looby/Bigstockphoto.com

# Probiotics, prebiotics

## Manipulating bacteria in the gut for health

Bob Rastall

**Key words**
digestion
bacteria
ecosystem
probiotics
prebiotics

*The human gut plays host to an enormous number of microorganisms, mainly bacteria. What role do they play, and can we change our diet to encourage beneficial organisms?*

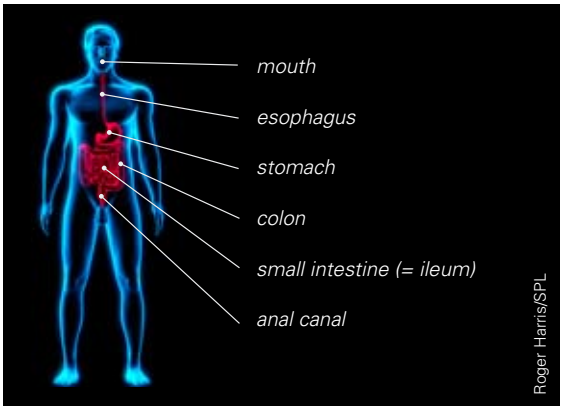


***Figure 1*** *The human gut*

## Bacteria in the gut

Let's take a journey down the gut (Figure 1), looking at the **microorganisms** present. The numbers in the stomach are very low, at around $10^3$ per millilitre due to the gastric acid. The small intestine contains around $10^4$ – $10^8$ per ml. The colon, however, has a huge microbial population – around $10^{12}$ per ml. Indeed, if you were to count up all of the living cells in an average adult, 95% of them would be colonic bacteria! There are at least 500 different species present in the colon and they produce very many different biochemicals. It is not surprising then that the colon is increasingly being recognised as a major metabolic organ that can have a significant impact on human health.

## Bacteria, good and bad

The bacteria in the colon form a complex, but self-regulating, ecosystem. They use food residues that have escaped digestion in the small intestine for energy and nutrition and produce a range of metabolic end products. We do not understand all of the activities of the bacteria in the colon, but we can broadly divide them into two categories (see Figure 2).

Some organisms are harmful: they produce a range of toxins and cancer-promoting chemicals.

Others are more benign and produce chemicals which act as fuel for the cells lining the gut and also antimicrobial compounds that can inhibit pathogens.

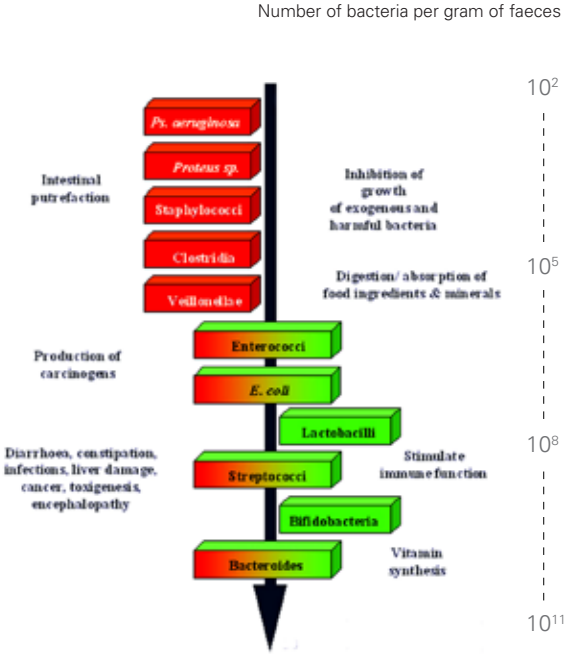


***Figure 2*** *The balance of harmful and beneficial bacteria in the human gut.*

## Acquiring bacteria

At birth we acquire our gut flora from either our mother's birth canal or from the environment, depending on delivery method. The population develops as we get older and by adulthood is stable. These organisms form a complex, balanced 'ecosystem' and it is likely that we each have our own characteristic set of bacteria. The balance of the ecosystem does, however, respond to diet and we can manipulate the colonic ecosystem by means of food ingredients.

## Dietary manipulation – probiotics, prebiotics and synbiotics

As we learn more about the bacteria in the colon and what these organisms are doing, the idea of deliberately changing the type and numbers present to improve health is supported. There are two ways that this can be attempted, the use of probiotics or prebiotics. **Probiotics** are live bacterial ingredients or supplements designed to multiply in the colon and have an impact on health.

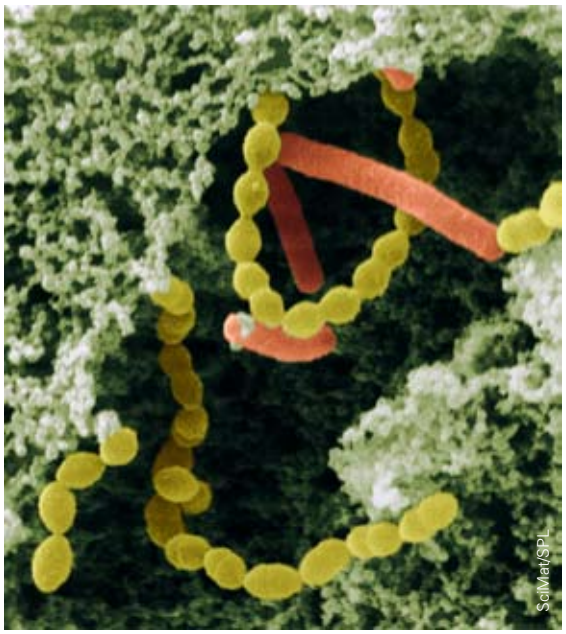


***Figure 3*** *A colour-enhanced electron micrograph of probiotic bacteria in yoghurt: Streptococcus thermophilus (yellow beads) and Lactobacillus bulgaricus (red rods).*

There is a long history of use of probiotics; indeed the concept was first outlined by Elie Metchnikoff over 100 years ago. Metchnikoff noticed that Bulgarians tended to live long and healthy lives and he put this down to their drinking milk fermented with bacteria. These bacteria produced lactic acid and were what we now call *Lactobacillus*, used in making yoghurt (Figure 3), cheese and other fermented foods.

There are nowadays a wide range of probiotic products in the supermarket. These are mainly dairy products such as yoghurts and the increasingly familiar 'small shot' bottles of fermented milk products. There are also a range of healthcare supplements available in pharmacies and health shops. These products mostly contain live cultures of bacteria such as species of *Lactobacillus* and *Bifidobacterium* and many of these commercial probiotics have been selected to survive the industrial chilling process, the acid in the stomach and the journey through the intestinal tract. Most of the probiotic products on the market claim to boost immunity and 'wellbeing'. These claims are rather vague as, at the present time, it is not permitted to make a specific health claim for any kind of food. This is likely to change to some degree in the future and probiotics are being very actively researched for a variety of health benefits.

### Box 1 An artificial gut

Researchers at Reading University have built a model human gut. This contains real bacteria and is used to test the effects of prebiotics.


*A researcher samples fluid from the artificial gut. The fluid will be tested to discover the chemical products of bacteria in the gut.*


*A technician counts colonies of bacteria grown in the model gut.*

## A new approach

At Reading University, we are working on the 'prebiotic approach' (see Box 1). A **prebiotic** is a carbohydrate that is not digestible by humans. Instead, it passes through to the colon where it is fermented by desirable bacteria. The target bacterial groups are the same genera that have been developed into probiotics, namely Lactobacilli and Bifidobacteria. Prebiotics have many advantages; principally the fact that they are not alive means that they can be processed into a much wider range of foods than can the fragile probiotics. The disadvantage is that the bacteria already present in the colon may not necessarily have the health benefits of the probiotics.

| Prebiotic | Source |
|---|---|
| Inulin | Chicory |
| Fructo-oligosaccharides (FOS) | Chicory; manufactured from sucrose |
| Galacto-oligosaccharides (GOS) | Manufactured from lactose |
| Lactulose | Manufactured from lactose |

***Table 1*** *Some prebiotic carbohydrates*

Several different carbohydrates have been found to possess prebiotic properties (Table 1). The main players at the moment are the fructose-based carbohydrates inulin and fructo-oligosaccharides (FOS). There are many scientific studies on these ingredients that have shown a positive effect and they are the most common type of prebiotic found in foods. Less common, but showing commercial growth and receiving a lot of interest from scientists, are the galacto-oligosaccharides (GOS). These are made from lactose, a by-product of cheese-making which many people find it hard to digest.

Prebiotics are being incorporated into all kinds of foods including bread, biscuits, breakfast cereals, yoghurts, milk drinks, infant formulae and sports supplements. GOS are mainly used in infant formulae or as consumer healthcare products.

Research at Reading and elsewhere is currently attempting to understand the basis of the prebiotic effect in the hope that we can one day design improved prebiotics with specific health benefits. We are also looking at other carbohydrates from plants and bacterial cultures that have beneficial properties in the gut and from these we hope to develop new ingredients.

A logical extension to the concept of prebiotics and probiotics is to combine the two. The result is a synbiotic and this is a very active area for research at the moment. The idea is that by combining a probiotic with a prebiotic that it can metabolise, we can improve the activity and persistence of the probiotic when it reaches the gut.

## Commercial developments

We are rapidly discovering more and more about the vast array of bacteria that live in our guts. As we learn more about their impact on health and disease (see Box 2), we will be able to identify specific changes we might be able to bring about in order to optimise human health. We are also developing the new food ingredients needed to bring about the changes and we will see much more commercial development in this area in the years to come.

***Bob Rastall*** *is Professor of Food Technology in the Department of Food Biosciences at the University of Reading.*

## Box 2 Gut bacteria and health

Probiotics and prebiotics are currently being studied to see if they contribute to certain diseases.

***Irritable bowel syndrome (IBS):*** This affects around 20% of individuals in Western Europe and the USA. It is often linked to stress and causes periods of constipation, diarrhoea or alternating periods of both. Although the exact causes are unclear, the yeast *Candida albicans* has been associated with the condition. Research is under way to find probiotics with good anti-*Candida* activity which might help to alleviate the symptoms.

***Ulcerative colitis (UC):*** This inflammatory disease affects predominantly young individuals on a Western diet. Again, the exact cause is unclear but there is strong evidence that there is a role for the gut bacteria – experimental animals without gut bacteria cannot develop the disease. Some lines of research have pointed to colonisation by sulfate-reducing bacteria. These bacteria adhere very strongly to the gut wall and reduce dietary sulphur compounds to $H_2S$ – a very potent toxin. Probiotics and prebiotics may prove useful in inhibiting sulphate reducers in the gut.

***Colon cancer:*** Colon cancer is the second most common form of cancer and certain gut bacteria can produce a range of carcinogens and tumour-promoting substances. Research in animals with probiotics has shown that they can reduce the concentration of such substances and that this provides protection against cancer. Recent trials have been carried out in humans with synbiotics with encouraging results. Levels of cancer-promoting substances were reduced and tumour development retarded.

***Antibiotic-associated diarrhoea (AAD):*** Administration of broad-spectrum antibiotics often causes a major imbalance in the gut bacterial ecosystem. This can mean that bacteria such as *Clostridium difficile* can multiply, although this is normally suppressed by the more desirable members of the gut flora. There is consequently much interest at the moment in probiotics that can inhibit this organism which may be of benefit in recovery from AAD.

***Autism:*** Although autistic spectrum disorders (ASD) are not actually caused by the bacteria in the gut, they may still play a role through the generation of toxins. Bacteria such as *Clostridium* species, common toxin producers, have been found to be elevated in children with ASD relative to other children. Probiotics have been isolated that have inhibitory effects against clostridia and they may prove useful in management of symptoms in children with ASD.

***Obesity:*** Recently there have been some very preliminary data published showing that the gut bacterial profiles of obese individuals may be different to those of non-obese people. So far the picture is very unclear and much more research is needed before the potential of probiotics or prebiotics in obesity management is clear.