switching endurance of the materials.

Conventional DNNs have grown large and now typically involve many thousands of neurons and millions of synapses. But photonic networks require waveguides that are spaced far from each other to prevent them from coupling, and that avoid sharp bends to prevent light from leaving the waveguide. Because crossing two waveguides introduces the risk of injecting undesired power into the wrong path, the 2D nature of a photonic chip presents a substantial design constraint.

Despite the long distances and large areas that are required for the implementation of photonic networks, fabrication of the key parts of each optical structure requires precision. This is because the waveguides and coupling regions — for instance, at the entrance and exit of each micro-ring resonator — must have the exact dimensions needed to obtain their desired performance. There are also limits to how small micro-ring resonators can be made. Finally, the relatively weak optical effects offered by modulation techniques require long interaction regions to enable their limited impact on passing light to build to a noticeable level.

Advances such as those made in Feldmann and colleagues' study and by others[8,13] are encouraging for the future of the field. The development of readily available broadband on-chip gain would help considerably, as would techniques that can support independent and arbitrary operations on each piece of optically encoded data, without requiring vast areas of the photonic chip. Should scalable photonic neural accelerators offering high energy efficiencies eventually emerge, we might well look back on the work of Feldmann *et al.* and others in the field as important early glimpses of the technology's promise. ■

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OBESITY

Rural areas drive the global weight gain

The global rise in the prevalence of obesity has been seen as an urban problem. A large-scale study challenges this view by showing that weight gain in rural areas is the main factor currently driving the obesity epidemic. SEE LETTER P.260

BARRY M. POPKIN

Urbanization has been linked to increased overweight and obesity levels across populations[1]. However, evidence for this association has been based mainly on calculations of the body mass index (BMI) — the most frequently used tool for measuring overweight and obesity — at the time of study. The dynamics of BMI change in urban and rural areas have not been investigated separately. On page 260, the members of the NCD Risk Factor Collaboration[2] challenge the idea that general BMI trends are mainly a result of urbanization.

The global problem of overweight and obesity has been seen chiefly as an urban issue, partly because access to food services is much greater and easier in cities than in rural areas. City dwellers have an array of options for purchasing highly processed foods and beverages, which are high in salt, saturated fat and sugar, and which are often termed 'ultra-processed obesogenic foods'. Many low-income communities in urban areas consume predominantly ultra-processed foods and beverages sold at fast-food and small retail outlets, often because they live in so-called 'food deserts' — low-income areas where these are the only available foods. Rural areas, on the other hand, have been seen as a different type of food desert, where people mainly consume produce from their own farms and gardens, and have less access to ultra-processed and packaged food.

Furthermore, the inhabitants of cities have better options for transport, greater access to smartphones and cable television, and more non-physical leisure opportunities than those living in rural areas. They are also more likely to have occupations that are not very physically demanding. All these factors limit energy expenditure. By contrast, rural areas have been seen as places where heavy work on farms, forestry and mining-related activities leads to high levels of energy expenditure. It was thought that the levels of physical activity in rural areas were much higher than those in cities, and hence that the likelihood of weight gain was much smaller in rural than in urban populations.

Research has shown that in some low-income countries, such as China, people living in urban areas have diets that are distinctly different from those of their rural counterparts[3]. In the past two decades, a shift towards obesogenic diets has promoted weight gain and increased the risk of health problems related to chronic diseases in urban areas in China[3].

But some research findings have indicated that the levels of overweight and obesity are increasing faster in rural than in urban areas, even in many low- and middle-income countries (LMICs)[4]. This is likely to be linked to the fact that rural areas in LMICs have begun to resemble urban areas, because the modern food supply is now available[5] (Fig. 1) in combination with cheap mechanized devices for farming and transport. Ultra-processed foods are becoming part of the diets of poor people in these countries, and there are reports that infants are even being fed with these foods[6]. Despite these observations, most research and policy efforts have been focused on tackling urbanization as a major driver of obesity, because the general thinking is still that people living in rural areas are much more likely to face hunger and undernutrition than to be exposed to factors that lead to excessive weight.

All earlier research on BMI trends was based on limited data, and focused on either LMICs or high-income countries[4]. In this context, the paper by the NCD Risk Factor Collaboration is ground-breaking, because it pulls together the latest data from almost all countries to comprehensively examine global BMI trends. The results show that the levels of overweight and obesity are already greater in rural than in urban areas in all high-income countries, and also suggest that the rate of change in many LMICs is such that the levels of overweight and obesity in rural areas will soon match, if not exceed, those in urban areas. Rural hunger, wasting and stunting are rapidly being replaced by overweight and obesity in most regions of the world except sub-Saharan Africa, South Asia and a small number of countries in other areas.

This finding is fundamental, because the

A, B, TIM GAINEY/ALAMY

Figure 1 | Food-supply changes in rural areas contribute to global obesity. The NCD Risk Factor Collaboration study[2] reveals that increases in body mass index in rural populations in most regions of the world, including low- and middle-income countries, are driving the global rise in obesity. Changes to the food supply in rural areas — from traditional staples (**a**) to modern ultra-processed foods (**b**) — combined with access to motorized transport and mechanized farming equipment in rural areas are contributing factors. **a**, A street market in Yenumula Palli, Andhra Pradesh, India. **b**, A village shop in Puttaparthi, Andhra Pradesh.

main focus of geographically targeted obesity-prevention programmes and policies around the globe has been to address urban obesity. Examples of urban-focused interventions include physical-activity policies such as the *ciclovias* of Latin America that close urban streets to stimulate walking and cycling; the construction of cycle paths in urban areas; the design of urban buildings to enhance movement; and the focus on creating spaces for walking and playing in cities, including creating parks. Initiatives that involve working with retailers and shops that sell food have also mostly taken place in cities. Apart from a small number of policies, such as the provision of government-sponsored shops selling cheap, healthier food in remote rural areas in Mexico, rural populations have been largely ignored.

The study by the NCD Risk Factor Collaboration challenges us to create programmes and policies that are rurally focused to prevent increased weight gain — a major global gap. Several fiscal and regulatory approaches can reach rural areas globally. These range from programmes that combine comprehensive marketing controls, school-food controls and labels on ultra-processed foods, such as those instituted in Chile[7], to the taxation of unhealthy ultra-processed foods and beverages, as in Mexico[8,9]. These are national programmes that require national legislation and are being implemented in an increasing number of LMICs. However, countries must coordinate multiple regulatory and fiscal programmes similar to those in Chile to truly have an impact on people's behaviour. ■

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GLOBAL HYDROLOGY

A river that flows free connects up in 4D

Humans have altered the natural flow of rivers, adversely affecting biodiversity and the services that these watercourses provide. The mapping of millions of kilometres of rivers reveals the extent of human interference. SEE ARTICLE P.215

N. LEROY POFF

On page 215, Grill *et al.*[1] report their use of the latest high-resolution hydrographic and land-use data to produce the first detailed, replicable global map of rivers whose flow has been largely unaffected by human activities. This not only adds greatly to our knowledge of where such rivers remain, but also reveals which rivers have been impaired through severing of the multidimensional river-flow continuum. Such mapping affords insight into how and where river management might be used to restore flow connectivity and thus boost ecosystem function and productivity.

Rivers are among the most productive and biodiverse ecosystems on the planet. Their bounty reflects an intimate connection of flowing water with the landscapes they drain, and with the landforms they create along their journeys to inland seas or the oceans. As small streams flow off the land and coalesce into larger rivers, they transport sediment and nutrients downstream to build natural habitats and fuel biological productivity.

Importantly, the flow of water occurs not only down the river channel (longitudinally), but also laterally onto floodplains and vertically through the river's bed and adjacent groundwaters. These different pathways of connectivity allow for the exchange of nutrients, organic matter and organisms in all directions, and underlie a river's capacity to generate valuable ecosystem services and benefits, including clean drinking water, inland fisheries and seasonal floods that agriculture can take advantage of. Rivers that are completely connected in the three spatial dimensions of flow and that vary naturally in their relative magnitudes over time (the fourth dimension) are wholly functionally intact — they are