Gut microbiota: roles in health and diseases and influential factors

CETL04D | 10-min teaching | Jan 16, 2019

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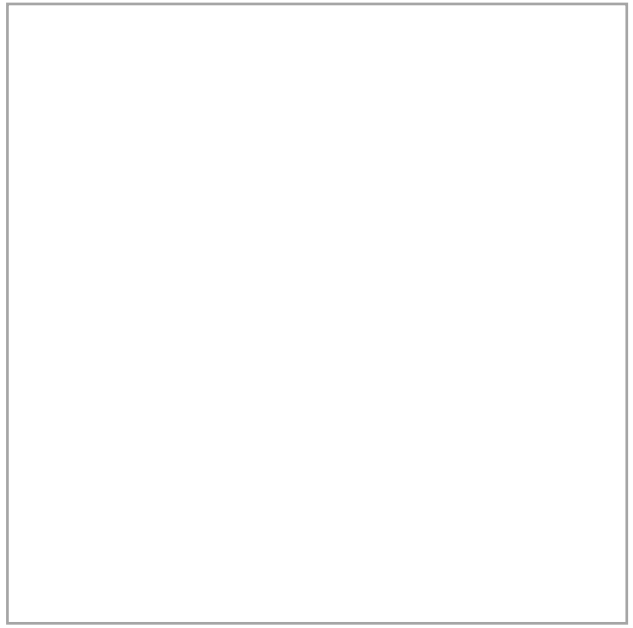
Learning Outcomes

- List some examples regarding health and diseases that are associated with gut microbiota
- Suggest good practices to have a healthy gut microbiota

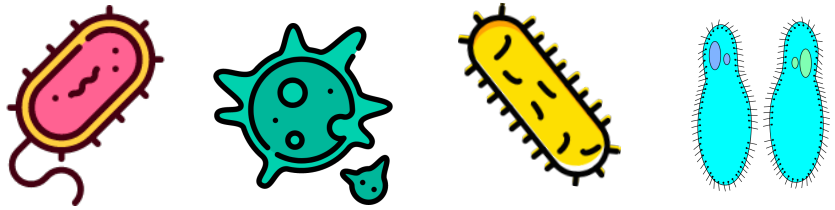
Before we board…

1. Kindly scan the QR code on the right
2. Complete the survey on Page 1
    - This is an anonymous survey
    - The 6-digit number is for your own reference
    - Data will be used in the 15-min demonstration only
3. Please do NOT turn to next page at this moment

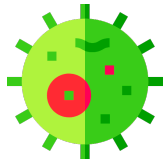


What is microbiota

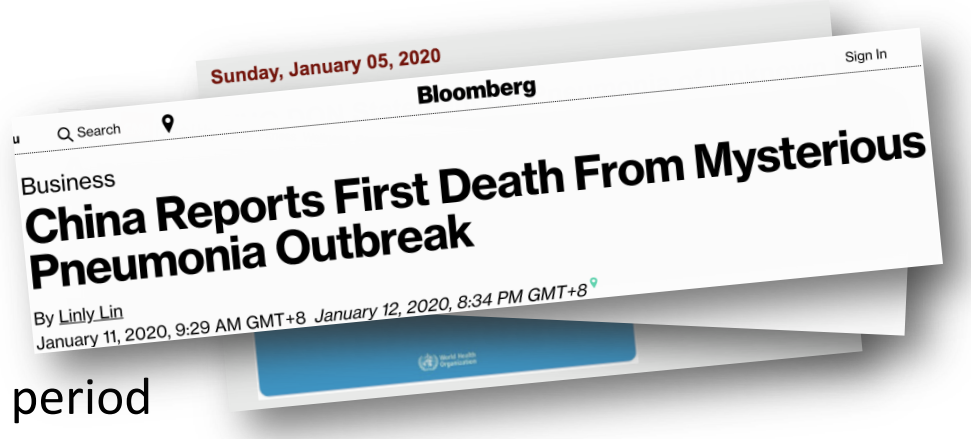
- Microorganisms/microbes
  - microscopic (tiny), living organisms
  - can be of bacteria, fungi, archaea, protists



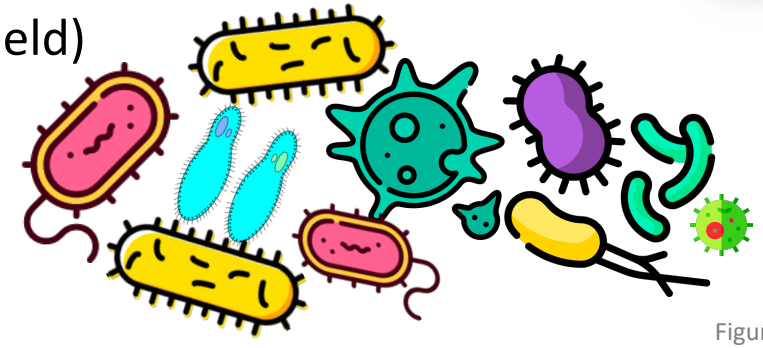
Viruses?



- not regarded as living
- strictly speaking, not microorganisms



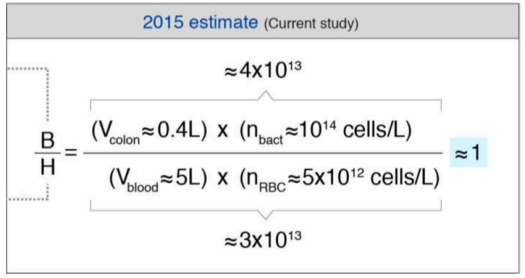
- Microbiota
  - microorganisms of a particular site, habitat, or geological period
  - Viruses are included (norm in the field)



Figures from https://www.flaticon.com/ and google

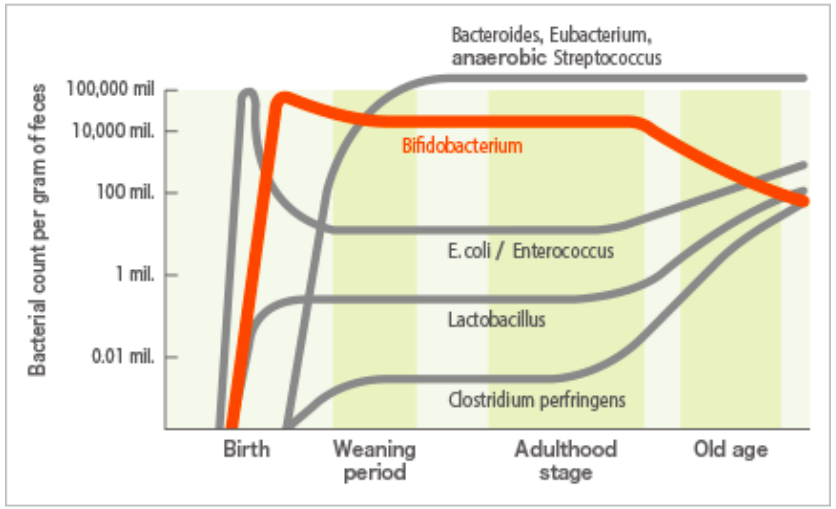
Can we get rid of microbiota? We can't!

We are only 10-50% human[1, 2]



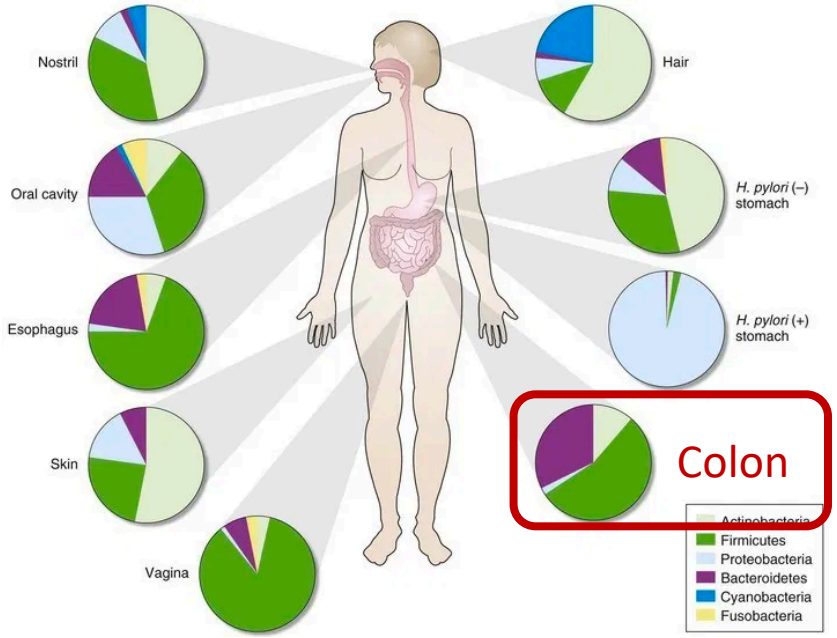
The composition of microbiota varies

- by age[3, 4]



(Mitsuoka, 1976)

- among body sites[5]

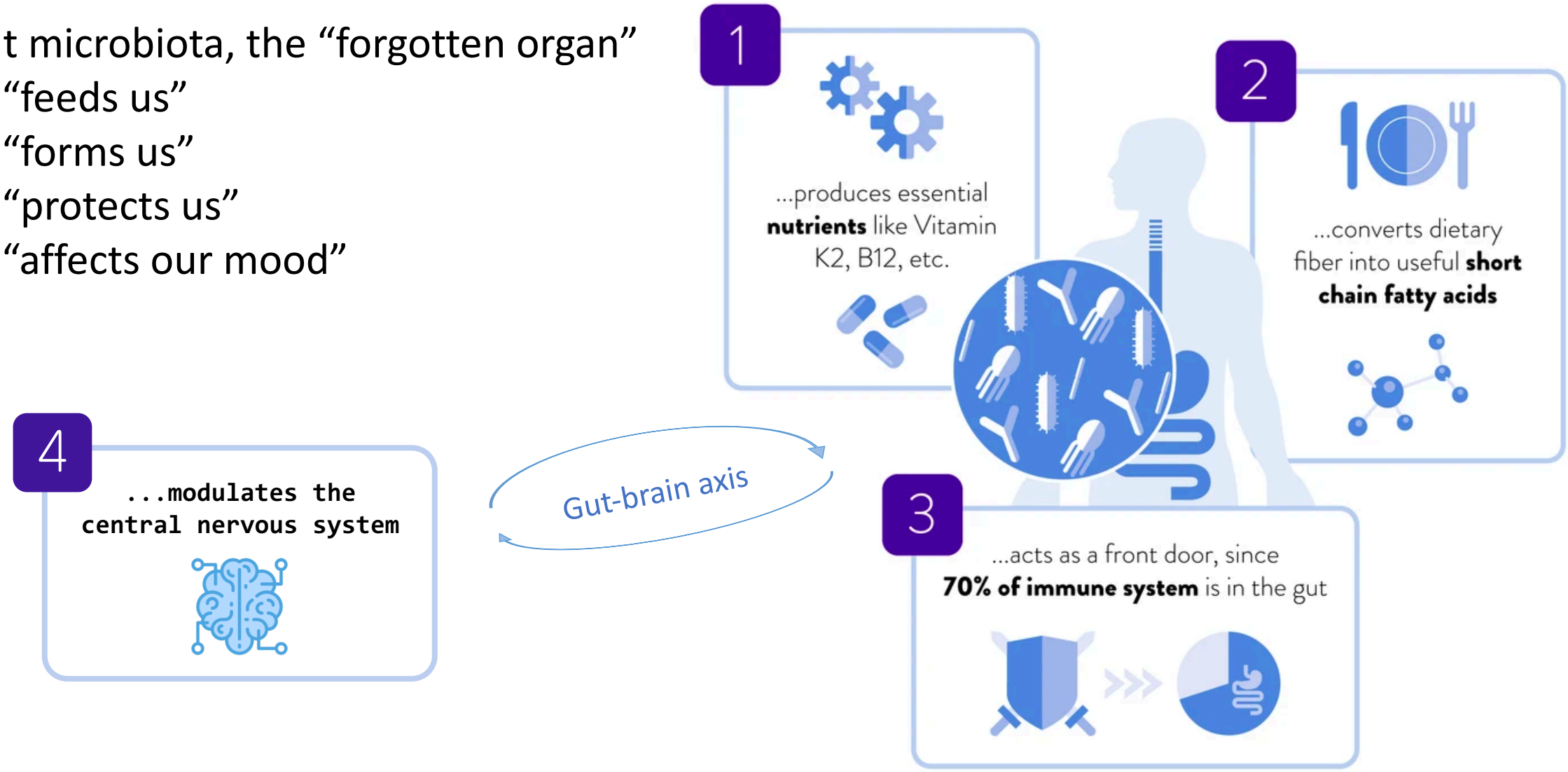


[1] https://rhapsodyinwords.com/tag/the-human-microbiome-project/; [2] PLOS Biology | DOI:10.1371/journal.pbio.1002533; [3] Figures adopted from Your Changing Microbiome. (2014, August 15); [4] https://www.bb536.jp/english/basic/basic02.html; [5] https://oncohemakey.com/the-human-microbiome-of-local-body-sites-and-their-unique-biology/;

Can we get rid of microbiota? We can't! And we shouldn't!

Gut microbiota, the "forgotten organ"

- "feeds us"
- "forms us"
- "protects us"
- "affects our mood"



[1] Figure adopted from https://innovixlabs.com/blogs/insights/3-reasons-why-your-gut-microbiome-is-called-the-forgotten-organ
[2] https://www.flaticon.com/free-icon/brain_2345027?term=brain&page=1&position=30; [3] doi:10.1136/archdischild-2016-311643

What if the gut microbiota is unhealthy?

Gut microbiota, the “forgotten organ”

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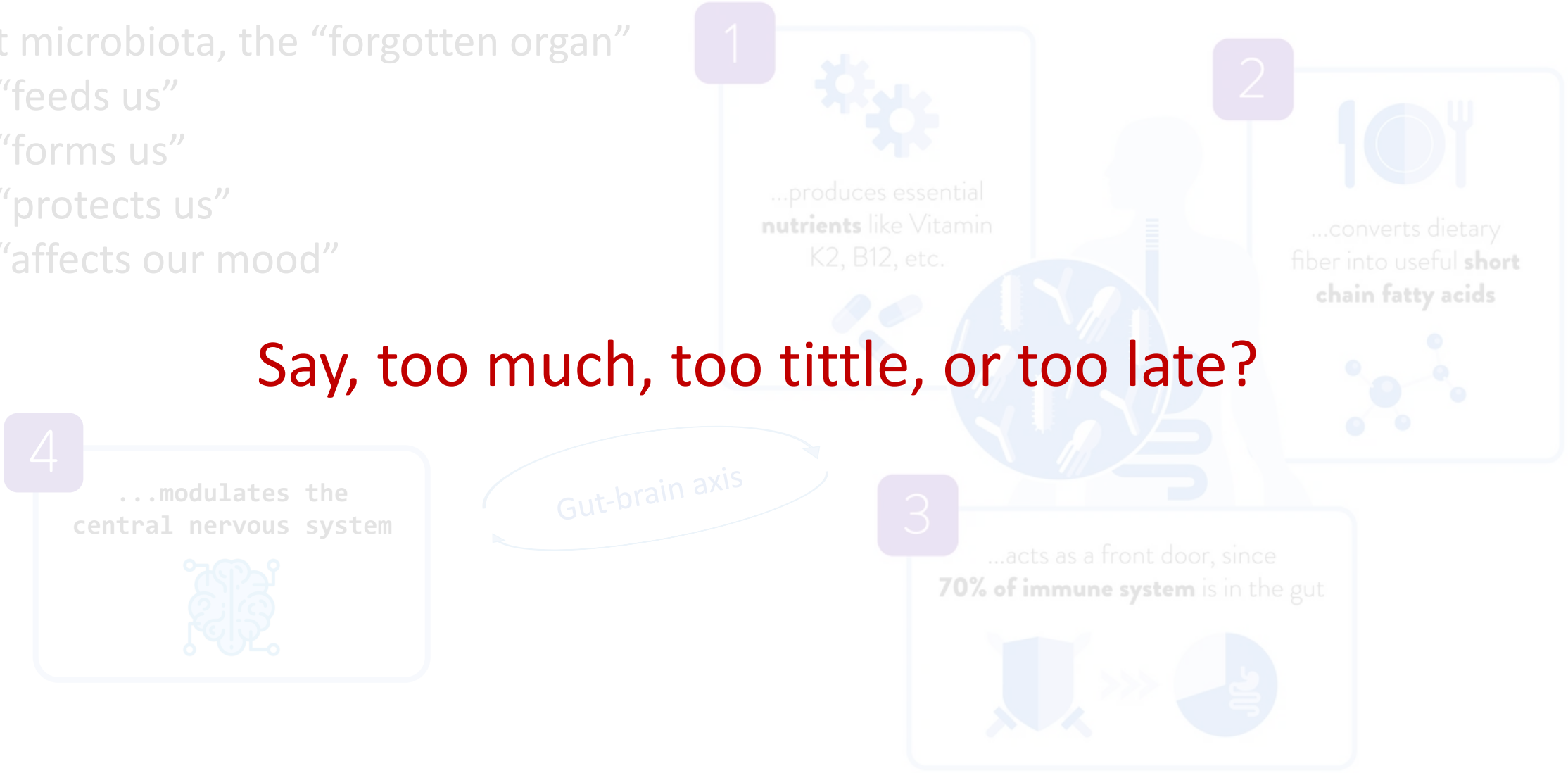
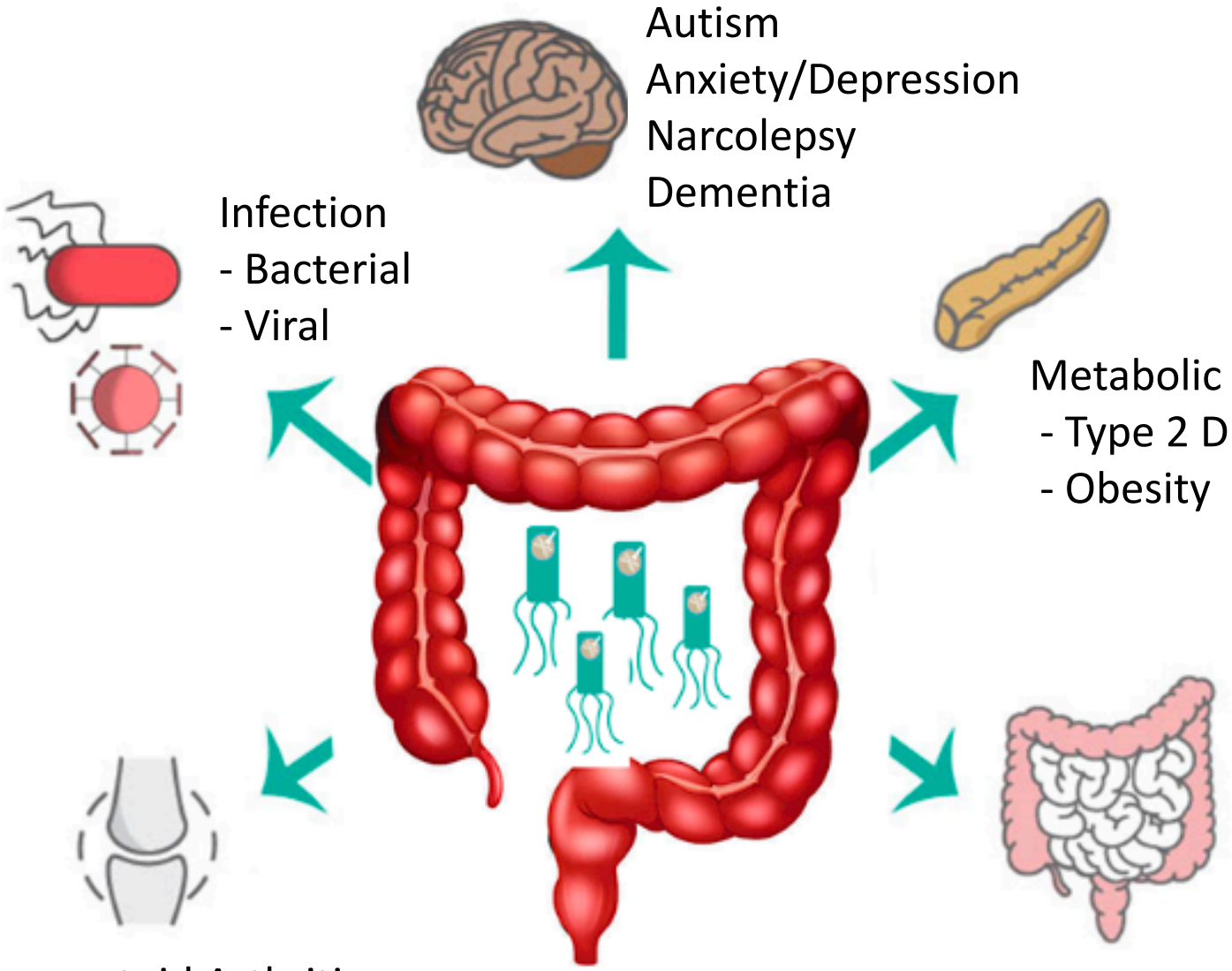


Say, too much, too tittle, or too late?

[1] Figure adopted from https://innovixlabs.com/blogs/insights/3-reasons-why-your-gut-microbiome-is-called-the-forgotten-organ
[2] https://www.flaticon.com/free-icon/brain_2345027?term=brain&page=1&position=30; [3] doi:10.1136/archdischild-2016-311643

What if the gut microbiota is unhealthy? We get diseases!



Autism
Anxiety/Depression
Narcolepsy
Dementia

Infection
- Bacterial
- Viral

Metabolic Disorders
- Type 2 Diabetes
- Obesity

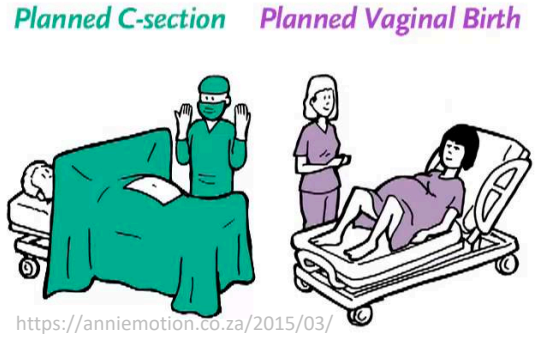
Cardiovascular Disorders
- Atherosclerosis
- Hypertension

Rheumatoid Arthritis
Gout

Inflammatory Bowel Disease
Colorectal Cancer

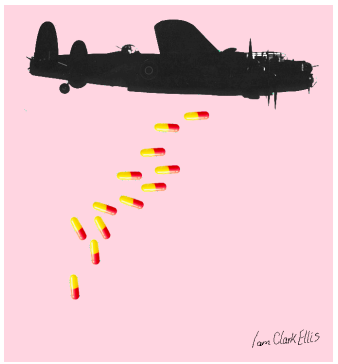
[1] Figure adopted from http://knowyourfoods.blog/
[2] doi:10.1136/archdischild-2016-311643

Influential factors on gut microbiota

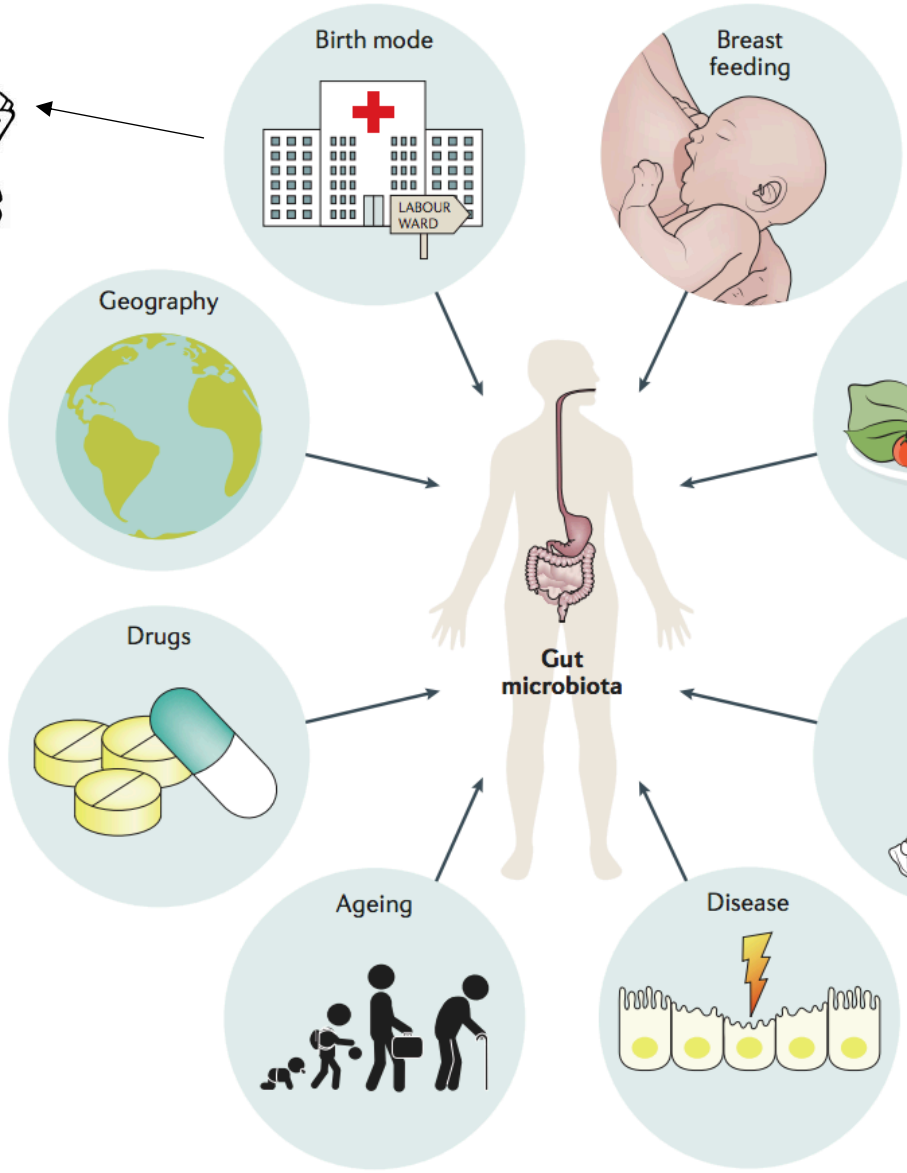


https://anniemotion.co.za/2015/03/27/vj-delivery-vs-c-section-delivery/

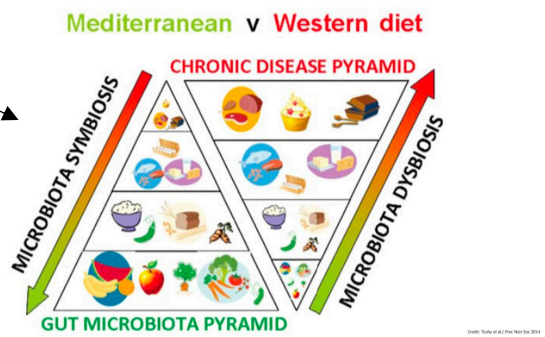
https://www.pinterest.com/pin/109775309638216176/



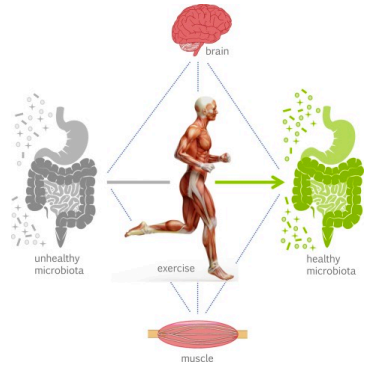
https://autodidactauthor.files.wordpress.com/2014/09/antibiotic-bombs1.png



http://www.coolbabykid.com/breastfeeding-vs-bottle-feeding/



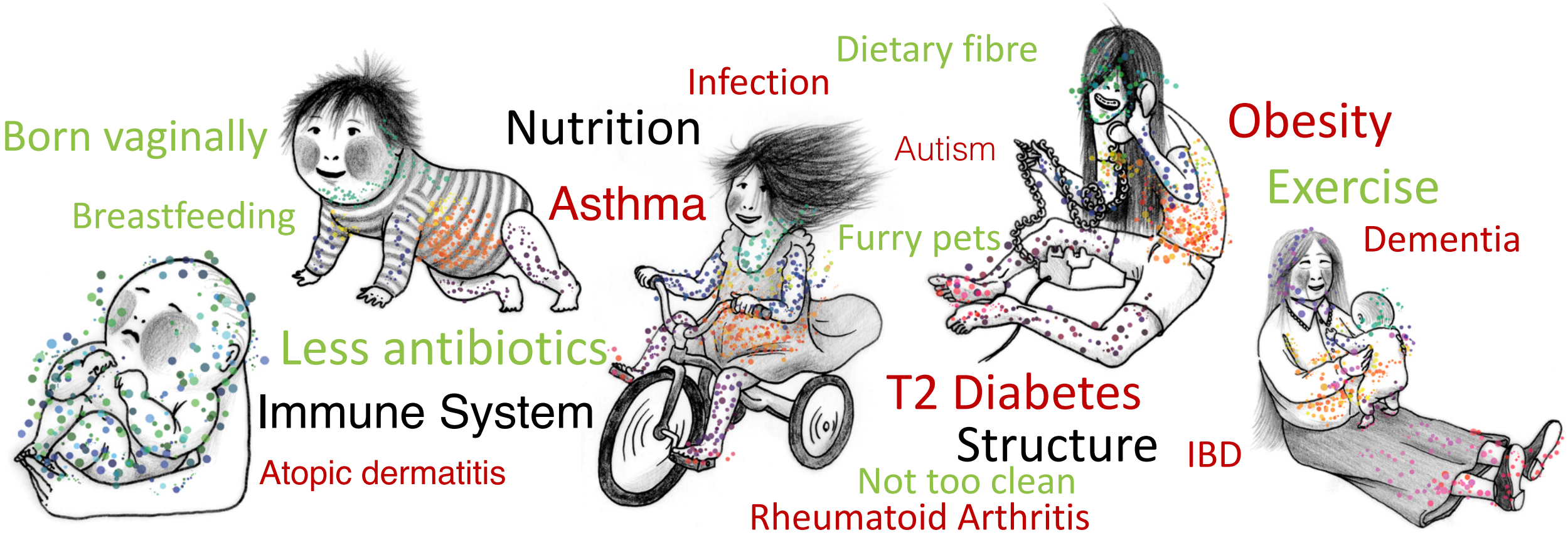
https://www.gutmicrobiotaforhealth.com/en/conserving-restoring-human-gut-microbiome-increasing-consumption-dietary-fibre/



https://doi.org/10.1016/j.dld.2017.11.016

doi:10.1038/nrgastro.2017.29

Summary



Figures adopted from Your Changing Microbiome. (2014, August 15)

Thank you!

Any questions you may have?

Contact: pengye@connect.hku.hk

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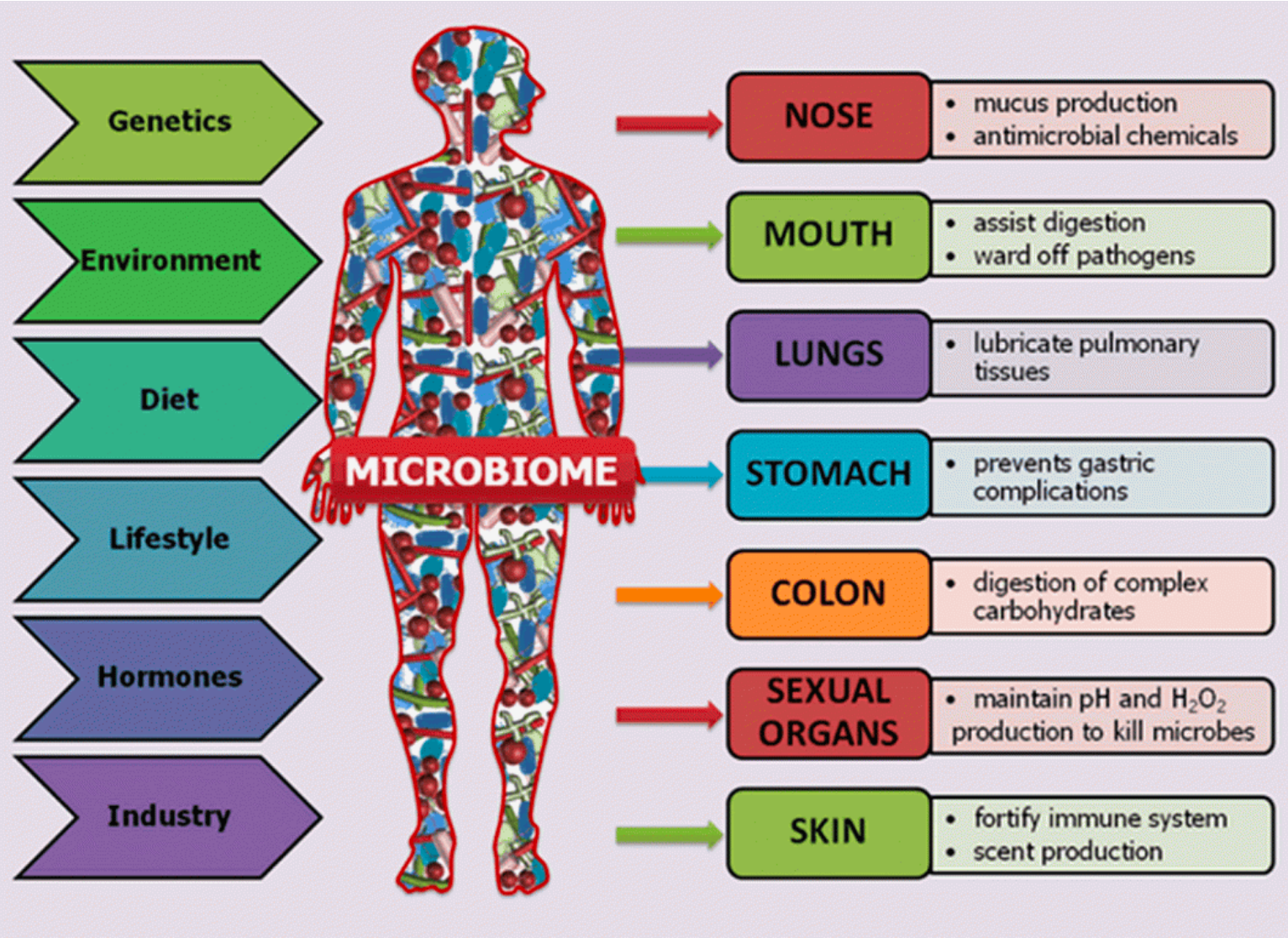
Supplementary Slide 1: major function of microbiota in different body sites



https://neurosciencenews.com/microbiome-health-neuroscience-14496/

Supplementary Slide 2: Gut-brain axis

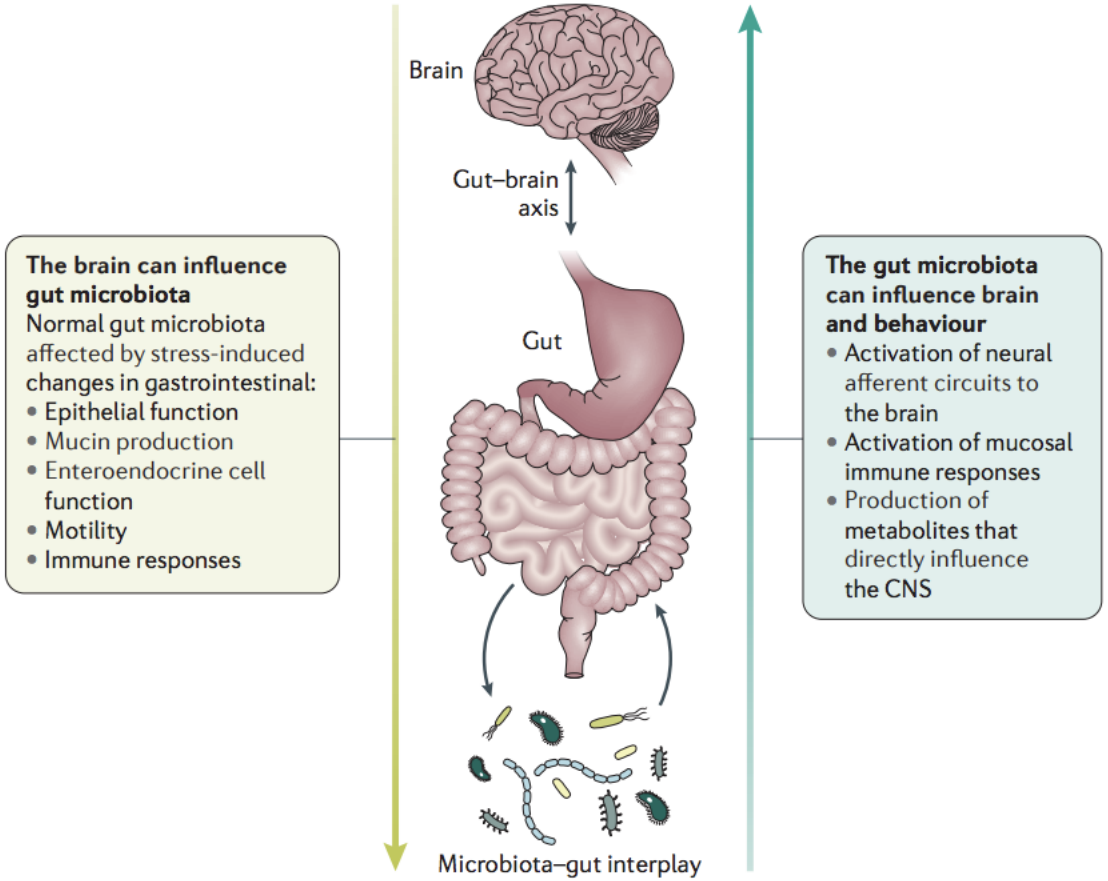
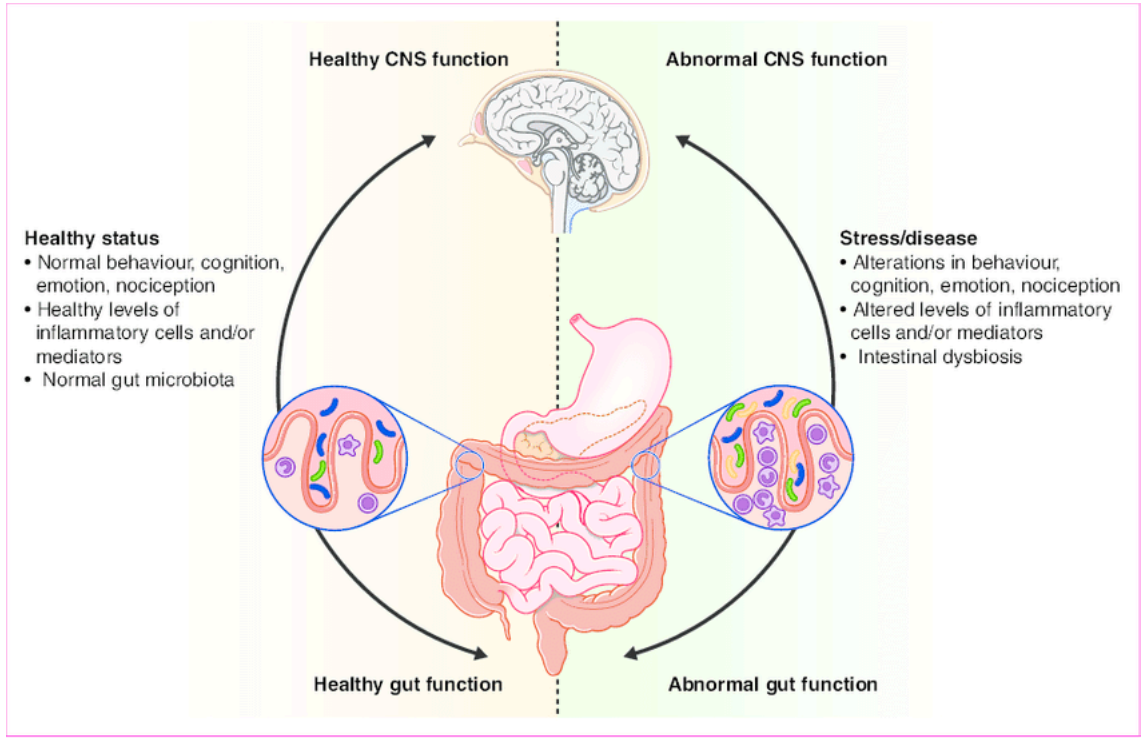


Figure 2 | **The microbiome–gut–brain axis.** A bidirectional interaction occurs between gut microbiota, the gut (including its immune and neural networks, as well as the gut barrier) and the brain. CNS, central nervous system. Modified, with permission, from Elsevier © Collins, S. M. & Bercik P. *Gastroenterology* **136**, 2003–2014 (2009).



[1] Quigley, E. M. M. (2017). Gut microbiome as a clinical tool in gastrointestinal disease management: are we there yet? Nature Reviews Gastroenterology & Hepatology, 14(5), 315–320. doi:10.1038/nrgastro.2017.29
[2] https://www.researchgate.net/figure/Impact-of-the-gut-microbiota-on-the-gut-brain-axis-in-health-and-disease-A-stable-gut_fig3_258198236

Supplementary Slide 3: Gut microbiota-associated human diseases (Source 1)

Disease categories	Specific diseases	Associated dysbiotic features	Reference
Immune-mediated/autoimmune diseases	inflammatory bowel disease (IBD)	• Increase in virulent gut microbes (*Enterobacteriaceae* species, *Bacteroides fragilis*) and mucolytic *Ruminococcus* sp. • Decrease in butyrate-producing *Firmicutes* (such as *Faecalibacterium prausnitzii, Roseburia hominis*)	Sokol et al., 2008; Png et al., 2010; Willing et al., 2010; Machiels et al., 2014
	Irritable bowel syndrome (IBS)	• Increase in *Escherichia coli* • Decrease in *Clostridium leptum* group of bacteria and *Bifidobacterium*. • Decrease in bile acid biotransformation	Duboc et al., 2012
	Celiac disease	• Increase in *Bacteroides–Prevotella* group • Decrease in *Bifidobacterium* • Varying observation (decrease or no change) in *Clostridium histolyticum*, *C. lituseburense,* and *Faecalibacterium prausnitzii* • Alteration in SCFAs composition, but overall increase in total SCFA	Tjellström et al., 2005; Nadal et al., 2007; De Palma et al., 2010
	Systemic lupus erythematosus (SLE)	• Increase in *Blautia* sp. and Gram-negative bacteria such as *Proteobacteria.* • Decrease in gut microbiota diversity, *Odoribacter* sp., *Alistipes* sp. • Increase in serum endotoxin	Shi et al., 2014; Luo et al., 2018
	Type-1 diabetes	• Increase in *Bacteroidetes* • Decrease in *Actinobacteria, Firmicutes,* and *Firmicutes/Bacteroidetes* ratio	Murri et al., 2013
	Rheumatoid arthritis (RA)	• Increase in *Prevotella copri* and decrease in *Bacteroides* sp. In new-onset RA • Increase in microbiota diversity of *Lactobacillus* genus in early RA	Liu et al., 2013; Scher et al., 2013
	Atopic disease (E.g., childhood allergic asthma)	• Increase in fecal burden of *Clostridium difficile,* and *C. difficile/Bifidobacteria* ratio	Kalliomäki et al., 2001
Metabolic disorders/cardiovascular disorders	Obesity	• Increase in *Firmicutes, Actinobacter* • Varying observation (decrease, no change, increase) in *Bacteroidetes* • Increase in glycoside hydrolase and SCFAs (butyrate and acetate)	Turnbaugh et al., 2006, 2009a; Koliada et al., 2017
	Type-2 diabetes	• Increase in *Lactobacillus* • Decrease in *Clostridium coccoides, Atopobium* cluster, and *Prevotella* • Decrease in butyrate biosynthesis	Qin et al., 2012; Sato et al., 2014
	Hypertension	• Increase in the Firmicutes/Bacteroidetes ratio, lactate-producer • Decrease in microbiota diversity, acetate- and butyrate-producers	Yang et al., 2015
	Atherosclerosis	• Increase in metabolites TMAO, endotoxin level (risk factor for early atherosclerosis)	Wiedermann et al., 1999; Koeth et al., 2013
Cancer	Colorectal cancer (CRC)	• Increase in enterotoxigenic *Bacteroides fragilis,* and pathobionts *Fusobacterium* and *Campylobacter* sp. • Decrease in butyrate-producer (*Faecalibacterium* and *Roseburia*)	Wang et al., 2012; Wu et al., 2013
Neurop sy chi atri c	Autism spectrum disorder (ASD)	• Increase in *Clostridium* sp., *Bacteroidetes, Lactobacillus, Desulfovibrio* • Decrease in *Bifidobacteria*	Song et al., 2004; Adams et al., 2011
	Alzheimer's disease	• Possible connection between gut microbiota-synthesized amyloids, LPS, γ-aminobutyric acid (GAB A – major inhibitory neurotransmitter), and the increased permeability of gut barrier and blood brain barrier with age	Pistollato et al., 2016
	Depression	• Increase in genus *Eggerthella, Holdemania, Gelria, Turicibacter, Paraprevotella, Anaerofilum* • Decrease in gut microbiota diversity, *Prevotella* and *Dialister*	Kelly et al., 2016
	Parkinson's Disease	• Increase in anti-inflammatory butyrate-producers from genus *Blautia, Coprococcus,* and *Roseburia* in patient fecal sample, pro-inflammatory *Proteobacteria* in patient mucosa • Increased gene expression in LPS biosynthesis and microbial type III secretion system	Keshavarzian et al., 2015
Infectious disease	*Clostridium difficile* infection (CDI)	• Increase in *Clostridium difficile;* • Decrease in gut microbiota diversity and secondary bile acids-producing *Clostridium scindens*	Theriot et al., 2014
Uremic disease	Chronic kidney disease	• Increase in *Firmicutes, Proteobacteria,* and *Actinobacteria* • Decrease in *Lactobacilli*	Vaziri et al., 2013

https://doi.org/10.3389/fmicb.2018.01835

Supplementary Slide 4: Gut microbiota-associated human diseases (Source 2)

Table 1. Summary of diet-microbiota interactions in health and disease.

Healthy Microbiota	Gut Dysbiosis	Other Cause/Consequence
High dietary fiber intake [115]	Western diet; low core diversity [10,83]	High in choline/fat/added sugar [105,117]
Plant foods low in choline [151]	High [TMAO] in blood [134]	Arterial plaque formation [135]
Fruits and vegetables; prebiotic-containing foods [4]	Low fiber intake/low FODMAP carbs [244]	Beer, bread, sugar/artificially-sweetened beverages [120,122]
High α species diversity; butyrate-producing [4,105,120]	Low short-chain fatty acid fermentation [100]	Intestinal inflammation [25,117]
Anti-inflammatory omega-3 [217]	Diet high in omega-6 fatty acids	Pro-inflammatory [149]
Lean body mass, increased lipolysis [84]	Obesity, vagal remodeling, increased energy harvest [85,105]	Increased appetite/lipogenesis [103]
High *Prevotella*/low *Bacteroides*; abundance of *A. muciniphila* [12,14,91]	Abundance of *Ruminococcus* [16,105]	High Firmicutes:Bacteroidetes ratio [85,105]
Glucose and lipid homeostasis [100]	Insulin resistance, bacterial encroachment [76,106,271]	Cardiovascular disease [111,151]
Beneficial bacteria/probiotics: *Bifidobacterium, Lactobacillus* [192,206]	Oxidative stress; facultative anaerobes; *E. coli* [38]	Broad-spectrum antibiotics [22,39,287]; medication dysbiosis [290]
Gut-brain interactions [78]	Mental health issues or visceral pain [72,296]	Leaky gut, plasma endotoxin, psychological stress; emulsifiers [54,272]
Regular intestinal motility [222,259]	Structural or functional bowel disorders [22,50]	Colorectal cancer [3]
Healthy fecal biomarkers [53]	Need butyrate/inulin supplementation [81,104,213]	Potential for fecal transplant [73,76]
Intermittent fasting; adipose beiging [273]	Excess starch/sugar consumption [120]	*Candida* overgrowth; gluten sensitivity [241,256]

Nutrients 2019, 11, 1613; doi:10.3390/nu11071613