Enteral nutrition and the gut microbiome

Microbiome in clinical practice Part 2: FODMAPs vs. FADMAPs

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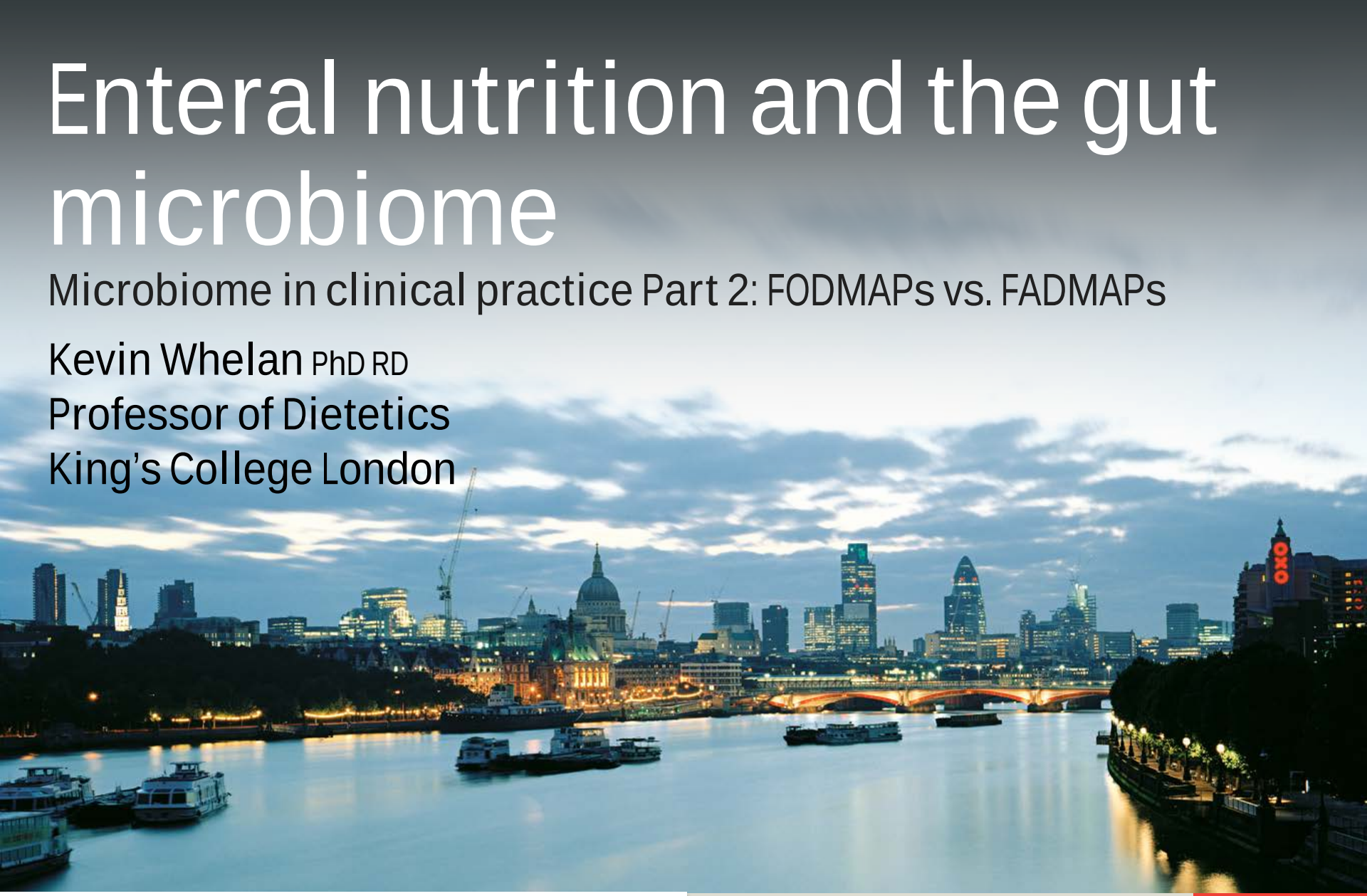

@ProfWhelan
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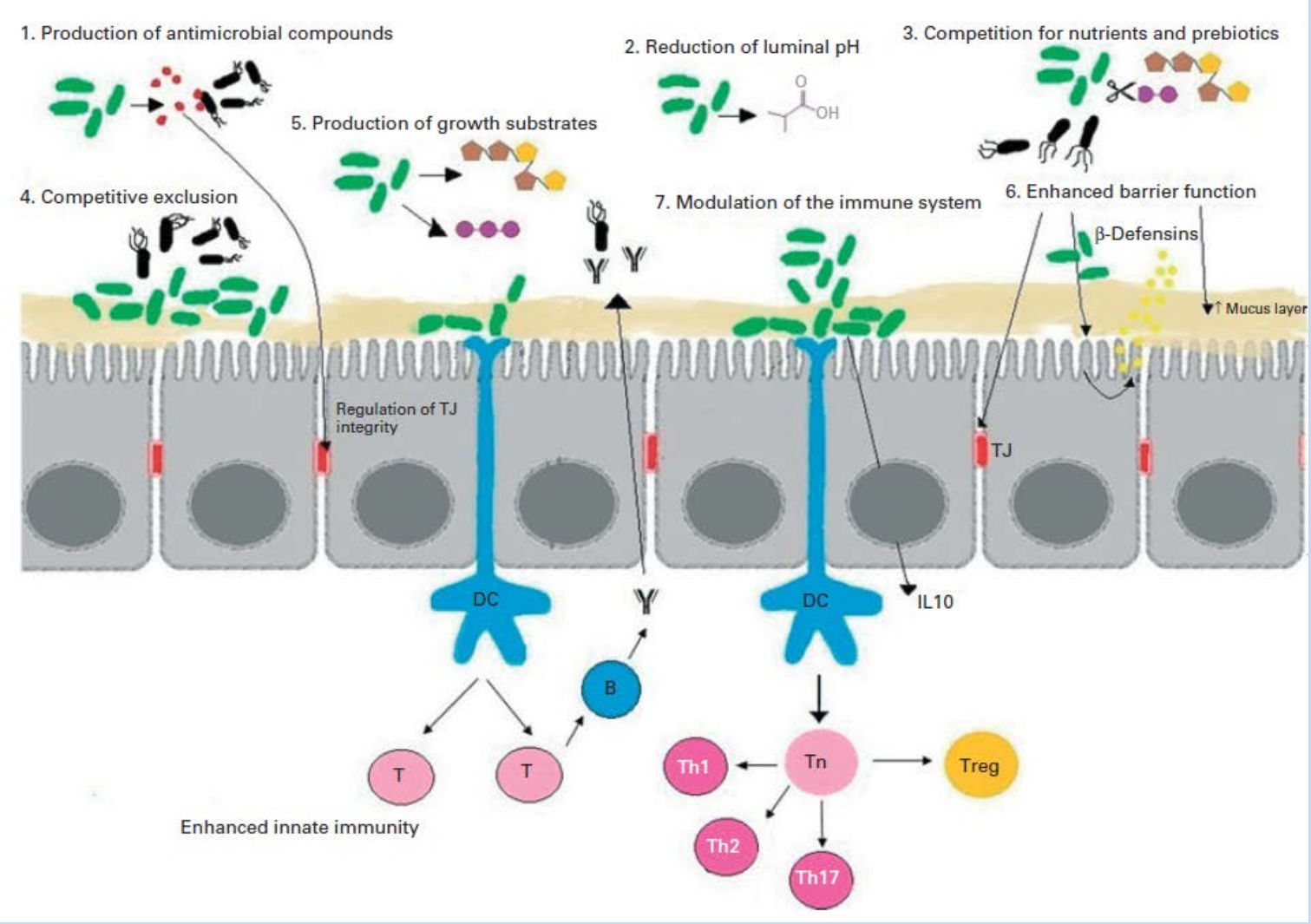
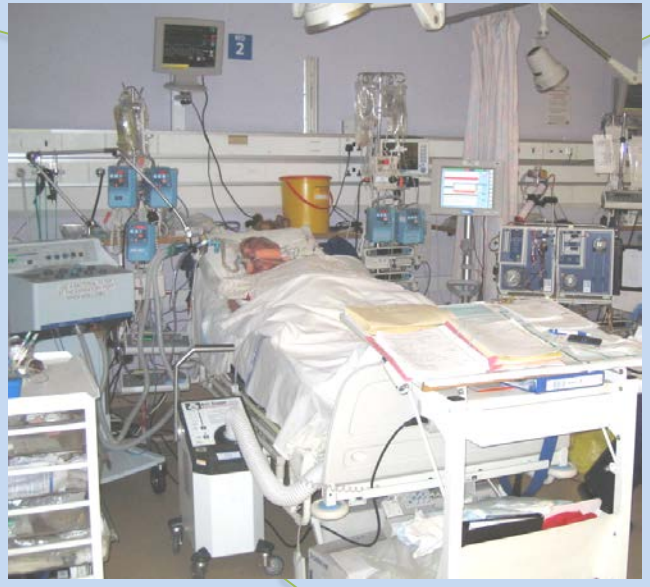
Microbiota: beneficial functions in health



Power *et al*, Brit J Nutr 2013

Factors influencing the gut microbiome in EN: The 3 Ds

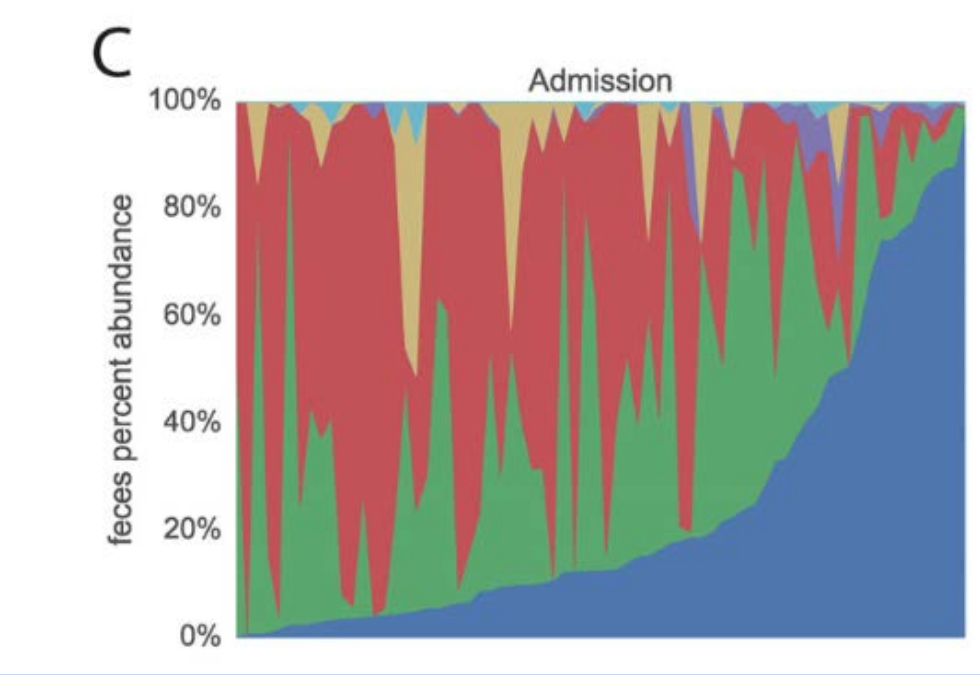
Disease



Drugs

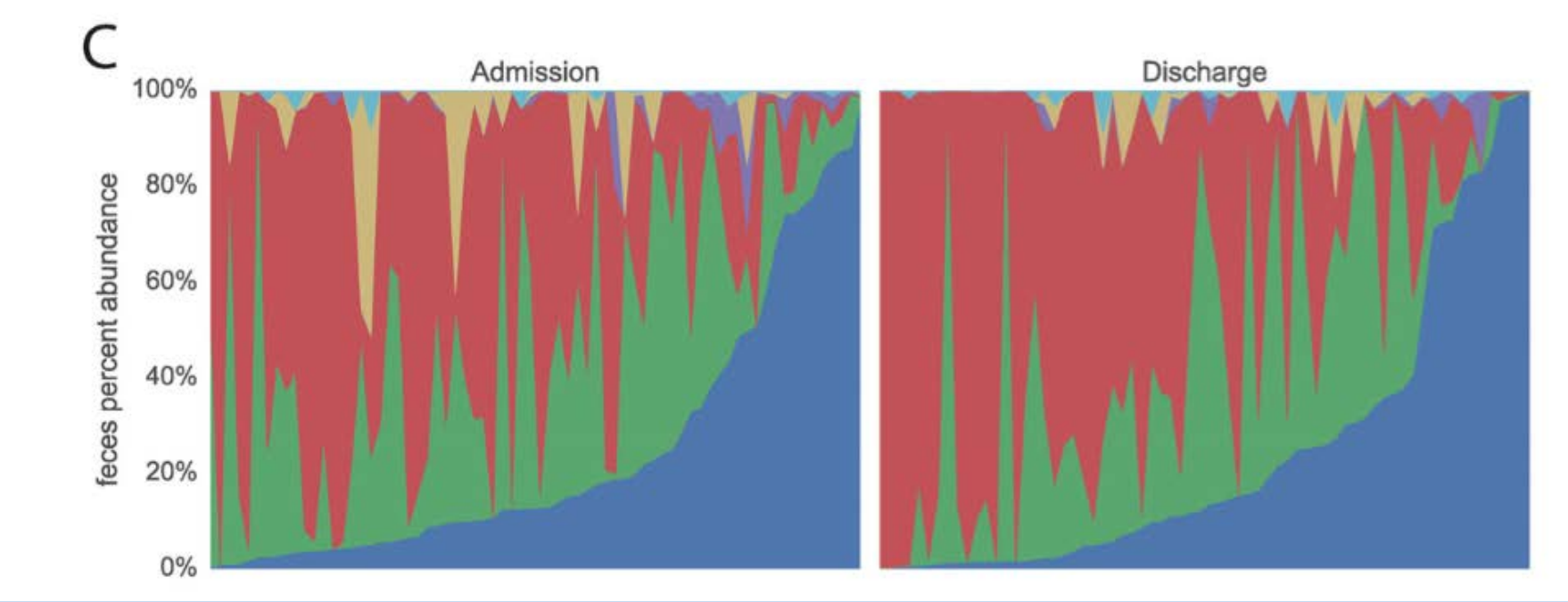
Diet
(enteral formula)

Patients receiving EN have altered gut microbiome



McDonald, mSphere 1: e00199-16

Patients receiving EN have altered gut microbiome



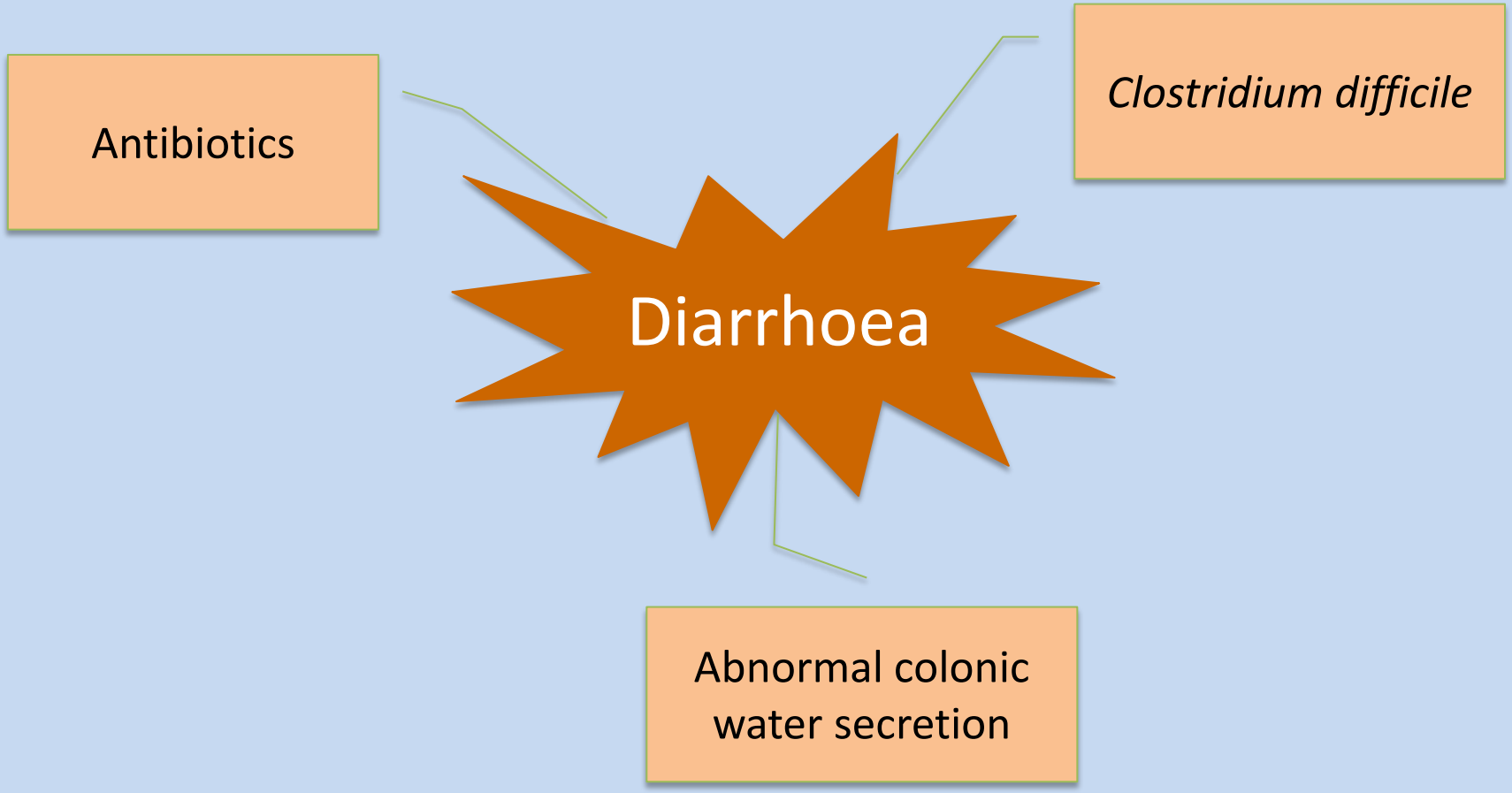
McDonald, mSphere 1: e00199-16

Alterations in gut microbiome in EN are important

	Start (days 1–4)	Middle (days 6–9)	End (days 11–14)	*P* value[1]
Microbiota, $n = 20$ (% of total)				
Bifidobacteria				
No diarrhea	4.3 ± 5.1	9.3 ± 16.0	12.2 ± 18.3	0.029
Diarrhea	0.6 ± 0.5	1.7 ± 3.2	0.4 ± 0.3	

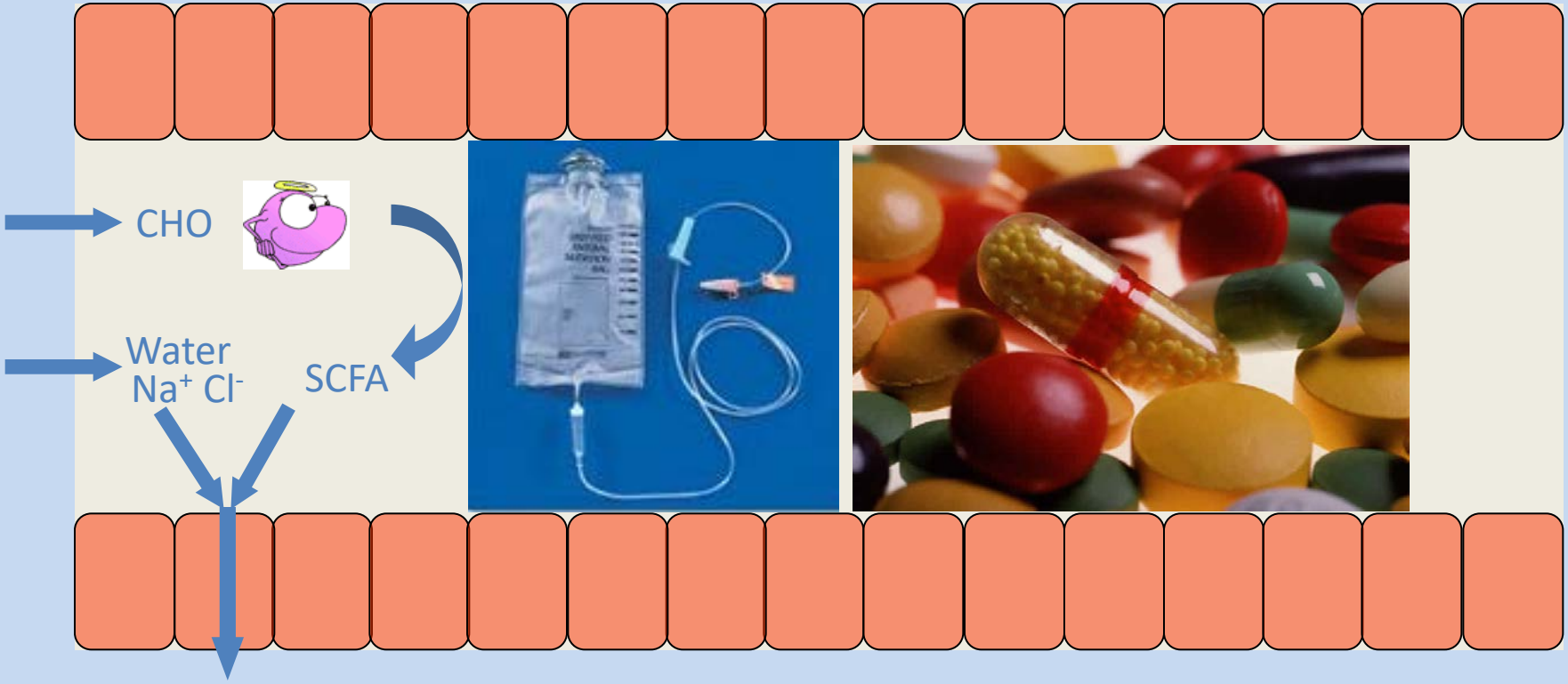
Whelan *et al.* Am J Clin Nutr. 2009; 89: 240-247

Microbiome, enteral nutrition and diarrhoea: Mechanisms

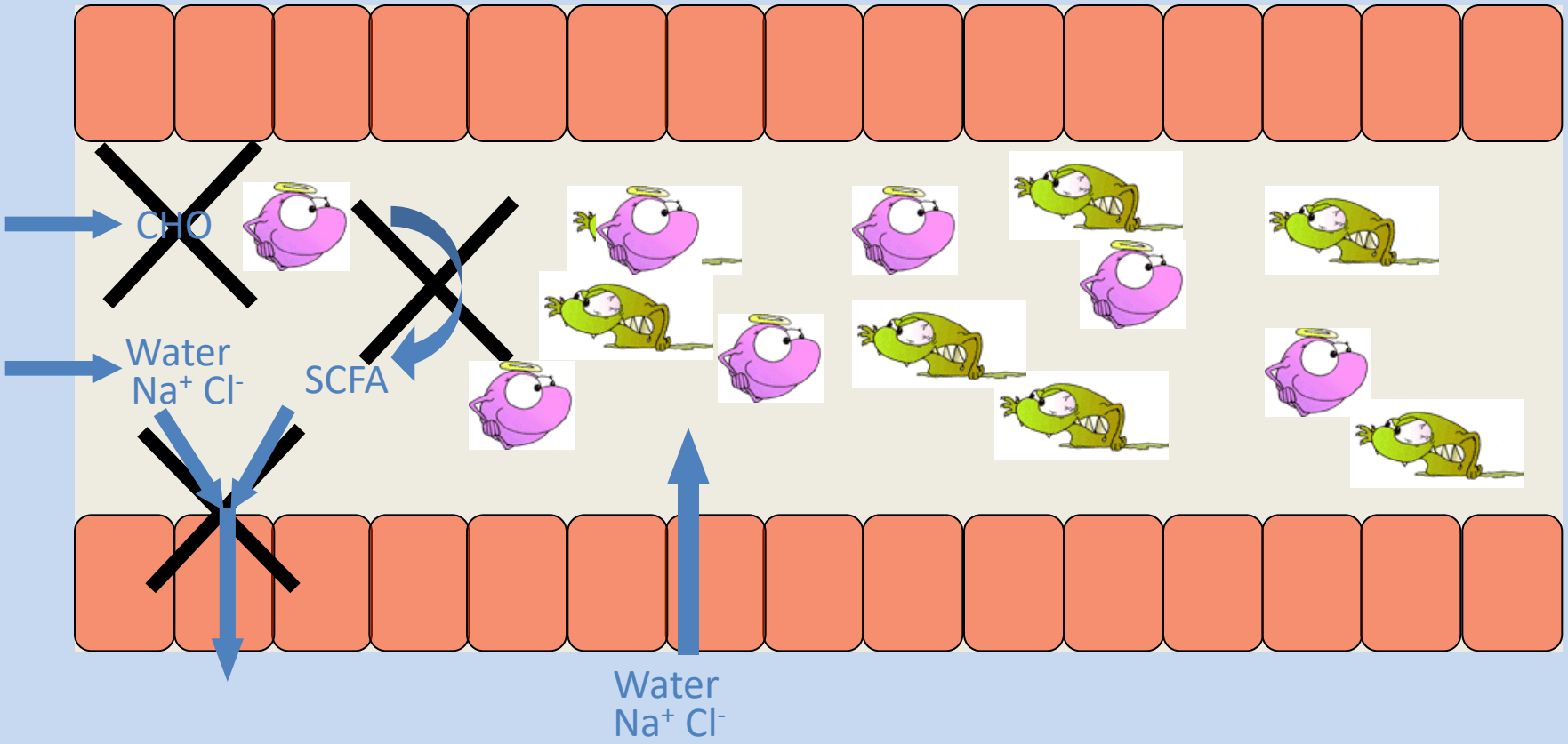


Whelan *et al.* Proc Nutr Soc. 2007; 66: 299-306

Microbiome, enteral nutrition and diarrhoea: Mechanisms

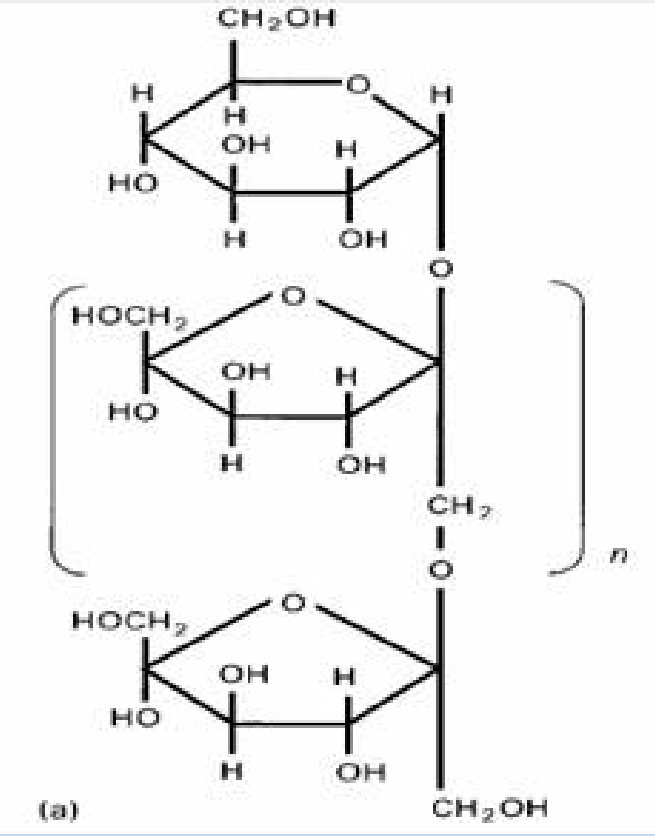


Microbiome, enteral nutrition and diarrhoea: Mechanisms



Do enteral formulas impact gut microbiome?

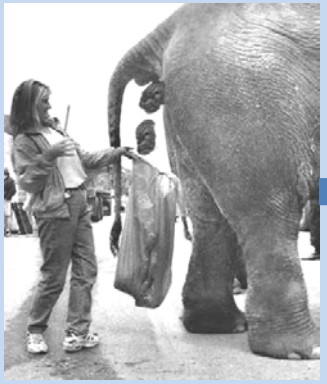
Prebiotics



A selectively fermented ingredient that results in specific changes in the composition and/or activity of the gastrointestinal microbiota, thus conferring benefit(s) upon host health (ISAPP, 2008)

Fructans (e.g. oligofructose, inulin, FOS)
Galacto-oligosaccharides)

Do enteral formulas impact gut microbiome?



3-day total stool collection

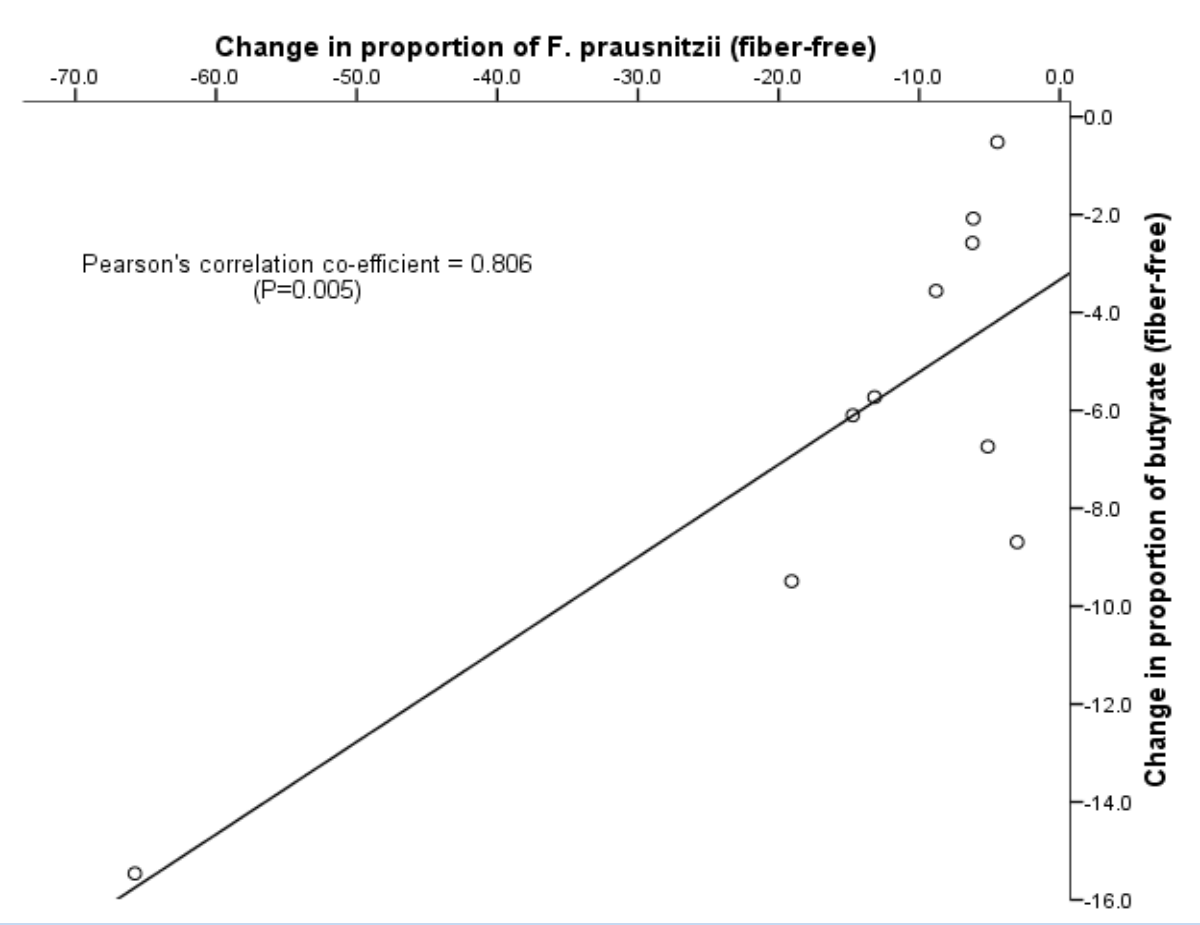
Healthy people stop eating for 2-weeks and consume enteral formula (+/- prebiotics)

3-day total stool collection

Healthy people stop eating for 2-weeks and consume enteral formula (+/- prebiotics)

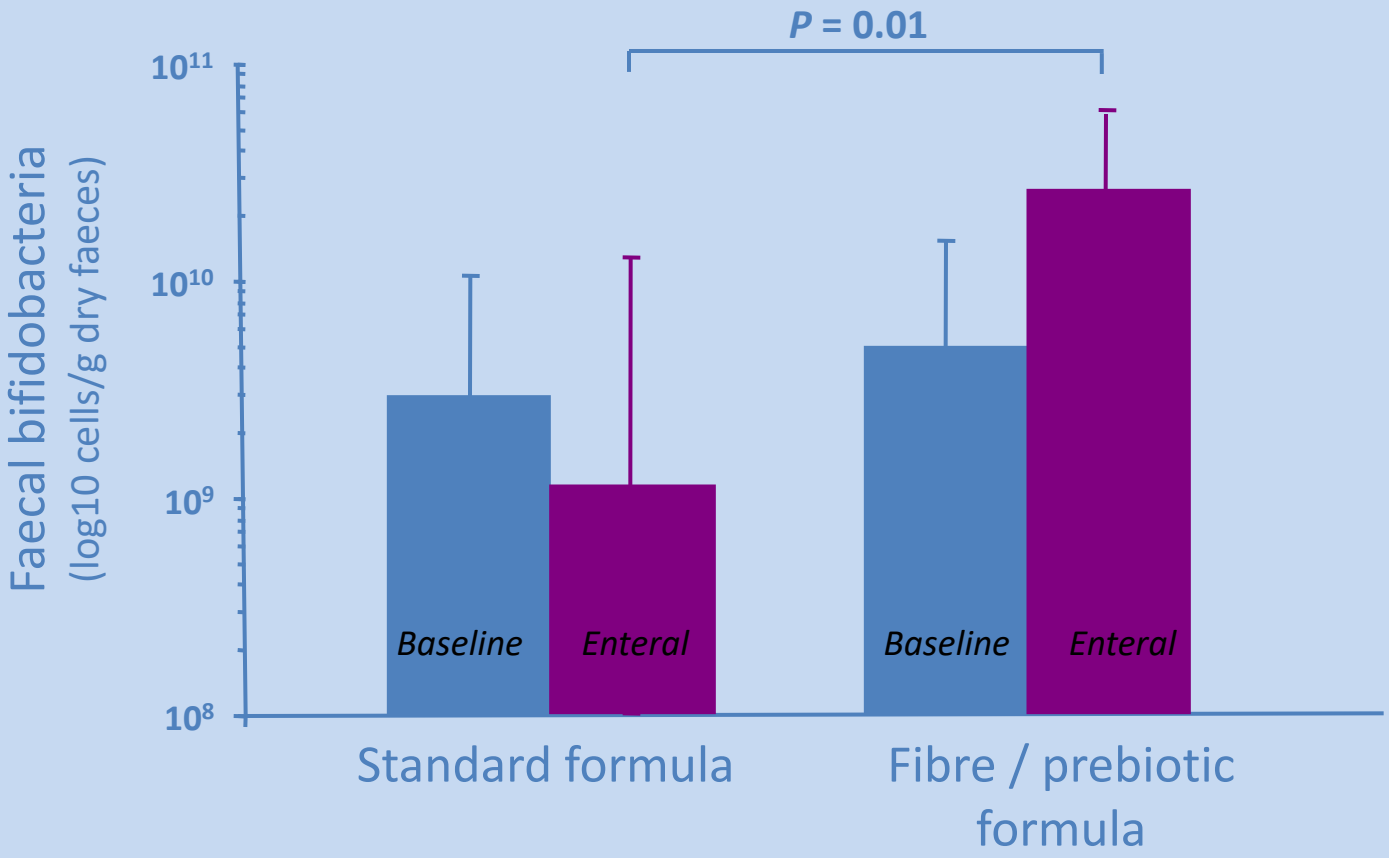
3-day total stool collection

Standard formulas reduce butyrate and *Faecalbacterium prausnitzii*



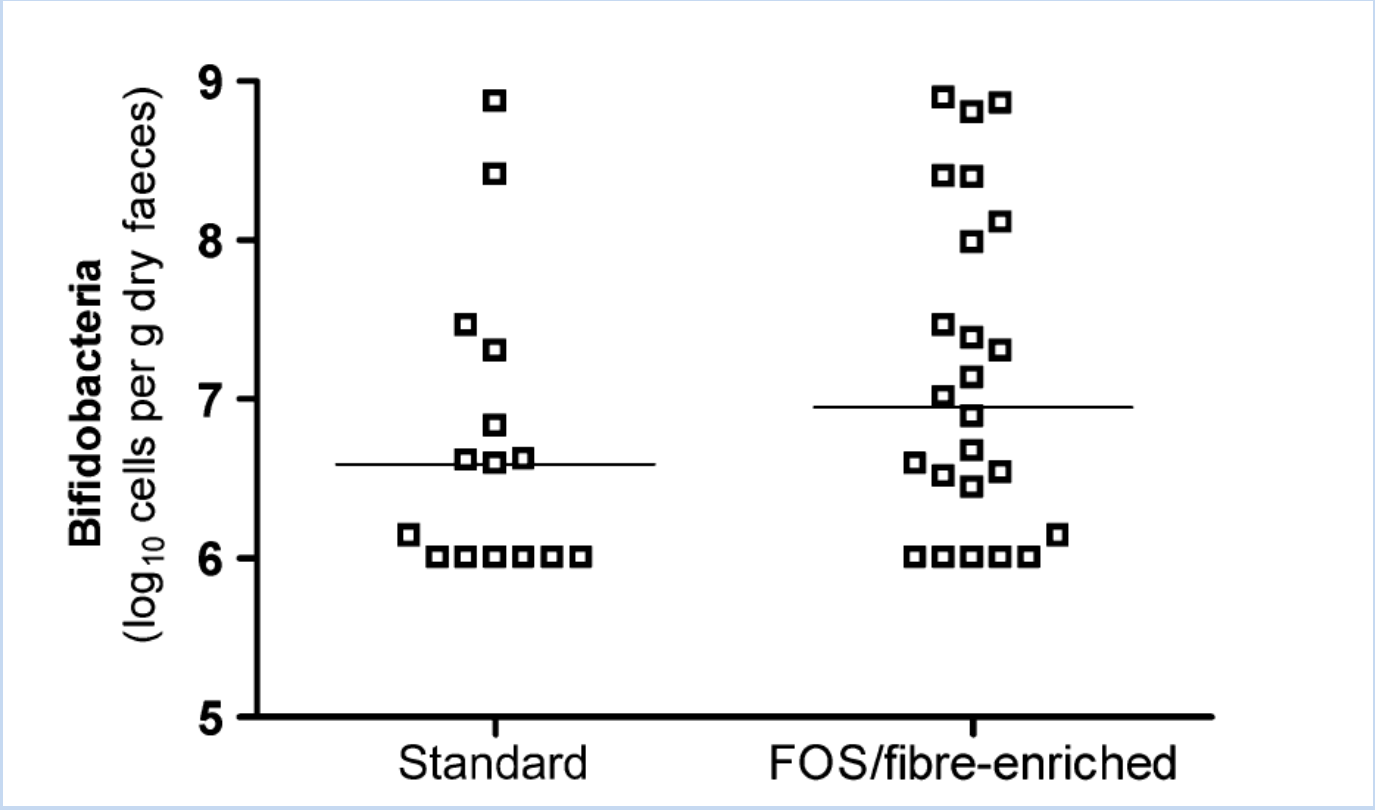
Benus *et al.* Brit J Nutr. 2010; 104: 693–700

Fibre / prebiotic formulas can "beneficially" impact gut microbiome (in healthy volunteers)



Whelan *et al*, J Nutrition 2005; 135: 1896-1902

Fibre / prebiotic formulas in acute in-patients receiving EN



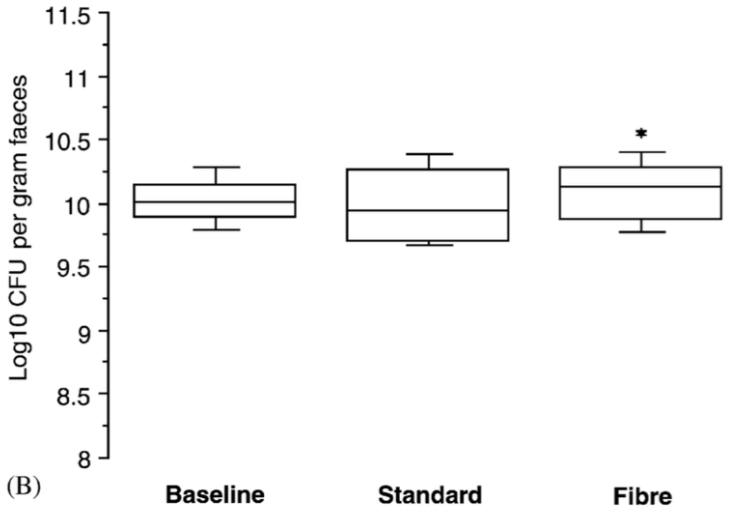
Majid *et al.* J Hum Nutr Diet. 2011; 24: 260-268

Fibre / prebiotic formulas in long term EN

Effects of total enteral nutrition supplemented with a multi-fibre mix on faecal short-chain fatty acids and microbiota

Stéphane M. Schneider[a,*], Fernand Girard-Pipau[b], Rodolphe Anty[a], Esmeralda G.M. van der Linde[c], Bertine J. Philipsen-Geerling[d], Jan Knol[c], Jérôme Filippi[a], Kamel Arab[a], Xavier Hébuterne[a]

15 patients on long term EN (3.5 years)
Randomised cross-over trial (14 d)



	Baseline	Fibre-free EN	Multi-fibre EN
Bifidobacteria	6.0 (6.0–10.4)	6.0 (6.0–10.4)	6.0 (6.0–10.4)
Bacteroides	8.2 (6.0–9.1)	8.2 (6.0–9.1)	8.4 (6.0–9.2)*
Clostridium	8.4 (6.0–9.2)	8.2 (6.0–9.1)	8.5 (6.0–8.9)
Streptococci–Lactococci	7.7 (6.0–8.2)	7.8 (6.0–8.7)	7.7 (6.0–8.3)
Escherichia coli	6.7 (6.0–8.8)	7.1 (6.0–8.7)	6.0 (6.0–8.4)
Lactobacilli–Enterococci	8.7 (7.9–9.5)	8.6 (7.7–9.4)	8.9 (7.4–9.4)
Eubacterium	9.0 (7.9–9.4)	8.9 (8.4–9.6)	8.9 (6.0–9.5)
Atopobium	6.0 (6.0–9.0)	6.0 (6.0–8.6)	6.0 (6.0–8.8)

Schneider et al, Clin Nutr 2006; 25: 82–90

Fibre / prebiotic formulas in long term EN

Effects of total enteral nutrition supplemented with a multi-fibre mix on faecal short-chain fatty acids and microbiota

Stéphane M. Schneider[a,*], Fernand Girard-Pipau[b], Rodolphe Anty[a], Esmeralda G.M. van der Linde[c], Bertine J. Philipsen-Geerling[d], Jan Knol[c], Jérôme Filippi[a], Kamel Arab[a], Xavier Hébuterne[a]

15 patients on long term EN (3.5 years)
Randomised cross-over trial (14 d)

	Baseline	Fibre-free EN	Multi-fibre EN
Acetic acid	29.1 (3.8–61.7)	35.8 (0–92.5)	49.6 (9.2–125.2)*
Propionic acid	9.9 (0–20.6)	10.4 (0–19.3)	12.4 (0–34.4)
Butyric acid	1.2 (0–17.8)	3.5 (0–10.1)	4.6 (0–25.8)**
Total SCFAs	37.1 (12.7–138.9)	51.4 (5.5–130.1)	66.6 (16.3–185.5)**

Schneider et al, Clin Nutr 2006; 25: 82–90

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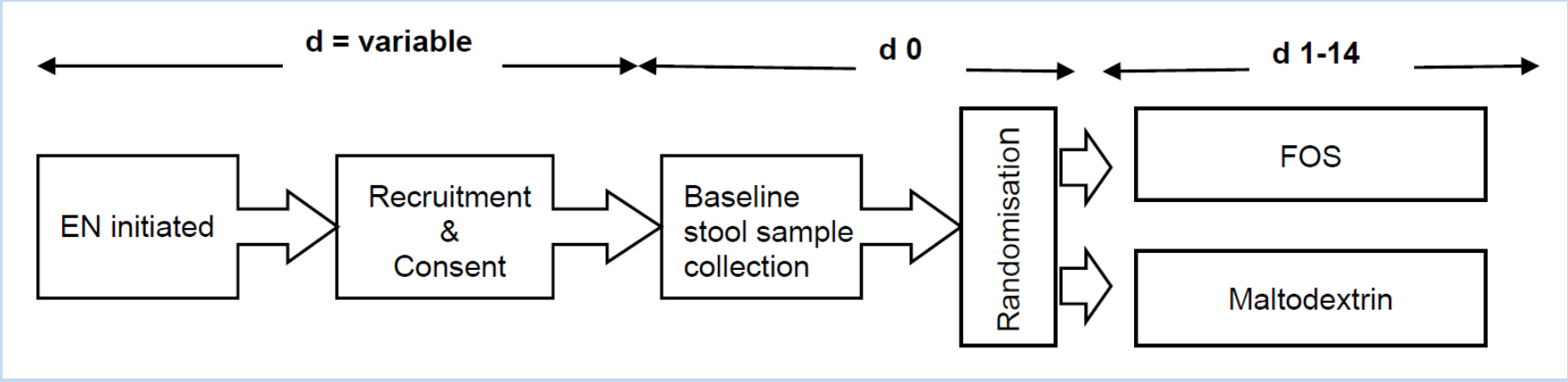
Add-FOS: RCT of 7 g/d additional prebiotics in enteral nutrition in patients on ICU



Majid et al, Clinical Nutrition, 2014; 33: 966-972

Add-FOS: additional prebiotics actually lowered *F. prausnitzii* in patients on ICU

		Post-intervention Adjusted mean[a] (SD)	*P* value ANCOVA
Total cells	Placebo	10.4 (0.4)	0.47
	Oligofructose/inulin	10.2 (0.4)	
Bacteroides-Prevotella	Placebo	9.9 (0.9)	0.05
	Oligofructose/inulin	9.1 (1.0)	
C. coccoides-E. rectale	Placebo	8.6 (0.9)	0.85
	Oligofructose/inulin	8.6 (1.0)	
F. prausnitzii	Placebo	8.4 (1.3)	0.01
	Oligofructose/inulin	7.0 (1.0)	
Bifidobacteria	Placebo	7.8 (1.3)	0.15
	Oligofructose/inulin	6.9 (1.4)	
Lactobacillus-enterococci	Placebo	7.4 (1.3)	0.51
	Oligofructose/inulin	7.0 (1.4)	

Majid et al, Clinical Nutrition, 2014; 33: 966-972

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Probiotics

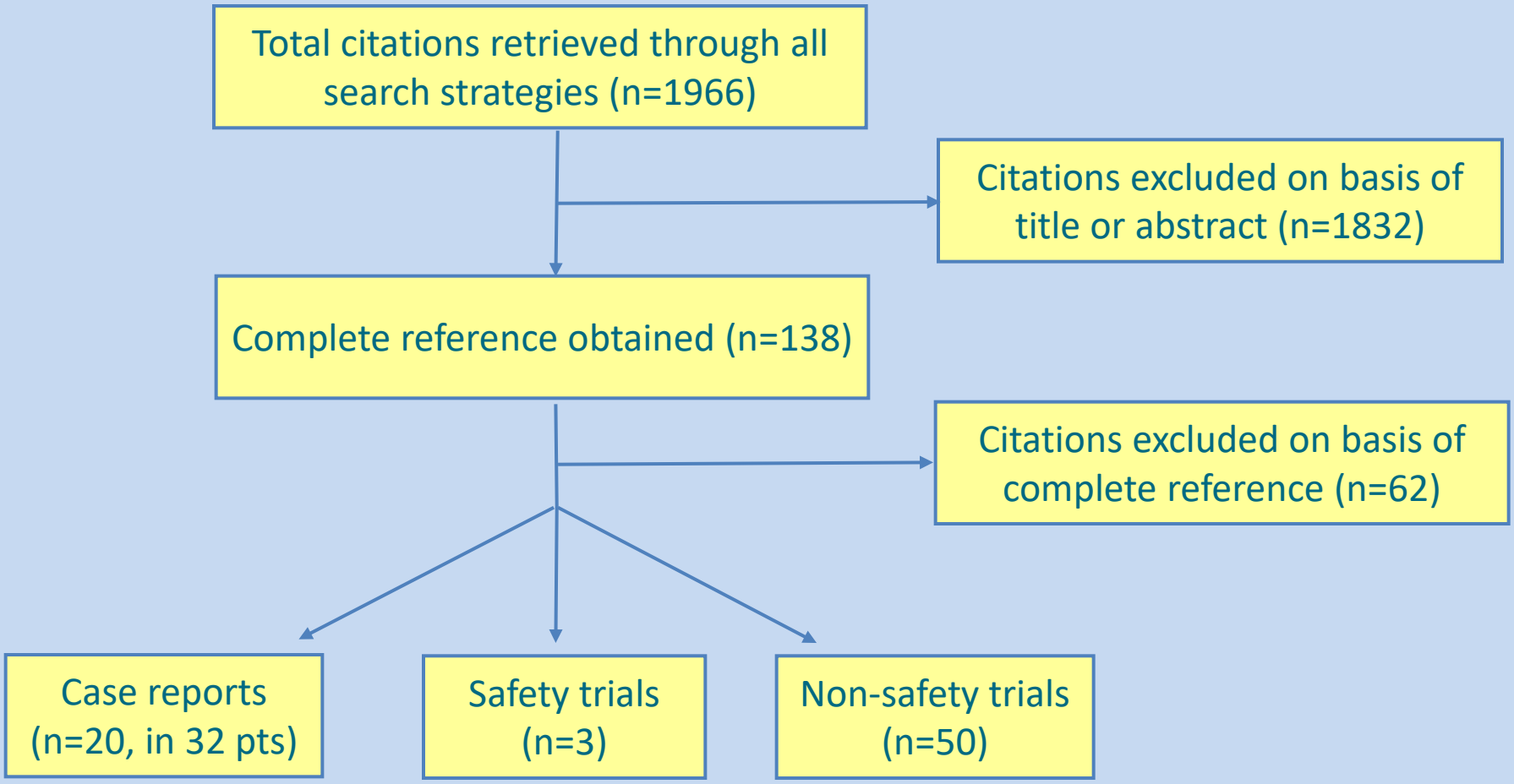
Live microorganisms that when administered in adequate amounts confer a health benefit on the host

(FAO/WHO, 2002)

(Some) probiotics may be beneficial

Meta-analyses				
Necrotizing enterocolitis	24 RCTs	RR 0.43 (0.33-0.56)		Cochrane Database 2014, CD005496
Antibiotic-associated diarrhoea	63 RCTs	RR 0.58 (0.50-0.68)		J Am Med Assoc 2012; 307:1959-69
Clostridium diffficile-associated diarrhoea	20 RCTs	RR 0.34 (0.24–0.49)		Ann Intern Med 2012; 157: 878-888
Post-operative infections	7 RCTs	OR 0.26 (0.12-0.55)		Eur J Clin Pharmacol 2009; 65: 561-70
RCTs				
Ventilator-associated pneumonia	n 146	Lacto GG Placebo	19.1% 40.0%	Am J Resp Crit Care 2010; 182: 1058-64
Enteral diarrhoea	n 128	S. boulardii Placebo	14.2% 18.9%	Intensive Care Med 1997; 23: 517-23

Probiotics in enteral nutrition: safety



Whelan & Myers, Am J Clin Nutr 2010; 91: 687-703

Probiotics in enteral nutrition: safety

52 papers reporting 53 trials

Probiotics (4131 pts) *vs* placebo (3643)

ICU, premature, surgical, transplant etc

Probiotics: Lactobacilli, Bifidobacteria, *S. boulardii,*

Mixtures (e.g. VSL#3)

Safety trials (n 3)

L. plantarum, B. breve, L. casei Shirota

No adverse events

No bacterial colonisation

Non-safety trials (n 50)

No increase in any negative outcomes (47)

Significant increase in negative outcome (3)

Generally "non-infectious"

- Liver transplant (stenosis)
- Neonatal ICU
- Pancreatitis (ischaemia, mortality)

Whelan & Myers, Am J Clin Nutr 2010; 91: 687-703

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PRObiotics in PAncreatitis TRIAl (PROPATRIA)

Probiotic prophylaxis in predicted severe acute pancreatitis: a randomised, double-blind, placebo-controlled trial

Marc G H Besselink, Hjalmar C van Santvoort, Erik Buskens, Marja A Boermeester, Harry van Goor, Harro M Timmerman, Vincent B Nieuwenhuijs, Thomas L Bollen, Bert van Ramshorst, Ben J M Witteman, Camiel Rosman, Rutger J Ploeg, Menno A Brink, Alexander F M Schaapherder, Cornelis H C Dejong, Peter J Wahab, Cees J H M van Laarhoven, Erwin van der Harst, Casper H J van Eijck, Miguel A Cuesta, Louis M A Akkermans, Hein G Gooszen, for the Dutch Acute Pancreatitis Study Group

Summary

Background Infectious complications and associated mortality are a major concern in acute pancreatitis. Enteral administration of probiotics could prevent infectious complications, but convincing evidence is scarce. Our aim was to assess the effects of probiotic prophylaxis in patients with predicted severe acute pancreatitis.

Methods In this multicentre randomised, double-blind, placebo-controlled trial, 298 patients with predicted severe acute pancreatitis (Acute Physiology and Chronic Health Evaluation [APACHE II] score ≥8, Imrie score ≥3, or C-reactive protein >150 mg/L) were randomly assigned within 72 h of onset of symptoms to receive a multispecies probiotic preparation (n=153) or placebo (n=145), administered enterally twice daily for 28 days. The primary endpoint was the composite of infectious complications—ie, infected pancreatic necrosis, bacteraemia, pneumonia, urosepsis, or infected ascites—during admission and 90-day follow-up. Analyses were by intention to treat. This study is registered, number ISRCTN38327949.

Findings One person in each group was excluded from analyses because of incorrect diagnoses of pancreatitis; thus, 152 individuals in the probiotics group and 144 in the placebo group were analysed. Groups were much the same at baseline in terms of patients' characteristics and disease severity. Infectious complications occurred in 46 (30%) patients in the probiotics group and 41 (28%) of those in the placebo group (relative risk 1·06, 95% CI 0·75–1·51). 24 (16%) patients in the probiotics group died, compared with nine (6%) in the placebo group (relative risk 2·53, 95% CI 1·22–5·25). Nine patients in the probiotics group developed bowel ischaemia (eight with fatal outcome), compared with none in the placebo group (p=0·004).

Interpretation In patients with predicted severe acute pancreatitis, probiotic prophylaxis with this combination of probiotic strains did not reduce the risk of infectious complications and was associated with an increased risk of mortality. Probiotic prophylaxis should therefore not be administered in this category of patients.

Introduction

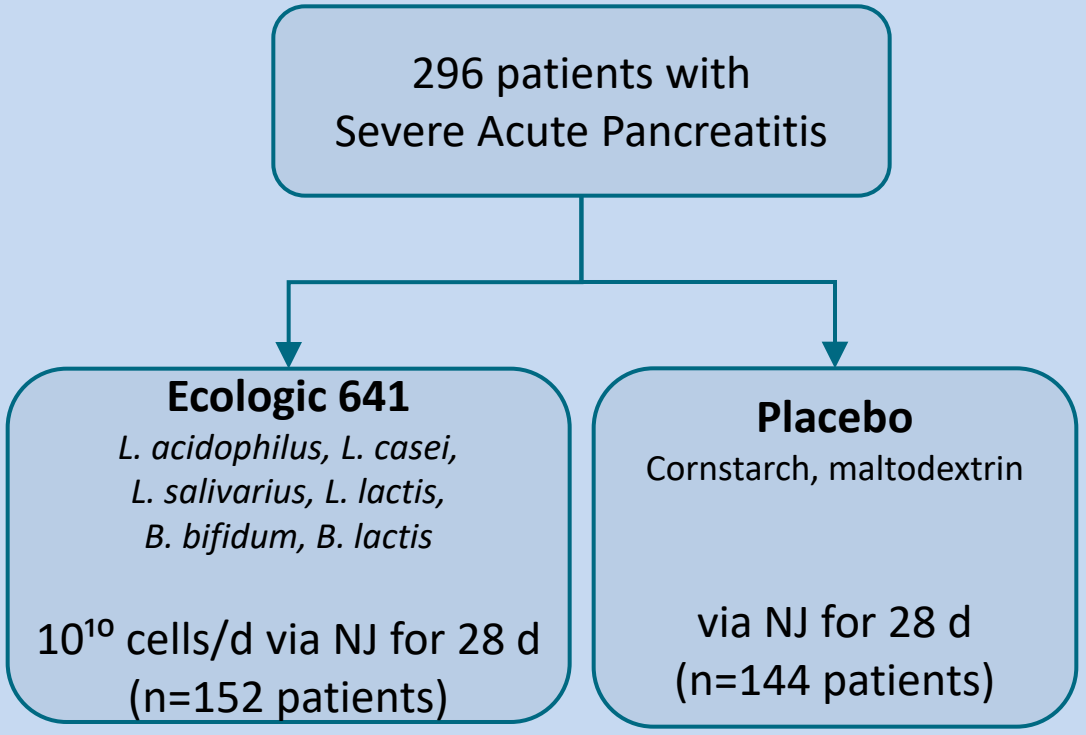
The incidence of acute pancreatitis in Europe and the USA is increasing by about 5% per year, mainly owing to an increase in biliary pancreatitis.[1-3] About a fifth of patients will develop necrotising pancreatitis, which is associated with a 10–30% mortality rate, mostly attributed to infectious complications and infection of (peri)pancreatic necrotic tissue in particular.[4] These infections are thought to be the sequelae of a cascade of events starting with small-bowel bacterial overgrowth, mucosal barrier failure, and a proinflammatory response leading to bacterial translocation of intestinal bacteria.[4-6] Systemic antibiotic prophylaxis has long been studied as a measure to prevent secondary infection in acute pancreatitis.[3] However, two double-blind, placebo-controlled trials[7,8] and two meta-analyses[9,10] have failed to show a beneficial effect, and many clinicians have abandoned this strategy. In the two antibiotic trials, the incidence of extrapancreatic infections (eg, bacteraemia, pneumonia) and pancreatic infection remained high.[7,8] Consequently, there is a clear need for other strategies to prevent infectious complications in patients with acute pancreatitis.

Probiotics, as an adjunct to enteral nutrition, have raised high expectations and are currently gaining worldwide popularity for their presumed health-promoting effects.[11,12] Certain strains of probiotic bacteria might prevent infectious complications by reducing small-bowel bacterial overgrowth, restoring gastrointestinal barrier function, and modulating the immune system.[11,12] A reduction of infectious complications has been reported in several clinical studies with probiotics in patients undergoing elective abdominal operations[13,14] and in patients with acute pancreatitis.[15] However, because of their small size and methodological quality, these studies do not justify global implementation of probiotics as a preventive measure in acute pancreatitis. Accordingly, we embarked on a nation-wide multicentre randomised, double-blind, placebo-controlled trial—the PRObiotics in PAncreatitis TRIAl (PROPATRIA)—to assess the effects of probiotic prophylaxis in patients with predicted severe acute pancreatitis.

Methods

Patients

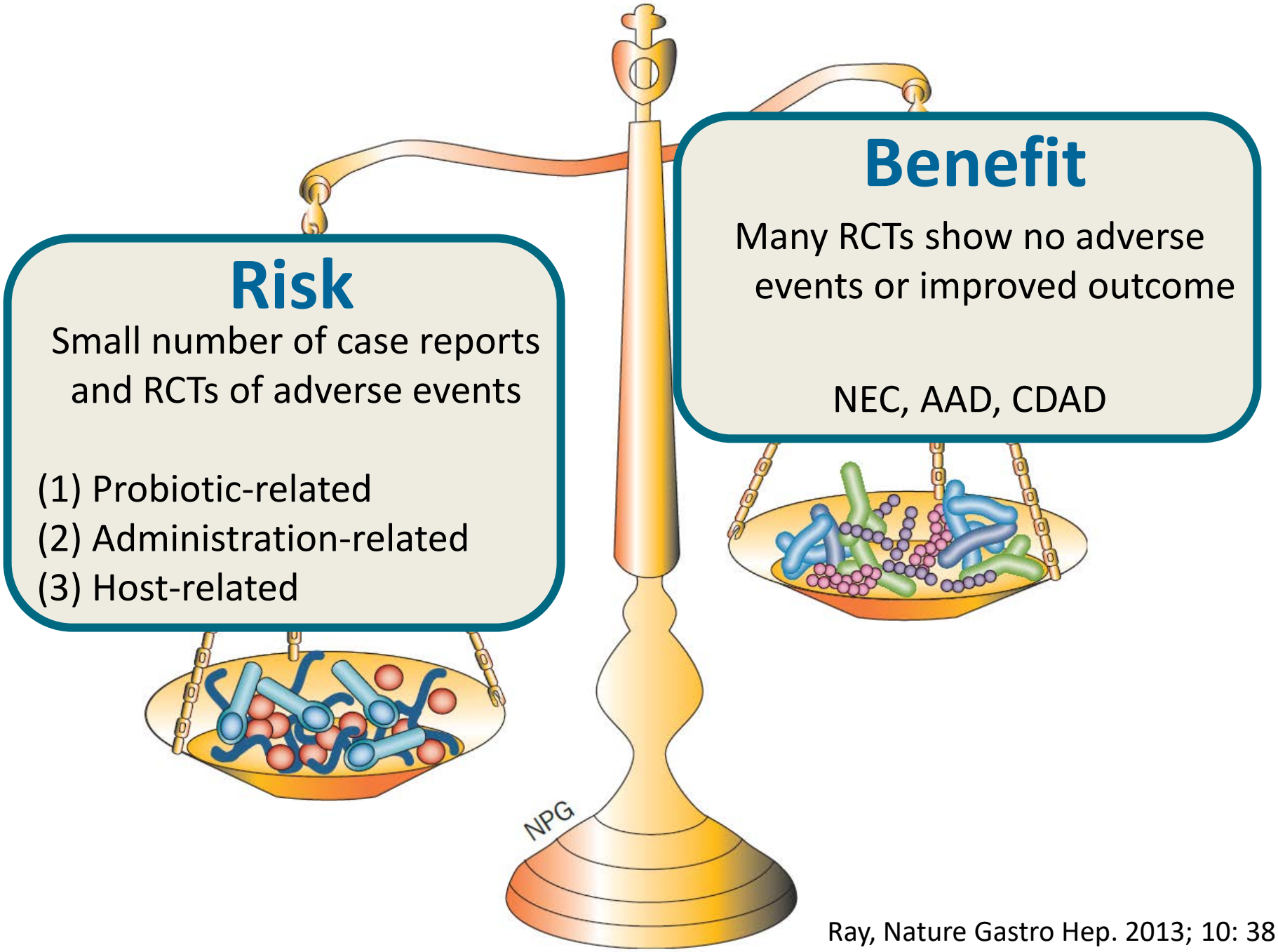
The design and rationale of the study have been described in detail elsewhere.[16] Adult patients admitted with a first



Besselink *et al Lancet*, 2008; 651-659

	Probiotics (N=152)	Placebo (N=144)	p value
Primary endpoint			
Any infectious complication*	46 (30%)	41 (28%)	0·80
Infected necrosis	21 (14%)	14 (10%)	0·29
Bacteraemia	33 (22%)	22 (15%)	0·18
Pneumonia	24 (16%)	16 (11%)	0·31
Urosepsis	1 (0·7%)	2 (1%)	0·61
Infected ascites	4 (3%)	0 (0%)	0·12
Secondary endpoint			
Use of antibiotics, any indication	75 (49%)	76 (53%)	0·56
Percutaneous drainage	14 (9%)	8 (6%)	0·23
Surgical intervention, any indication	28 (18%)	14 (10%)	0·05
Necrosectomy	24 (16%)	14 (10%)	0·16
Intensive care admission	47 (31%)	34 (24%)	0·19
Intensive care stay (days)	6·6 (17·1)	3·0 (9·3)	0·08
Hospital stay (days)	28·9 (41·5)	23·5 (25·9)	0·98
Nausea	20 (13%)	23 (16%)	0·51
Abdominal fullness	36 (24%)	43 (30%)	0·24
Diarrhoea	25 (16%)	28 (19%)	0·55
Bowel ischaemia	9 (6%)	0 (0%)	0·004
Mortality	24 (16%)	9 (6%)	0·01

Besselink *et al Lancet*, 2008; 651-659



Ray, Nature Gastro Hep. 2013; 10: 381

Fermentable

Oligosaccharides (inulin-type fructans)

(α-galacto-oligosaccharides)

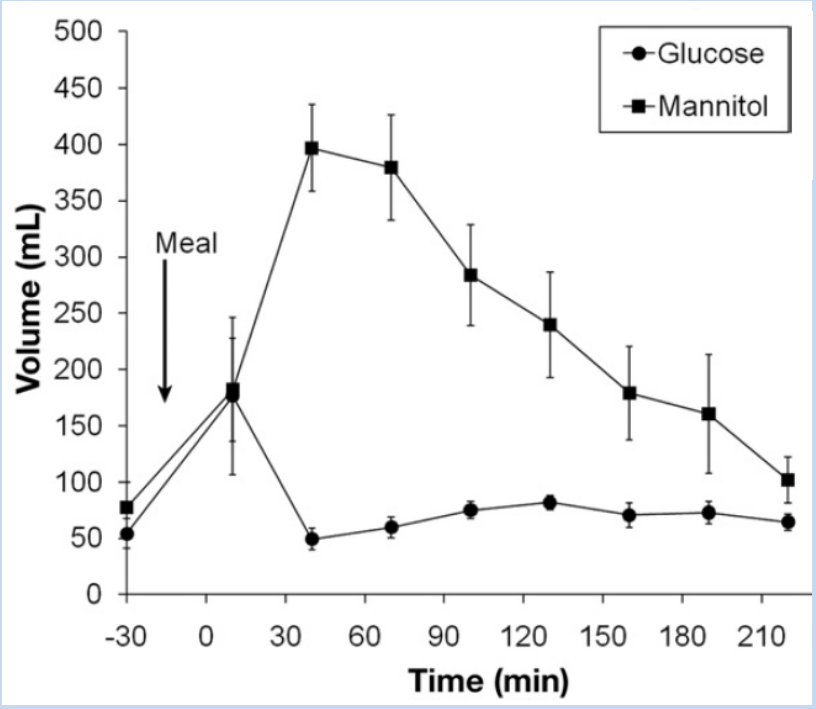
Disaccharides (lactose)

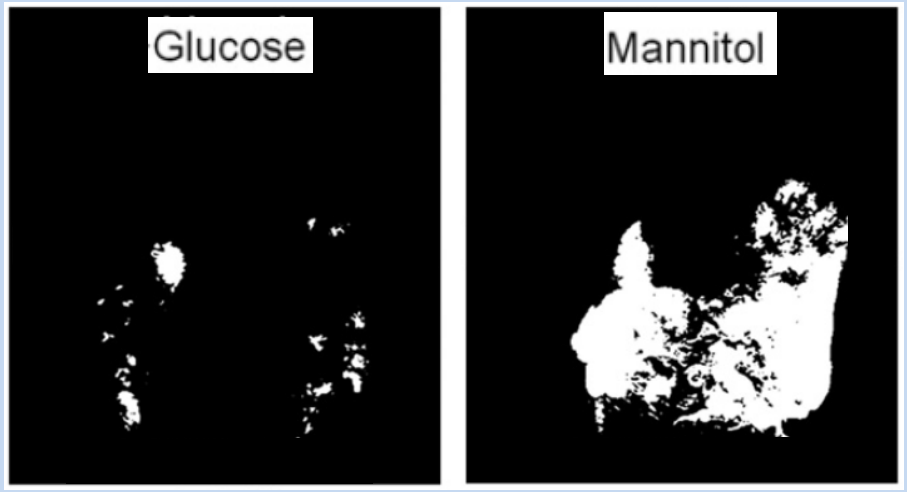
Monosaccharides (fructose)

And

Polyol**S** (sorbitol, mannitol)

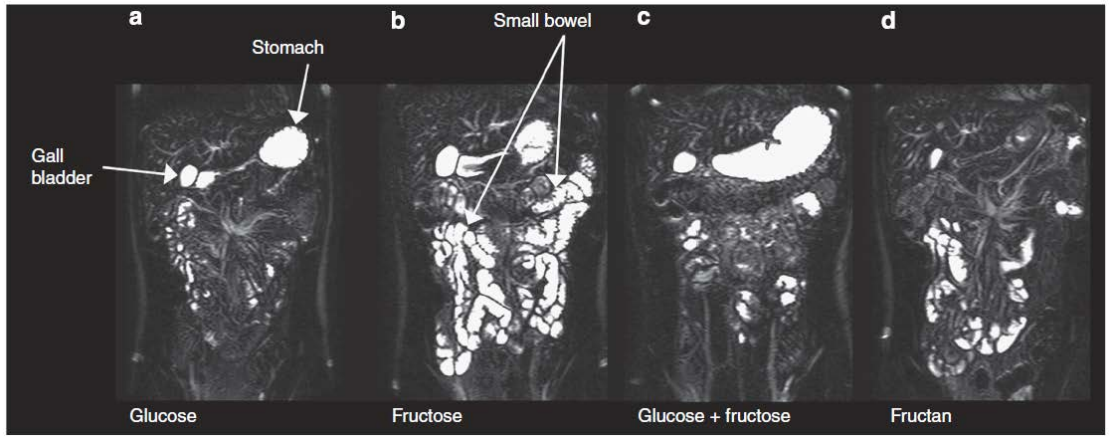
Mannitol increases small intestinal water





Marciani *et al*, Gastro 2010; 138: 469-477

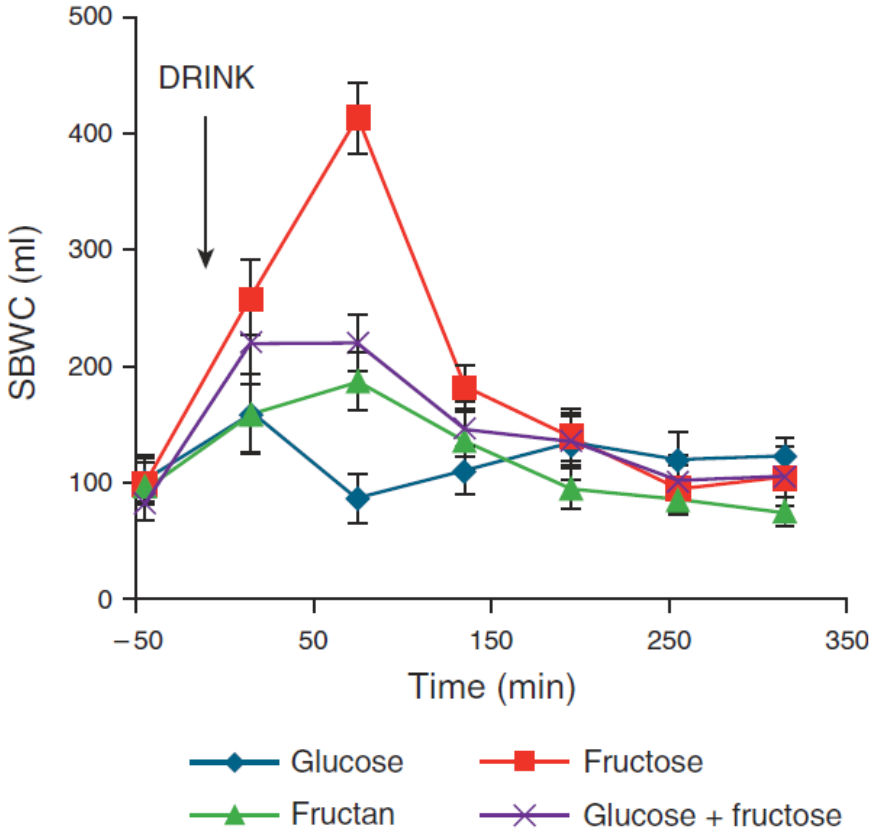
Fructose also increases small intestinal water



Differential Effects of FODMAPs (Fermentable Oligo-, Di-, Mono-Saccharides and Polyols) on Small and Large Intestinal Contents in Healthy Subjects Shown by MRI

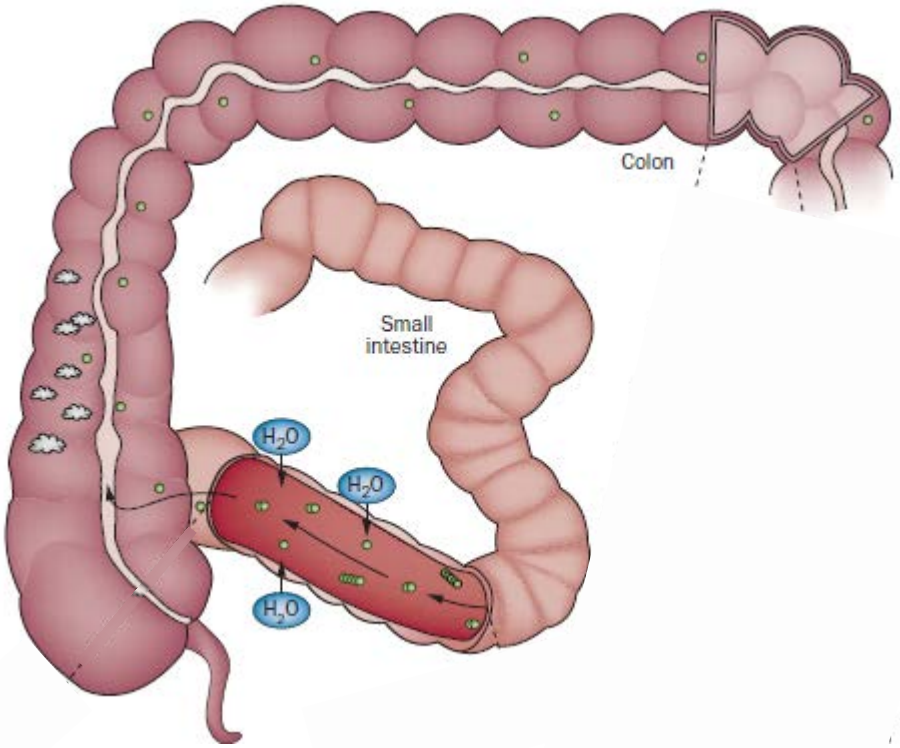
Kathryn Murray, PhD[1], Victoria Wilkinson-Smith, BMedSci[2], Caroline Hoad, PhD[1], Carolyn Costigan, MSc[1], Eleanor Cox, PhD[1], Ching Lam, MB BCh[2], Luca Marciani, PhD[2], Penny Gowland, PhD[1] and Robin C. Spiller, MD, FRCP[2]

16 healthy people
Normal diet
Challenges (40 g of each)



Murray et al, Am J Gastro 2014; 109: 110-9

Staudacher et al
Nature Reviews Gastro Hep
2014; 11: 256–266



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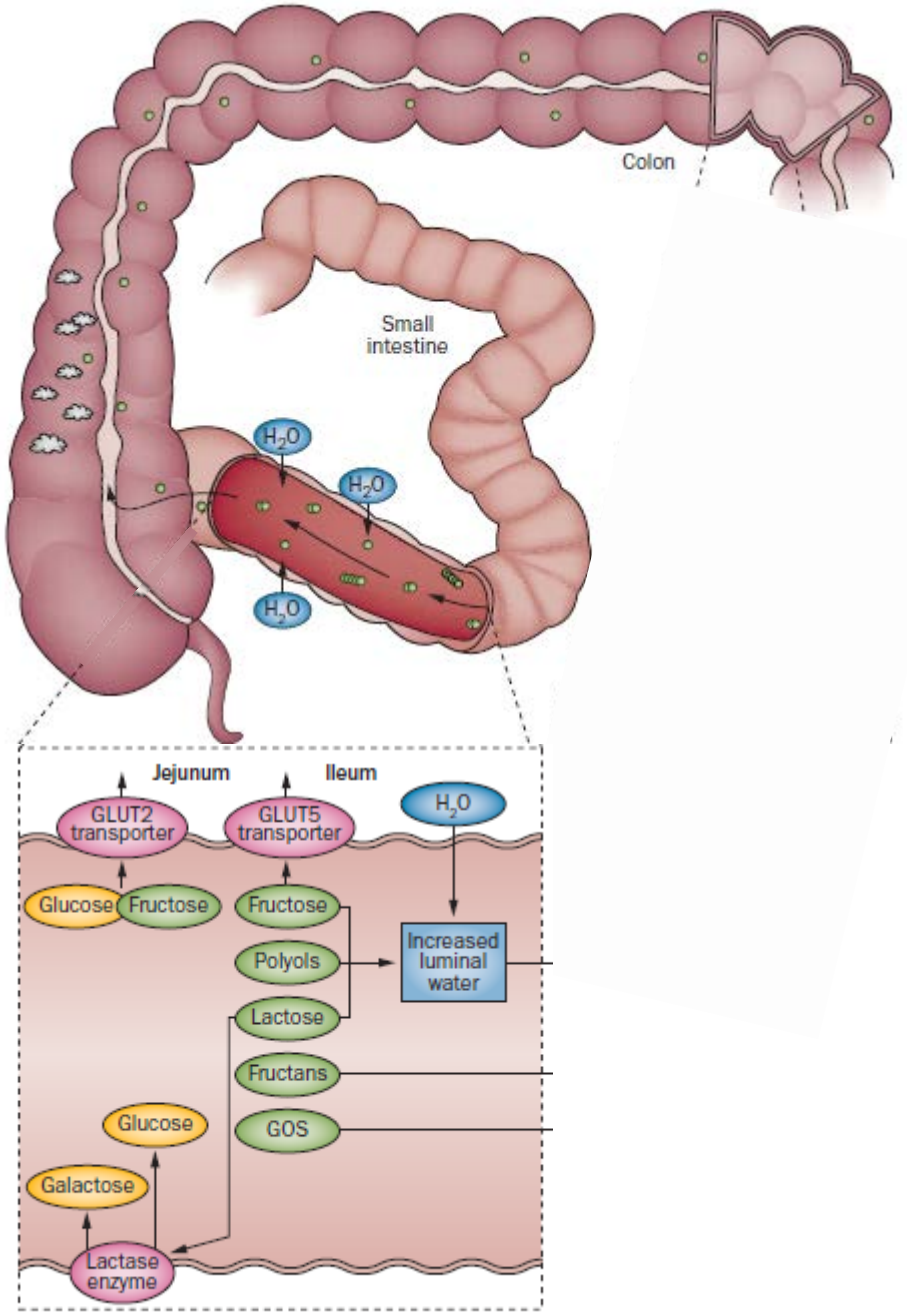

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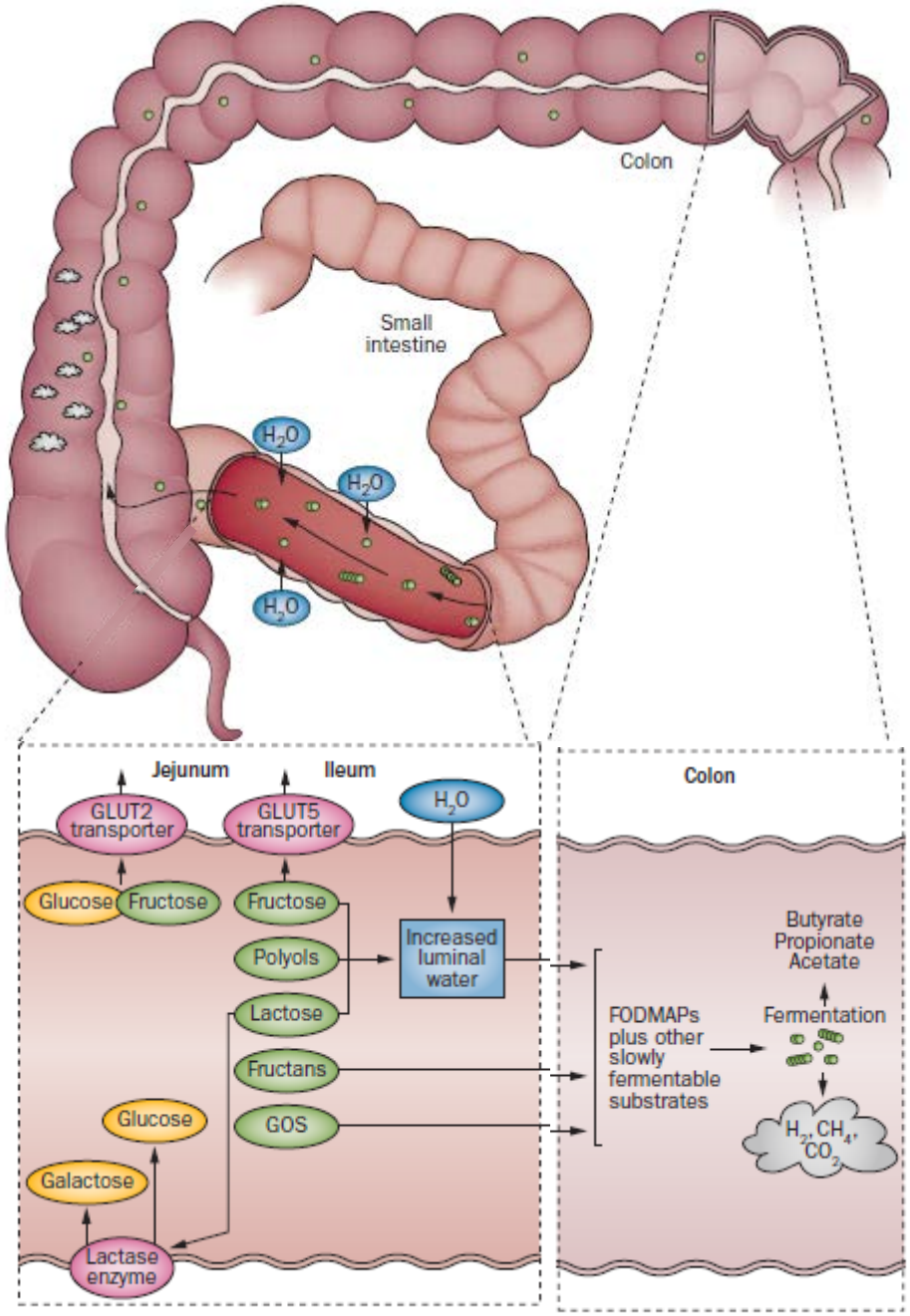
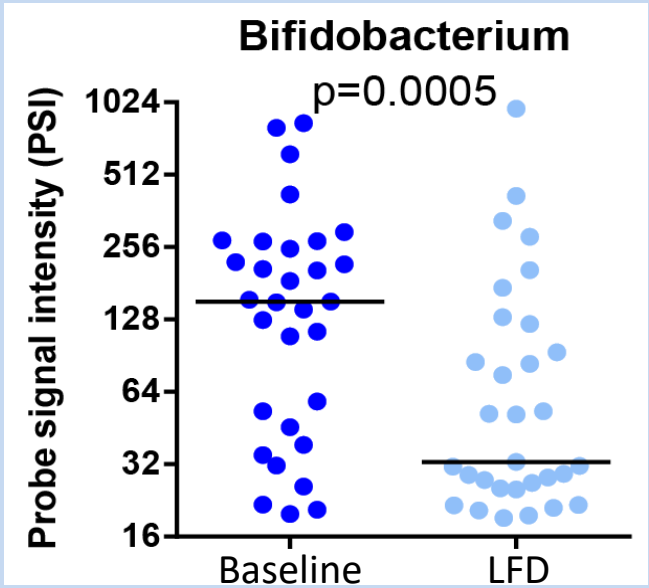


Low FODMAP diet impacts microbiota (in IBS!)

	Control	Intervention	*P*	Control	Intervention	*P*
	Concentration, *log_{10} cells/g feces*			Proportion of total bacteria, *%*		
Total bacteria	9.7 (9.5–9.8)	9.7 (9.6–9.9)	0.52	—	—	—
Bacteroides-Prevotella	8.7 (8.6–8.9)	8.8 (8.6–8.9)	0.52	17.4 (9.2–25.7)	15.2 (6.2–24.3)	0.72
E. rectale-C. coccoides	8.8 (8.6–8.9)	8.7 (8.6–8.9)	0.89	15.7 (10.9–20.5)	11.8 (6.6–17.0)	0.27
F. prausnitzii	8.8 (8.6–9.0)	8.8 (8.5–9.0)	0.58	17.9 (13.3–22.6)	13.1 (8.0–18.2)	0.16
Bifidobacteria	8.2 (7.9–8.5)	7.4 (7.1–7.7)	<0.001	3.2[4] (1.8–5.8)	0.5[4] (0.2–0.9)	<0.001
Lactobacillus, enterococcus	7.4 (7.1–7.7)	7.4 (7.1–7.7)	0.98	1.0 (0.7–1.4)	0.6 (0.2–1.1)	0.17

Bacteria	Australian diet	Low FODMAP diet	p Value
Total bacteria	9.83 (9.72–9.93)	9.63* (9.53–9.73)	<0.001
Clostridium cluster IV	8.33 (8.15–8.52)	8.05* (7.88–8.23)	<0.001
Faecalibacterium prausnitzii	7.72 (7.49–7.95)	7.45* (7.25–7.65)	<0.001
Clostridium cluster XIVa	9.05* (8.93–9.16)	8.03 (7.91–8.15)	<0.001
Roseburia	7.72 (7.59–7.85)	7.49 (7.34–7.63)	<0.001
Lactobacilli	6.35 (6.20–6.50)	6.08 (5.91–6.24)	0.003
Bifidobacteria	7.71 (7.53–7.88)	7.30* (7.11–7.50)	<0.001
Akkermansia muciniphila†	5.46* (4.88–6.04)	4.29 (3.58–4.99)	<0.001
Ruminococcus gnavus	7.26 (7.14–7.37)	7.10 (6.96–7.25)	0.002
Ruminococcus torques	6.08 (5.85–6.31)	6.23 (6.07–6.39)	0.140



Staudacher, J Nutrition 2012; 142: 1510-8
Halmos, Gut, 2015, 64: 93-100

Bennet
UEGW, 2016

UNIVERSITY OF GOTHENBURG

Low FODMAP formulas and diarrhoea: Retrospective case note review

AP&T Alimentary Pharmacology and Therapeutics

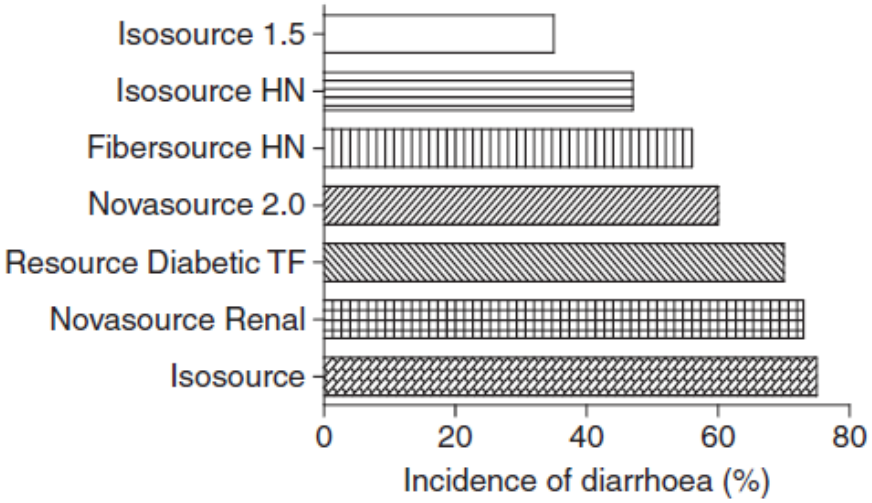
Diarrhoea during enteral nutrition is predicted by the poorly absorbed short-chain carbohydrate (FODMAP) content of the formula

Variable	All (*n* = 160)
Male	77 (48%)
Age (years)	76 (66–92)*
Length of stay (days)	22 (15–35)*
Duration of EN (days)	11 (6–20)*
Texture modified diet	52 (33%)
Antibiotics	97 (61%)
Proton pump inhibitors	44 (28%)
Laxatives	83 (52%)

RETROSPECTIVE CASE NOTE REVIEW

Halmos *et al*, Alim Pharm Ther 2010; 32: 925–933

Low FODMAP formulas and diarrhoea: Retrospective case note review



FODMAP content (g)	Fibre content (g)	Osmolality (mOsm/L)
10.6	7.4	650
31.0	0	490
33.0	12	490
36.5	0	790
20.1	17.8	400
23.0	0	700
31.0	0	490

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Low FODMAP formulas and diarrhoea: Retrospective case note review

Variable	*n*	Diarrhoea present (%)	*P* value	Estimated OR
Age >65 years	123	77 (63)	0.840	1.10
Stroke unit	65	36 (55)	0.637	0.785
Intensive care unit	42	32 (76)	0.505	1.46
Length of stay >21 days	**80**	**62 (78)**	**0.026**	**2.70**
EN duration >11 days	**79**	**61 (77)**	**0.021**	**2.91**
Antibiotics	107	72 (67)	0.443	1.39
Proton pump inhibitors	45	33 (73)	0.642	1.25
Laxatives	83	49 (59)	0.784	0.90
Texture modified diet	52	35 (67)	0.515	1.36
Initiated bolus delivery	32	16 (50)	0.982	1.00
Initiated Isosource 1.5*	**20**	**7 (35)**	**0.029**	**0.18**
Initiated Fibersource HN/Resource Diabetic TF†	71	41 (58)	0.273	0.49
Initiated Isosource HN/Isosource‡	50	25 (50)	0.213	0.44
Initiated Novasource Renal/Novasource 2.0§	16	11 (69)	0.938	1.07

Halmos *et al*, Alim Pharm Ther 2010; 32: 925–933

KING'S College LONDON

Low FODMAP formulas and diarrhoea: RCT

Low-FODMAP formula improves diarrhea and nutritional status in hospitalized patients receiving enteral nutrition: a randomized, multicenter, double-blind clinical trial

So Ra Yoon[1], Jong Hwa Lee[2], Jae Hyang Lee[1], Ga Yoon Na[2], Kyun-Hee Lee[3], Yoon-Bok Lee[3], Gu-Hun Jung[3] and Oh Yoen Kim[1*]

Per can (200 mL)	Low-FODMAP	Moderate-FODMAP	High-FODMAP
Calorie (kcal)	200	200	200
Total FODMAPs (g)	0.320	0.753	1.222
Fructose (g)	- (N.D.)	-	-
Lactose (g)	-	-	-
Raffinose (g)	0.079	0.229	0.285
Stachyose (g)	-	-	0.239
1-Kestose (g)	-	-	0.511
Nystose (g)	-	-	-
1-Fructofuranosylnystose (g)	0.233	0.509	0.411

Yoon et al, Nutrition J. 2015; 14: 116

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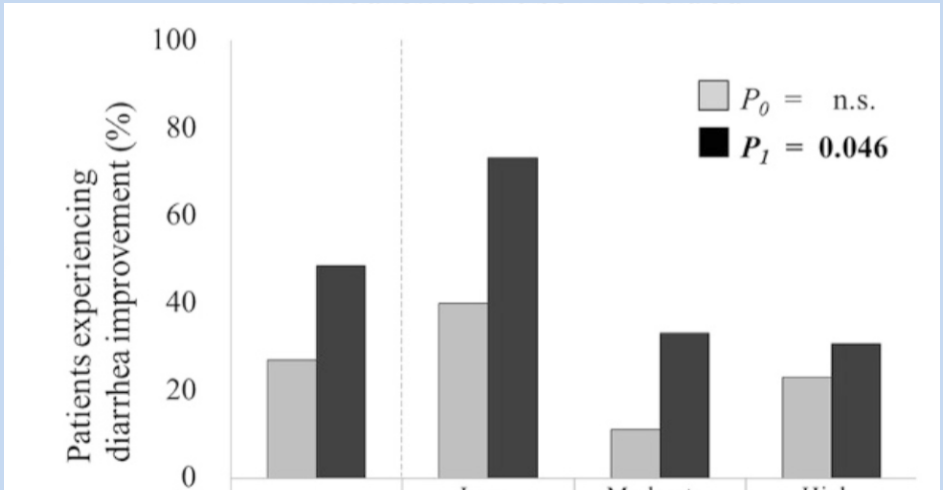
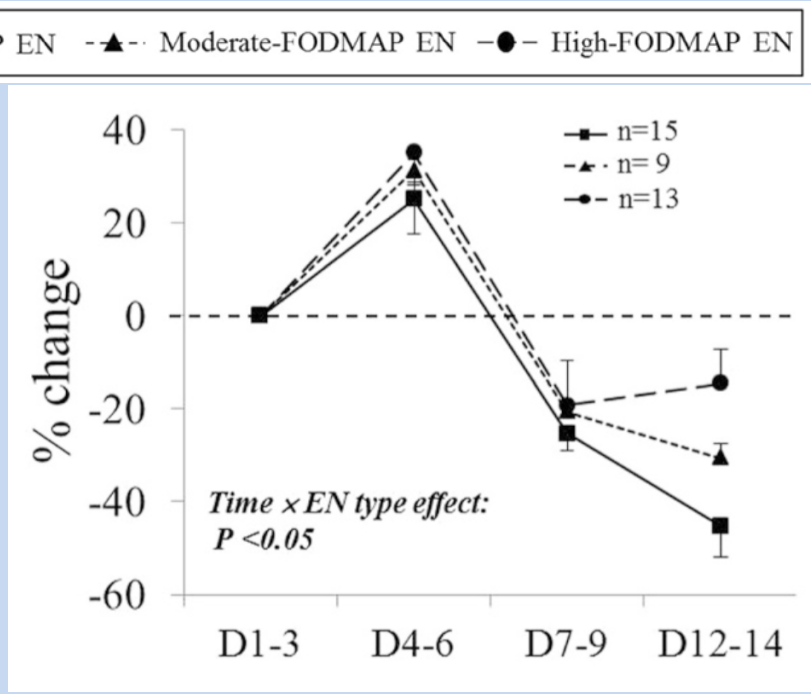
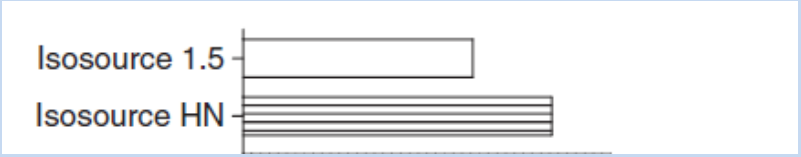


	Total (n=37)	Low-FODMAP (n=15)	Moderate-FODMAP (n=9)	High-FODMAP (n=13)
Early improvement	27.0	40.0	11.1	23.1
Final improvement	48.6	73.3	33.3	30.8



Yoon et al, Nutrition J. 2015; 14: 116

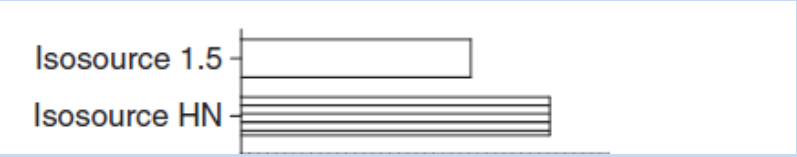
But… problems in measuring FODMAPs in enteral formulas



Enteral Formula and Recommended Daily Volume[b]	FODMAP Content, g/Daily Volume								Fiber Content, g/ Daily Volume
	Total FODMAP	Total Fructan		GOS		Free Fructose[c]	Lactose	Polyols	
		Method	Content	Method	Content				
Isosource 1.5, 930 mL/d	10.6	Fructan	7.9	HPLC	2.7	ND	ND	ND	7.4
Isosource HN, 1200 mL/d	31.0	Fructan	13.7	HPLC	17.3	ND	ND	ND	0

Halmos et al, J Parent Ent Nutr. 2016 (in press)

But… problems in measuring FODMAPs in enteral formulas



Enteral Formula and Recommended Daily Volume[b]	FODMAP Content, g/Daily Volume								Fiber Content, g/ Daily Volume
	Total FODMAP	Total Fructan		GOS		Free Fructose[c]	Lactose	Polyols	
		Method	Content	Method	Content				
Isosource 1.5, 930 mL/d	10.6	Fructan assay A[d]	7.9	HPLC	2.7	ND	ND	ND	7.4
	1.22	Fructan assay B[e]	0.84	Enzymatic[f]	0.38[g]				
Isosource HN, 1200 mL/d	31.0	Fructan assay A[c]	13.7	HPLC	17.3	ND	ND	ND	0
	4.04	Fructan assay B[e]	1.68	Enzymatic[f]	2.36[g]				

Halmos et al, J Parent Ent Nutr. 2016 (in press)

Summary

The microbiome is impacted by disease, drugs and diet

Enteral formulas without fibre impact the gut microbiome, which is partially prevented by addition of fibre and prebiotics, although this is not necessarily the case in patients with disease and on drugs

Probiotics also modify the microbiota in EN and may have beneficial effects

Low FODMAP formulas were shown to prevent diarrhoea, but previous studies in this area must be re-analysed due to problems of analysing FODMAPs in enteral formulas

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