The story of wheat

# Ears of plenty

## The story of man's staple food

IN 10,000 years, the earth's population has doubled ten times, from less than 10m to more than six billion now and ten million soon. Most of the calories that made that increase possible have come from three plants: maize, rice and wheat. The oldest, most widespread and until recently biggest of the three crops is wheat (see chart on next page). To a first approximation wheat is the staple food of mankind, and its history is that of humanity.

Yet today, wheat is losing its crown. The tonnage (though not the acreage) of maize harvested in the world began consistently to exceed that of wheat for the first time in 1998; rice followed suit in 1999. Genetic modification, which has transformed maize, rice and soyabeans, has largely passed wheat by—to such an extent that it is in danger of becoming an "orphan crop". The Atkins diet and a fashion for gluten allergies have made wheat seem less wholesome. And with population growth rates falling sharply while yields continue to rise, even the acreage devoted to wheat may now begin to decline for the first time since the stone age.

It is time to pay tribute to this strange little grass that has done so much for the human race. Strange is the word, for wheat is a genetic monster. A typical wheat variety is hexaploid—it has six copies of each gene, where most creatures have two. Its 21 chromosomes contain a massive 16 billion base pairs of DNA, 40 times as much as rice, six times as much as maize and five times as much as people. It is derived from three wild ancestral species in two separate mergers. The first took place in the Levant 10,000 years ago, the second near the Caspian Sea 2,000 years later. The result was a plant with extra-large seeds incapable of dispersal in the wild, dependent entirely on people to sow them.

The story actually starts much earlier, around 12,000 years ago. At the time, after several warm millennia, a melting ice sheet in North America collapsed and a gigantic lake drained into the North Atlantic through the St Lawrence seaway. The torrent of cool, fresh water altered the climate so drastically that the ice age, which had been in full retreat, resumed for a further 11 centuries. The Scandinavian ice sheet surged south. Western Asia became not only cooler, but much drier. The Black Sea all but dried out.

People in what is now Syria had been subsisting happily on a diet of acorns, gazelles and grass seeds. The centuries of drought drove them to depend increasingly on wild grass seeds. Abruptly, soon after 11,000 years ago, they began to cultivate rye and chickpeas, then einkorn and emmer, two ancestors of wheat, and later barley. Soon cultivated grain was their staple food. It happened first in the Karacadag Mountains in south-eastern Turkey—it is only here that wild einkorn grass contains the identical genetic fingerprint of modern domesticated wheat.

Who first replanted the seeds and why? For a start, he was probably a she: women have primary responsibilities for plant gathering in hunter-gatherer societies. The time was certainly ripe for agriculture: the ability to make tools and control fire (cooking makes many plants more digestible) was already well established. But was it an act of inspiration or desperation? Did it perhaps happen by accident, as discarded grains germinated around human settlements?

The wheat plant evolved three new traits to suit its new servants: the seeds grew larger; the "rachis" which binds the seeds together became less brittle so whole ears of grass, rather than individual seeds, could be gathered; and the leaf-like glumes that covered each seed loosened, thus making the grains "free-threshing". In the past two years, the very mutations that allowed these changes have been located within the wheat plant's genome.

Wheat's servants now became its slaves. Agriculture brought drudgery, subjugation and malnutrition, because unlike hunter-gatherers, farmers could eke out a living when times were bad. But at least that meant that they could survive. Population growth was now inevitable. Within a few generations, wheat farmers were on the march, displacing and overwhelming hunter-gatherers as they went, and bringing with them their distinct Indo-Euro- »

**GM was invented in 1983 as a gentler, safer, and more predictable alternative to mutation breeding**

pean language, of which Sanskrit and Irish are both descendants. By 5,000 years ago wheat had reached Ireland, Spain, Ethiopia and India. A millennium later it reached China: paddy rice was still thousands of years in the future.

Wherever they went, the farmers brought their habits: not just sowing, reaping and threshing, but baking, fermenting, owning, hoarding. By 9,000 years ago they had domesticated cattle, to which they could feed wheat to get meat and milk. They could also get precious manure to fertilise the fields. Not until 6,000 years ago did somebody invent the first plough to turn the earth, burying weeds and breaking up the seedbed.

Innovations came slowly in wheat farming. The horse collar arrived in the third century BC, in China. By not pressing on the animal's windpipe, it enabled the animal to drag greater weight—and faster than an ox. In 1701 AD the Berkshire farmer Jethro Tull devised a simple seed drill based on organ pipes, which resulted in eight times as many grains harvested for every grain sown. Like most agricultural innovators since, he was vilified. A century later the threshing machine was greeted by riots.

In 1815 a gigantic volcanic eruption at Tambora in Indonesia led to the famous "year without a summer". New England had frosts in July. France had bitter cold in August. Wheat prices reached a level that would never be seen again in real terms, nearly $3 a bushel. Thomas Robert Malthus was then at the height of his fame and the harvest failure seemed to bear out his pessimism. In 1798 he had forecast a population crash, based on the calculation that it was impossible to improve wheat yields as fast as people made babies (each new baby can make more babies; each new field of grain leaves less new land to cultivate).

The Malthusian crash was staved off in the 19th century by bringing more land under the plough—in North America, Argentina and Australia especially. But wheat yields per acre grew worse if anything as soil nutrients were depleted. So in 1898, in a speech to the British Association, a chemist, Sir William Crookes, argued again that worldwide starvation was inevitable within a generation. Population was rising fast. There was little new land to plough. Famines became worse each season, especially in Asia.

This time it was the tractor that averted Malthusian disaster. The first tractors had few advantages over the best horses, but they did not eat hay or oats. The replacement of draft animals by machines released about 25% more land for growing food for human consumption.

The Malthusian limit would surely be reached one day, though. The only way to increase yield was to find a way of supplying extra nitrogen, phosphorus and potassium to the soil. Neither a break crop of legumes, nor manure was the answer, since both demanded precious acres to produce. The search for fertiliser took unexpected turns. British entrepreneurs scoured the old battlefields of Europe searching for phosphorus-rich bones. In about 1830 a magic ingredient was found: guano. On the dry seabird islands off the South American and South African coasts, immense deposits of bird droppings, rich in nitrogen and phosphorus, had accumulated over centuries. Guano mining became a profitable business, and a grim one. Off South-West Africa, the discovery in 1843 of the tiny island of Ichaboe, covered in 25 feet of penguin and gannet excrement, led to a guano rush followed by a mutiny and battles. By 1850, Ichaboe, minus 800,000 tonnes of guano, was deserted again.

Between 1840 and 1880, guano nitrogen made a vast difference to European agriculture. But soon the best deposits were exhausted. In the dry uplands of Chile, rich mineral nitrate deposits were then found, and gradually took the place of guano in the late 19th century. The nitrate mines fuelled Chile's economy and fertilised Europe's farms.

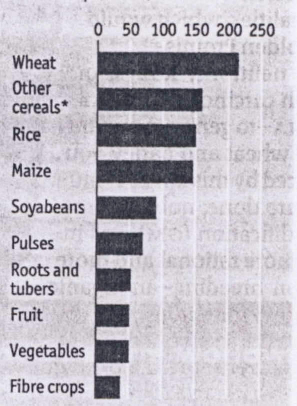
On July 2nd 1909, with the help of an engineer named Carl Bosch from the BASF company, Fritz Haber succeeded in combining nitrogen (from the air) with hydrogen (from coal) to make ammonia. In a few short years, BASF had scaled up the process to factory size and the sky could be mined for nitrogen. Today nearly half the nitrogen atoms in the proteins of an average human being's body came at some time or another through an ammonia factory. In the short term, though, Haber merely saved the German war effort as it was on the brink of running out of nitrogen explosives in 1914, cut off from Chilean nitrates. He went on to make lethal gas for chemical warfare and genocide.

On farms, Haber nitrogen ran into much the same revulsion as had greeted the seed drill. For many farmers, the goodness of manure could not be reduced to a white powder. Fertiliser must in some sense be alive. Haber nitrogen was not used as fertiliser in large quantities until the middle of the 20th century, and for a good reason. If you put extra nitrogen on wheat, the crop grew taller and thicker than usual, fell over in the wind and rotted. On General Douglas MacArthur's team in Japan at the end of the second world war a wheat expert named Cecil Salmon collected 16 varieties of wheat including one called "Norin 10", which grew just two feet tall, instead of the usual four. Salmon sent it back to a scientist named Orville Vogel in Oregon in 1949. Vogel began crossing Norin 10 with other wheats to make new short-strawed varieties.

In 1952 news of Vogel's wheat filtered down to a remote research station in Mexico, where a man named Norman Borlaug was breeding fungus-resistant wheat for a project funded by the Rockefeller Foundation. Borlaug took some Norin, and Norin-Brevor hybrid, seeds to Mexico and began to grow new crosses. Within a few short years he had produced wheat that yielded three times as much as before. By 1963 95% of Mexico's wheat was Borlaug's variety, and the country's wheat harvest was six times what it had been when Borlaug set foot in the country.

**Wheat leads the field**

World crops, 2004, m hectares




*Barley, rye, millet, etc

Source: Food and Agriculture Organisation

In 1961 Borlaug was invited to visit India by M. S. Swaminathan, adviser to the Indian minister of agriculture. India was on the brink of mass famine. Huge shipments of food aid from America were all that stood between its swelling population and a terrible fate. One or two people were starting to say the unsayable. After an epiphany in a taxi in a crowded Delhi street, the environmentalist Paul Ehrlich wrote a best-seller arguing that the world had "too many people". Not only could America ▸▸

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No need to starve

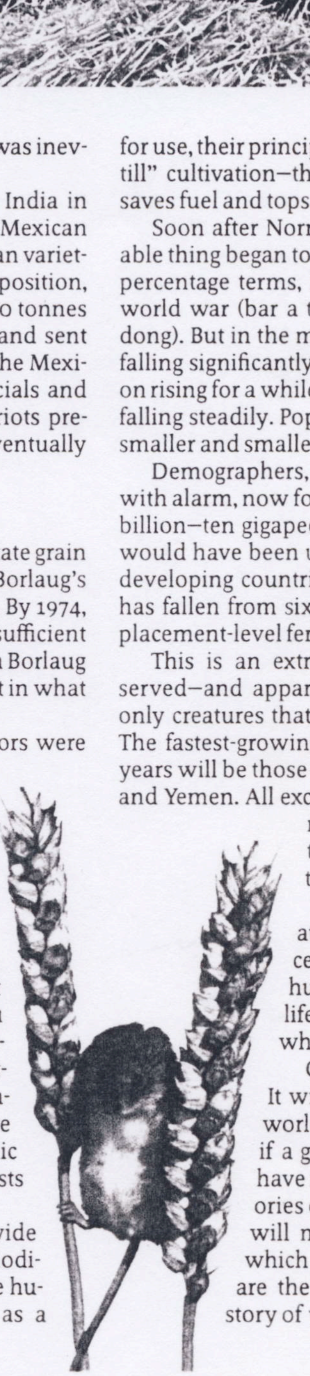
not save India; it should not save India. Mass starvation was inevitable, and not just for India, but for the world.

Borlaug refused to be so pessimistic. He arrived in India in March 1963 and began testing three new varieties of Mexican wheat. The yields were four or five times better than Indian varieties. In 1965, after overcoming much bureaucratic opposition, Swaminathan persuaded his government to order 18,000 tonnes of Borlaug's seed. Borlaug loaded 35 trucks in Mexico and sent them north to Los Angeles. The convoy was held up by the Mexican police, stopped at the border by United States officials and then held up by the National Guard when the Watts riots prevented them reaching the port. Then, as the shipment eventually sailed, war broke out between India and Pakistan.

### Natural-born mutants

As it happened, the war proved a godsend, because the state grain monopolies lost their power to block the spread of Borlaug's wheat. Eager farmers took it up with astonishing results. By 1974, India wheat production had tripled and India was self-sufficient in food; it has never faced a famine since. In 1970 Norman Borlaug was awarded the Nobel Peace Prize for firing the first shot in what came to be called the "green revolution".

Borlaug had used natural mutants; soon his successors were bringing on mutations artificially. In 1956, a sample of a barley variety called Maythorpe was irradiated at Britain's Atomic Energy Research Establishment. The result was a strain with stiffer, shorter straw but the same early harvest and malting qualities, which would eventually reach the market as "Golden Promise".



Today scientists use thermal neutrons, X-rays, or ethyl methane sulphonate, a harsh carcinogenic chemical—anything that will damage DNA—to generate mutant cereals. Virtually every variety of wheat and barley you see growing in the field was produced by this kind of "mutation breeding". No safety tests are done; nobody protests. The irony is that genetic modification (GM) was invented in 1983 as a gentler, safer, more rational and more predictable alternative to mutation breeding—an organic technology, in fact. Instead of random mutations, scientists could now add the traits they wanted.

In 2004 200m acres of GM crops were grown worldwide with good effects on yield (up), pesticide use (down), biodiversity (up) and cost (down). There has not been a single human health problem. Yet, far from being welcomed as a greener green revolution, genetic modification soon ran into fierce opposition from the environmental movement. Around 1998, a century after Crookes and two centuries after Malthus, green pressure groups began picking up public disquiet about GM and rushed the issue to the top of their agendas, where it quickly brought them the attention and funds they crave.

Wheat, because of its unwieldy hexaploid genome, has largely missed out on the GM revolution, as maize and rice accelerate into world leadership. The first GM wheats have only recently been approved for use, their principal advantage to the farmer being so-called "no till" cultivation—the planting of seed directly into untilled soil saves fuel and topsoil.

Soon after Norman Borlaug went to India in 1963, a remarkable thing began to happen. The world population growth rate, in percentage terms, had been climbing steadily since the second world war (bar a two-year drop in 1959-60 caused by Mao Xedong). But in the mid 1960s it stopped rising. And by 1974 it was falling significantly. The number of people added each year kept on rising for a while, but even that peaked in 1989, and then began falling steadily. Population was still growing, but it was adding a smaller and smaller number each year.

Demographers, who had been watching the exponential rise with alarm, now forecast that the population will peak below ten billion—ten gigapeople—not long after 2050. Such a low forecast would have been unthinkable just two decades ago. Already, in developing countries, the number of children born per woman has fallen from six to three in 50 years. It will have reached replacement-level fertility (where deaths equal births) by 2035.

This is an extraordinary development, unexpected, undeserved—and apparently unnatural. Human beings may be the only creatures that have fewer babies when they are better fed. The fastest-growing populations in the world over the next 50 years will be those of Burkina Faso, Mali, Niger, Somalia, Uganda and Yemen. All except in Yemen are in Africa. All are hungry. All remain untouched by Borlaug's green Revolution: all depend on primarily organic agriculture.

In 10,000 years the population has doubled at least ten times. Yet suddenly the doubling has ceased. It will never double again. The end of humanity's population boom will happen in the lifetimes of people alive today. It is the moment when Malthus was wrong for the last time.

Of course feeding ten billion will not be trivial. It will require at least 35% more calories than the world's farmers grow today, probably much more if a growing proportion of those ten billion are to have meat more than once a month. (It takes ten calories of wheat to produce one calorie of meat.) That will mean either better yields or less rainforest—which is why fertilisers, pesticides and transgenes are the best possible protectors of the planet. The story of wheat is not finished yet. ■