-Administration of Soy Isoflavones and Vitamin D in Management of Irritable Bowel Disease. *PLoS One* 11, e0158545 (2016).
1100. Abbasnezhad, A. et al. Effect of vitamin D on gastrointestinal symptoms and health-related quality of life in irritable bowel syndrome patients: a randomized double-blind clinical trial. *Neurogastroenterology and Motility* (2016). doi:10.1111/nmo.12851.
1101. El Amrousy, D., Hassan, S., El Ashry, H., Yousef, M. & Hodeib, H. Vitamin D supplementation in adolescents with irritable bowel syndrome: Is it useful? A randomized controlled trial. *Saudi Journal of Gastroenterology* 24, 109 (2018).
1102. El Amrousy, D., El Ashry, H., Hodeib, H. & Hassan, S. Vitamin D in Children With Inflammatory Bowel Disease: A Randomized Controlled Clinical Trial. *Journal of Clinical Gastroenterology* (2020). doi:10.1097/mcg.0000000000001443.
1103. Zhao, H. et al. Protective role of 1,25(OH)<sub>2</sub>vitamin D3 in the mucosal injury and epithelial barrier disruption in DSS-induced acute colitis in mice. *BMC Gastroenterology* 12 (2012). doi: 10.1186/1471-230X-12-57.
1104. Sun, J. Vitamin D and mucosal immune function: Current Opinion in Gastroenterology 26, 591–595 (2010).
1105. Liu, H.-N. et al. Altered molecular signature of intestinal microbiota in irritable bowel syndrome patients compared with healthy controls: A systematic review and meta-analysis. *Digestive and Liver Disease* 49, 331–337 (2017).
1106. Li, Y. C., Chen, Y. & Du, J. Critical roles of intestinal epithelial vitamin D receptor signaling in controlling gut mucosal inflammation. *The Journal of Steroid Biochemistry and Molecular Biology* 148, 179–183 (2015).
1107. Nowak, A. et al. Effect of vitamin D3 on self-perceived fatigue: A double-blind randomized placebo-controlled trial. *Medicine* 95, e5353 (2016).
1108. Ligaarden, S. C., Lydersen, S. & Farup, P. G. Diet in subjects with irritable bowel syndrome: A cross-sectional study in the general population. *BMC Gastroenterology* 12, 57 (2012). doi: 10.1186/1471-230X-12-61.
1109. Prescha, A. et al. Assessment of dietary intake of patients with irritable bowel syndrome. *Annals of the National Institute of Hygiene* 60, 185–189 (2009).
1110. El-Salhy, M. Diet and effects of diet management on quality of life and symptoms in patients with irritable bowel syndrome. *Molecular Medicine Reports* (2012). doi:10.3892/mmr.2012.843.
1111. Mazzawi, T., Hausken, T., Gundersen, D. & El-Salhy, M. Effects of dietary guidance on the symptoms, quality of life and habitual dietary intake of patients with irritable bowel syndrome. *Molecular Medicine Reports* 8, 845–852 (2013).
1112. Hu, M., Li, Y., Decker, E. A. & McClements, D. J. Role of calcium and calcium-binding agents on the lipase digestibility of emulsified lipids using an in vitro digestion model. *Food Hydrocolloids* 24, 719–725 (2010).
1113. Stevenson, C., Blaauw, R., Fredericks, E., Visser, J. & Roux, S. Food avoidance in irritable bowel syndrome leads to a nutrition-deficient diet. *South African Journal of Clinical Nutrition* 27, 25–30 (2014).
1114. Ligaarden, S. C. & Farup, P. G. Low intake of vitamin B6 is associated with irritable bowel syndrome symptoms. *Nutrition Research* 31, 356–361 (2011).
1115. Clavel, T., Fricke, F., Gessner, A. & Hiergeist, A. Aus dem Labor: Wie vermisst man das Darmmikrobiom? *Trillium Immunologie* (2019).
1116. Gessner, A. & Hiergeist, A. Qualitätsmanagement der Mikrobiom-Analytik. *Trillium Diagnostik* (2019).
1117. Simeonova, D., Ivanovska, M., Murdjeva, M., Carvalho, A. F. & Maes, M. Recognizing the Leaky Gut as a Trans-diagnostic Target for Neuroimmune Disorders Using Clinical Chemistry and Molecular Immunology Assays. *Current Topics in Medicinal Chemistry* 18, 1641–1655 (2018).
1118. Langhorst, J. et al. Noninvasive markers in the assessment of intestinal inflammation in inflammatory bowel diseases: performance of fecal lactoferrin, calprotectin, and PMN-elastase, CRP, and clinical indices. *American Journal of Gastroenterology* 103, 162–169 (2008).
1119. Zhou, X. et al. Fecal lactoferrin in discriminating inflammatory bowel disease from Irritable bowel syndrome: a diagnostic meta-analysis. *BMC Gastroenterology* 14, 121 (2014).
1120. Becker, K., Frieling, T. & Häussinger, D. Quantification of fecal alpha 1-antitrypsin excretion for assessment of inflammatory bowel diseases. *European Journal of Medical Research* 3, 65–70 (1998).
1121. Sluys Veer, A., Biemond, I., Verspaget, H. W. & Lamers, C. B. Faecal parameters in the assessment of activity in inflammatory bowel disease. *Scandinavian Journal of Gastroenterology Supplement* 230, 106–110 (1999).
1122. Aldhous, M. C., Noble, C. L. & Satsangi, J. Dysregulation of human beta-defensin-2 protein in inflammatory bowel disease. *PLoS One* 4, e6285 (2009).
1123. Relja, B. et al. Intestinal-FABP and liver-FABP: Novel markers for severe abdominal injury. *Academic Emergency Medicine* 17, 729–735 (2010).
1124. Reisinger, K. W. et al. Intestinal fatty acid-binding protein: a possible marker for gut maturation. *Pediatric Research* 76, 261–268 (2014).
1125. Timmermans, K. et al. Circulating iFABP Levels as a marker of intestinal damage in trauma patients. *Shock* 43, 117–120 (2015).
1126. Naruse, S. et al. Fecal pancreatic elastase: a reproducible marker for severe exocrine pancreatic insufficiency. *Journal of Gastroenterology* 41, 901–908 (2006).
1127. Jungvogel, A., Michel, M., Bechthold, A. & Wendt, I. Die Lebensmittelbezogenen Ernährungsempfehlungen der DGE. Wissenschaftliche Ableitung und praktische Anwendung der Modelle. *ErnährungsUmschau M474–M481* (2016). doi:10.4455/eu.2016.037.
1128. Boeing, H. et al. Gemüse und Obst in der Prävention ausgewählter chronischer Krankheiten - Stellungnahme der Deutschen Gesellschaft für Ernährung (DGE). (2012).
1129. Dimidi, E., Cox, S. R., Rossi, M. & Whelan, K. Fermented Foods: Definitions and Characteristics, Impact on the Gut Microbiota and Effects on Gastrointestinal Health and Disease. *Nutrients* 11, 1806 (2019).
1130. World Cancer Research Fund & American Institute for Cancer Research. Diet, nutrition, physical activity and cancer: a global perspective. A summary of the Third Expert Report. (2018).