

## MICROBIOME

## Fibre for the future

A chronic lack of dietary fibre has been found to reduce the diversity of bacteria in the guts of mice. This effect is not fully reversed when fibre is reintroduced, and increases in severity over multiple generations. [SEE LETTER P.212](#)

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People living in industrialized nations routinely consume much less than the recommended amount of 25–38 grams of dietary fibre per day. Physicians and nutritionists have been imploring us for decades to bolster our fibre intake to help stave off maladies ranging from heart disease to intestinal disorders. The mechanisms through which fibre consumption modulates health are manifold, including a role in maintaining our resident gut microorganisms. On page 212 of this issue, Sonnenburg *et al.*<sup>1</sup> reveal that a lack of dietary fibre leads to a substantial loss of diversity in this microbial community, and influences the ability of gut bacteria to be transferred from parents to their offspring. Furthermore, it seems that simply restoring fibre consumption is not enough to reverse this effect once it has been passed to subsequent generations.

The ‘fibre’ that we see quantified on food labels is a catch-all category encompassing dozens of different molecules, mostly complex carbohydrates (linear and branched chains of simple sugars such as glucose). But the human genome encodes only around a dozen digestive enzymes that target complex carbohydrates. Technically speaking, dietary fibre comprises

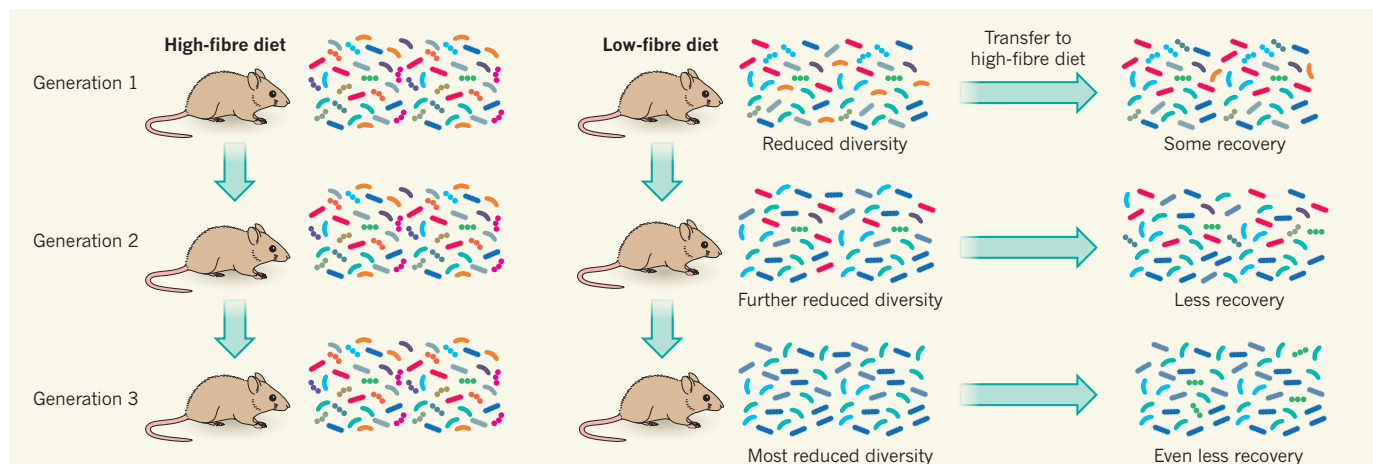
the polymeric molecules that cannot be broken down by these enzymes. However, these nutrients do not go to waste. Instead, the diverse microorganisms that have evolved to inhabit the human intestine — collectively called the gut microbiota — produce thousands of enzymes that specifically target dietary fibre<sup>2–4</sup>. Some individual bacteria produce more than 300 such enzymes<sup>5</sup>. These organisms ferment the released sugars into short-chain fatty acids, which are used as fuel for intestinal cells and which influence systemic physiology and the development of immune responses<sup>6</sup>.

The gut microbiota of each person typically contains hundreds of different bacterial species. We do not each harbour exactly the same community members; rather, the composition of our microbiota is drawn from a larger set of potential colonizers on the basis of parental and environmental exposure that begins at birth. Many microorganisms that live in the human gut exist only in this niche, and thus rely on successful transfer between generations to avoid extinction.

Sonnenburg *et al.* posed the question: what happens to the microbiota when dietary fibre is withheld for prolonged periods? The researchers colonized the intestines of germ-free mice (those that lack any resident microorganisms) with a human faecal sample, which contains a

representative complement of the gut microbiota members. They then fed the mice a diet rich in dietary fibre or one that contained only low fibre, in a form poorly accessible to the microbiota. After several weeks of fibre deprivation, the microbiota showed a reduction in the abundance of many bacterial groups that had been previously present (Fig. 1). These bacteria continued to thrive in the mice that were fed a high-fibre diet. When the fibre-starved mice were returned to a normal diet and allowed to recover for several weeks, many of these groups came back, but some failed to return to their previous levels, revealing that prolonged diet shifts can inflict changes that persist after dietary intervention.

The authors next investigated how fibre consumption affects the microbiota over multiple generations. They allowed the mice colonized with human bacteria, from both the high- and low-fibre cohorts, to breed within their cohorts, and for natural microbial colonization of the offspring to occur through maternal contact. Offspring born to parents fed the low-fibre diet had reduced microbiota diversity irrespective of whether they were weaned onto the same diet as their parents or onto a high-fibre diet. Strikingly, the reduction in gut bacterial diversity that was observed in the first generation was compounded over each



**Figure 1 | Loss of diversity.** Sonnenburg *et al.*<sup>1</sup> found that mice fed a low-fibre diet had a lower species diversity in their gut microbiota than mice fed a high-fibre diet. In first-generation mice, most (but not all) of this diversity was recoverable when mice on the low-fibre diet were switched to a high-fibre diet. However, the authors found that diversity loss was greater in each subsequent generation maintained on a low-fibre diet, and that the degree of recovery also decreased, implying extinction of some microbial species.

of four subsequent generations. Moreover, the inferred genomic content of the bacteria that remained after four generations suggested that the abundance of several fibre-degrading enzyme families had been reduced. But further work is required to find out whether a loss in fibre-degrading capacity occurred.

To assess whether dietary change might ameliorate these deficiencies, Sonnenburg *et al.* placed some of the mice from each generation of fibre-deprived mice on a high-fibre diet. The inability to recover lost diversity was a consistent characteristic at each generation (Fig. 1). However, transplanting the fibre-starved mice with a faecal sample from mice fed a high-fibre diet successfully restored most of the missing bacteria.

It is becoming increasingly apparent that the gut microbiota of people in cultures that eat less-processed and higher-fibre diets differ from those of people in industrialized countries, and often contain a higher diversity of microorganisms<sup>7–9</sup>. Humans have co-evolved with symbiotic bacteria, and these microbial partners shoulder most of the burden of digesting complex carbohydrates. It remains to be determined whether some of this functionality has already been lost in some people and, if so, to what extent. However, in the future, we may turn to probiotic formulations, possibly derived from humans or animals that have not yet restricted their gut microbiome through a low-fibre diet, to restore essential functions that have been lost.

Carbohydrates frequently get a bad rap in fad diets, largely owing to simple carbohydrates such as glucose and fructose that permeate Western diets and provide us with an excess of easy calories. However, their complex cousins that are naturally present in plants, whole grains and a variety of other sources are worth consuming in greater amounts. Two authors of this study last year published a book for the popular press, *The Good Gut*<sup>10</sup>, which chronicles the interaction between diet, the microbiome and health, and is replete with high-fibre recipes. You just might consider choosing a salad at lunch today or an extra serving of beans at dinner. Future generations may thank you, too. ■

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## COSMOLOGY

# Photons from dwarf galaxy zap hydrogen

The detection of photons sufficiently energetic to ionize neutral hydrogen, coming from a compact, star-forming galaxy, offers clues to how the first generation of galaxies may have reionized hydrogen gas in the early Universe. [SEE LETTER P.178](#)

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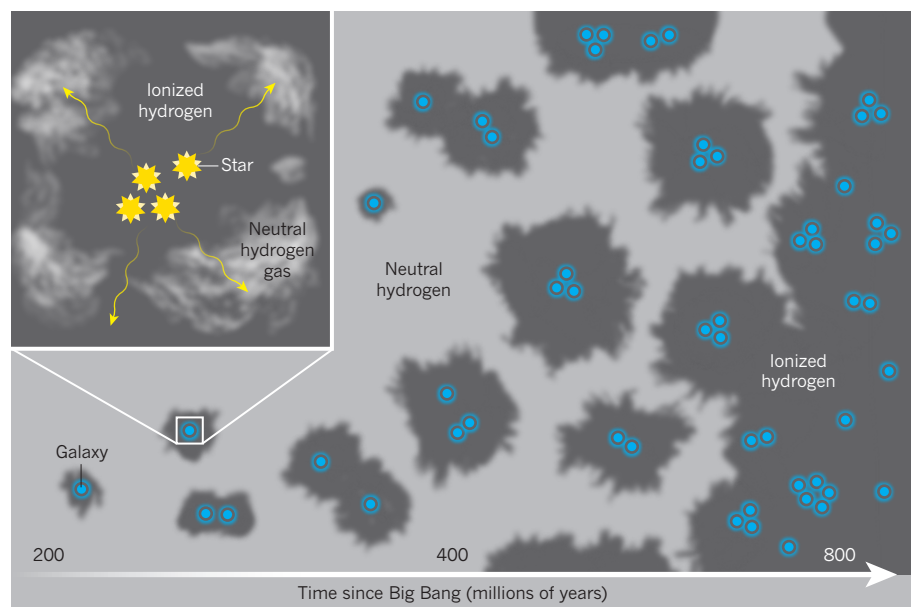
Most of the ordinary matter in the Universe is found not in stars, but in the diffuse gas between galaxies: the intergalactic medium (IGM), which is mainly hydrogen. This gas is almost completely ionized, and has been so since the formation of the first stars and galaxies a few hundred million years after the Big Bang. But few details are known about the sources of the radiation that ionized the gas, or how this radiation escaped from its source galaxies. On page 178 of this issue, Izotov *et al.*<sup>1</sup> report the detection of ionizing radiation from a star-forming dwarf galaxy in the local Universe, which may clarify the escape question.

The hydrogen gas that pervades the Universe has undergone phase changes over 13.8 billion years. The early Universe was too hot for protons and electrons to combine into neutral

hydrogen, so the hydrogen was ionized. The Universe cooled as it expanded, and about 375,000 years after the Big Bang, the temperature decreased enough for neutral hydrogen to form.

The gas remained neutral for the next few hundred million years, until the epoch of reionization — the last major phase transition in the Universe (Fig. 1). This transition occurred when the first sources of photons that were energetic enough to ionize hydrogen appeared in sufficient numbers to reionize the IGM. These photons are known as Lyman continuum photons because they have wavelengths shorter than the Lyman limit of 912 ångströms, which corresponds to the energy required to ionize the hydrogen atom (13.6 electronvolts).

We now know, from the scattering of cosmic microwave background photons by reionized electrons<sup>2</sup> and from observations of the



**Figure 1 | Escape of ionizing radiation from a galaxy.** The hydrogen gas between galaxies was ionized gradually (main panel): radiation from stars and galaxies ionized increasingly large bubbles of gas, until the ionized regions completely overlapped. For this to happen, photons with enough energy to ionize hydrogen must escape from galaxies. Such escape is challenging, because galaxies are filled with neutral hydrogen gas that absorbs ionizing radiation (inset; arrows represent ionizing photons). Izotov *et al.*<sup>1</sup> report the detection of ionizing photons from a compact starburst galaxy in the nearby Universe, a discovery that helps to explain the conditions that allow such radiation to escape from galaxies.