Extract from Genetic Revolution book by Patrick Dixon - published by Kingsway in 1995. Many things have changed since 1995 - huge growth in market for genetically modified foods, and in general we have become far more relaxed about eating them - with many safety studies published since the book was written.

Farming is a high risk business

The genetic engineer is already making huge changes to the way farmers are growing food.Farming has never been riskier or more competitive than today.In many countries food production is artificially stimulated or destroyed by large fluctuations in market prices.Some of these fluctu -ations are natural due to variations in crop yields from year to year for example.Others are due to systematic rigging of the markets through governments guaranteeing minimum prices.These steps were designed to prevent the boom and bust effect from year to year and to guarantee regular farming income.However they have led to situations where at a time of mass starvation in Africa, farmers are paid to produce more non-transport -able food than we need (milk, butter, beef).European farmers are now to be paid instead not to farm their land - maybe to plant trees instead.

Dumping subsidised food onto the world market - during famine, dumping free food can become disguised or relabelled as "aid" - also has massive effects on small two-thirds world farmers who can find the value of their produce disappear overnight.

For a Western farmer high yield for low cost is always the key factor: more crops per acre, lower seed cost, lower wastage from disease, greater resistance to frost, heat and drought, quicker ripening time, and less need for fertilizers or pesticides.

A difference of five to ten percent in yield makes all the difference between catastrophic loss and a reasonable return.

So what can the genetic engineer offer the farmer?Large manufacturers of pesticides, fertilizers and seed suppliers might look at it all another way.What could the genetic engineers of a rival company come up with that might damage sales?

Four huge areas lie waiting for the farmer of cereal crops:

1.better seed - greater yield

2.lower need for pesticides

3.lower need for fertilizers

4.biological warfare against pests

In fact the last two could be dealt with by getting the genetic code right in the first place.At least 27 of the world's largest chemical companies are attempting to change the genetic code of cereals to produce a new product they can sell.As long ago as 1985 a company in the US successful -ly took out a patent on one of the first newly "invented" cereals: this was to protect the creation of a new type of maize with high loads of a substance called tryptophan (580).

Lower need for fertilizers

Taking the issue of fertilizers first: there are some bacteria which take nitrogen out of the atmosphere - it is the major gas we breathe - and turn it into nitrates which are the chemicals plants use to grow, because they are needed to form amino acids, used as building blocks in making proteins (p).Nitrates are artificially applied in fertilizers.Some plants such as carrots and turnips have self-fertilizing factories in nodules attached to their roots.They create homes for these special bacteria who produce nitrates just where they are needed, at the roots of the plants.These plants tend to leave more nitrates in the soil at the end of the year than there were at the beginning.So much so in fact that before the widespread use of fertilizers farmers would often sow one of these types of plants into each field roughly every third year to restore the exhausted soil.

The farmer's dream would be to take genetic code for these roots and add them to the genetic code of cereals.Attempts are currently under way to do this.If successful, the turnover of many large chemical companies would be damaged overnight which is why so many are locked in a genetic-engineering race, expecting to switch production from chemical fertilizers to genetically engineered products soon.

A further dream would be to grow crops containing their own fungicides and pesticides - substances made inside the cells of each plant instead of being absorbed artificially through spraying.Clearly these substances would need to be non-toxic to humans or at least not find their way through the sap into the harvested seed. The dream is becoming reality with viruses already modified to infect and transform plants giving them insect and disease resistance and weedkiller (herbicide) tolerance (585).

Such steps also could have alarming implications for pesticide manufac -turers.

Insecticides and pesticides

It is interesting that one company (Calgene) is now marketing a new genetically engineered seed which gives resistance to damage from a powerful applied weedkiller - it just happens to be specific protection to the weedkiller produced by the same company.Pesticides or insecticides themselves can also be produced by genetic engineering - programming bacteria to produce them (590).This approach guarantees sale of expensive super-seed and own-brand chemicals.Work is continuing on cotton, tomatoes, rape seed, potatoes and sugar beet (600).

At first, "green" consumers may be misled into thinking that new crops grown without pesticides or fertilizers are more ecologically sound.However they may soon be wondering what the side effects are of eating vegetables or other crops programmed to fill themselves with home-made poisons.

At the moment there is no legislation to protect consumers from such crops. If the substances are produced within a plant then the plant is deemed as safe and as wholesome as it's original ancestor.Nor does there have to be any indication in the shop.Safety testing is being carried out (610) but in almost every country of the world there is no regulatory authority for genetically created foods.

You have probably already eaten your first genetically engineered food without even knowing it - after all it is hardly something shops want to shout about, and manufacturers are keeping a very low profile for the same reasons.It could be the quickest way to kill sales by causing anxiety in shoppers in our supermarkets.

Rapid production of new seed

Genetic engineering also allows us to produce new strains of seed more quickly.Usually a single cross-bred cereal plant has to be bred from seed through several generations over several years to produce enough seed to sell and be able to produce more.

Incidentally there are huge commercial advantages in selling genetically engineered seed with all advantages but producing sterile seed.In other words the farmer having lost the need to buy pesticides and fertilizers now has to buy new seed at inflated prices each year where previously he would have kept some of the harvest back for next year's sowing.

Here is the simple answer to raising millions of seeds from just one genetically engineered plant in just twelve months: plant cloning.Hundreds or even thousands of identical growing plants from just one original.The result is fields ready for harvest -ing by summer, to produce a massive crop of commercial seed for sale.Plant cloning is of course a well established practice.A type of plant cloning is taking cuttings and transplanting them.This has been a standard procedure commercially for decades.

Germ warfare protects plants.

Progress is also being made in designing new plants which are virus-resistant (615).

Another option for the farmer is to use germ warfare against insects which eat his crops.Research is going on to develop insect viruses which can either be sprayed onto crops or which will be released into the sap by plant cells.In one experiment, a new insect virus was developed which when injected into silkworm larvae caused an overdose of a particular insect hormone to be produced by the silkworm.The new virus was 20% more lethal than the original (620). Other types of laboratory made viruses have also been developed recently by using genetic code for poisons produced by bacteria and inserting it into viruses. The end result was the same as in silkworms, with the insect larvae infected beginning to produce minute doses of the insecticide themselves in their own body cells (625).

However this has more implications for human safety.Do we want to eat genetically engineered plant viruses with our fresh salad?

If we turn from cereals to vegetables we find genetic engineers have already left their mark.Unlike cereals which have a long shelf life when dried, vegetables quickly decay due to their high water content.

New fruit and vegetables

Many vegetables are also soft and susceptible to bruising especially if ripe.Farmers are faced with a stark choice: either harvest unripe crop and hope it softens in the supermar -ket, or harvest it ripe - heavier and better quality - but with a risk of severe damage by the time it reaches the wholesalers.

The tomato is a high value vegetable (some would say it is a fruit) that has been studied carefully by genetic engineers.Small adjustments have been made to produce a "non-bruising" tomato.It looks good, survives travel well but some say it's taste is strange or inferior.Recent advertisements in Sunday newspapers in the UK were promoting a genetically engineered strain of tomato bush, guaranteed to grow without support in any soil, producing huge tomatoes up to 12-15 inches in circumfer -ence.

Horticulture Research International is a British company making big strides forward in this area.In 1986 the company bred a new apple called "Fiesta".They are now working on genetic markers which will tell them when the new genes for pest and disease resistance have successfully "taken".They are still at the stage of having to plant trees and watching an orchard develop over a number of years.The company has also produced a new type of mushroom with better storage qualities and double the shelf life after harvest.The Company was funded by the

Government but this has stopped now that commercially viable products are resulting.The government now expects industry to provide all the investment.The British horticultural industry is providing ?2.5 million of finance over the next two years (630).

There are some foods that we will never see in the West unless genetic engineering provides some answers.Only visitors to Africa know what bananas are supposed to taste like.Supermarket bananas have been picked very early when they are small and have a low sugar content.Locally picked ripe bananas taste like supermarket ones mashed up with brown demerara sugar.

There are other kinds of bananas in Africa that do not even survive air-travel well. These will never be eaten in quantity abroad - without a genetic refit.

The strawberry is another obvious target for genetic changes as a high value for weight food. The farmer is faced either with going for good taste but lower yield, or high yield with poor flavour and all the same problems about ripeness and bruising.

Faster growing animals

Genetic engineering has much to offer farmers looking for higher animal yields - of meat or milk for example.There does not need to be a change in the genetic code of the animal itself: we can use genetically engineered bacteria to produce hormones to drive the bodies of animals as hard as they can go for maximum profit.This is a similar approach to using insulin as a genetically engineered medicine in humans.One example of such an applica -tion has resulted from the discovery of the genetic code for growth hormone in chickens.This could soon be used to produce larger chickens faster (640). Other experiments on chickens are using viruses to programme germ cells, with the aim of producing chicks which hatch out with a built in resistance to chicken viral disease (648).

The company Monsanto has just applied to the European Commission for a licence to use a genetically engineered drug on cows called bovine somatotrophin (650).This artificially stimulates extra milk production producing the same yield with 30% fewer cattle (651).The Commission has approved the drug use but the Council for Veterinary medicinal Products has not reached a verdict.In the meantime a ban was applied in the European Community until the end of 1991 while it considered a whole range of similar biotechnology products (650).However despite the great debates, milk from cows treated with genetically produced bovine growth hormone has been drunk by the British public since 1986 - from ten test farms (660).Although some farmers are opposed to this farming method because they fear bankruptcy if the price of milk falls as a result, environmentalists also question the need for it when Europe already overproduces milk.As we saw earlier, farmers are already being encouraged with financial incentives to take land out of farm production because it is cheaper than caring for butter mountains.

In early 1991 the British Veterinary Product Committee recom -mended that the British government should refuse a licence to the two companies wanting to market the drug.The grounds for objection where not risks to humans or the environment, but concern for the welfare of the overstimulated animals.However other scientists in the US also query human safety - small amounts of an insulin-like substance seem to be secreted into the milk of treated cows.Some are also concerned about a possible new milk allergy in humans as a result.The hormone does increase the incidence of udder infection (mastitis) and the treatment involves giving cows painful injections.

In November 1990 new evidence was emerging of other problems, possibly including increased miscarriages in pregnant cows being treated.These new findings have led the US Food and Drugs Administration (FDA) to say that the drug was unlikely to be licensed for use in the US "for some time" (660).With a ban already announced by German Parliament, the strengthof the "caution" lobby is growing.Meanwhile in the US alone, four companies hope to market the drug and have already spent hundreds of millions of dollars in research and development (660).

We can also use genetic engineering to produce vaccines against animal diseases such as foot and mouth disease (670).

New "Super-animals"

However as we have already seen, the biggest stakes of all are in genetically engineered farm animals or "super animals" (651).We have already seen how the sex of embryos can be determined using genetic techniques (680), and how a whole new herd can be created in months by cloning.But how about genetically altering the first animal before we begin? (690)

In 1987 a scientific paper said that "within the foreseeable future it will be possible to add foreign genes to the genetic composition of animals in order to transfer disease resistance, rapid growth, fertility and efficient use of foodstuffs to their offspring." (651)Patent protection has been available on newly created animals as well as plants under US law since a historic decision by the US supreme court in 1987 (700).The test case involved polypoid oysters.In fact the first gene transfers in mammals happened in mice over 15 years ago in 1976 (710).

Food fads come and go.Doctors are still unable to agree about the relationship between high levels of animal fat in the diet and heart disease.What seems likely is that a small proportion of the population is sensitive to the damaging effect of animal fats while for the rest of us the advice is probably irrelevant.We can probably detect who needs to be on low fat diets through family history of heart disease or strokes, by testing blood cholesterol levels - and in the future by inspecting the genetic code because such sensitivity seems to be inherited.

New pigs

However the public perception of the dangers in eating animal fats is now firmly rooted and the demand for low fat meat is therefore growing.In 1987 a new kind of "transgenic" pig was created for the first time with lower than normal body fat (720).Fertilized eggs from pigs were injected with a strip of genetic code formed from two fragments, one from a human with the instructions to produce human growth hormone, and the other from a mouse with instructions to activate the gene.The technology for injecting a single microscopic cell has been well established for many years (730).The middle of a hollow piece of glass tubing is heated in a flame while pulling at both ends.As the glass softens the two ends suddenly shoot apart.The middle becomes thinner and smaller until finally it is hundreds of times thinner than a human hair and snaps.It is fascinating to watch it happen.You are left with two pieces of glass tubing which taper off at one end to microscopic size.The tubing is then attached to a microscope with special controls so it can be precisely positioned in an individual cell (740).

Once injected the injected cells were returned to the womb to develop.Out of 341 pigs that resulted, 31 were reprogrammed (720).They developed as a new species containing pig, mouse and human genetic code.The human growth hormone production in the animals lowered body fat, and stimulated mammary development (milk production).Moreover, the new species gave birth to identical offspring five out of six times.

New sheep

The same experiments were also repeated using fertilised eggs from sheep with less success - only three of 111 lambs born were a new creation (720).However, as long as you can reproduce from the new stock, you only need to have a one in a thousand success rate or less to make the effort worth -while.After all, how much will a company pay for the first of a new superbreed of cow, likely to become a new world class breed?

Other methods of reprogramming fertilised eggs include infecting them with genetically engineered viruses (740).This is fast becoming a standard technique.

The demand is also rising for skimmed milk.What do you do with all the cream when you cannot sell it as cream or as butter?

The udders of cows have been particular targets for the genetic engineer: here is a massive chemical factory producing very large amounts of complex proteins.We can either try to adjust the composition and flavour of the milk in some way, or programme the udders to manufacture completely new substances which we can later extract from the milk to use as medicines (750).Such milk would be unlikely to be suitable for drinking, even after extraction of the medicine.

Mothers are also being increasingly driven again to old fashioned breast feeding of their babies as more and more evidence grows of the long term damage to some through early feeding on cow's milk - even in modified powder form.

New cows

A first immediate challenge has been to reprogramme the udders of a cow by inserting the human genes a mother's breast cells use to make the special formula for human breast milk.This has been done in cow embryos and the reprogrammed cows are now growing up fast.We can expect to see human breast milk substitute bottled direct from cows in the near future.

The next problem is to alter the metabolism of animals so they grow more flesh faster and less bone or fat (760).This is just an extension of selective breeding which as we have seen is centuries old.

A genetic engineering company called Granada Genetics in Texas said recently that: "The concept of producing large numbers of genetically identical embryos, frozen, sexed, screened for economic traits and produced inexpensively from slaughterhouse by-products is within our grasp....all...have already been demonstrated."What will happen to protein production when commercial cow herds can be made up of one or two female clone lines mated to bulls of the same clone?The obvious answeris predictability of performance to a magnitude never before achieved in agriculture" (765).

Rapid progress is being made.It is even possible that we may see new animals emerging although one suspects consumer pressure will mean they will still be called by familiar names to avoid anxieties being raised. Would you buy geep meat at 40p a pound less than lamb - combined goat and sheep?Sheep have already been modified although not as dramatically as this yet (770).

New fish

New species of fish are also being made.Rainbow trout have been reprogrammed by taking fertilised eggs and adding a second copy of the gene for Rainbow trout growth hormone attached to a mouse gene designed to activate it artificially.In 1990, of 3,104 eggs treated in this way, 25% - 783 - hatched out of which 4% were of the new species.Of 180 hatchlings, 35 survived as adult fish.Two were of the new species (transgenic).The new species gave rise also to offspring with the same genetic characteristics (780).

The list of transformed creatures is huge - even rabbits have been changed (790).

Once a transgenic animal has been made, very large numbers of others can be created by cloning, well established as we have seen for duplicating sheep and cattle embryos.These are produced by separating cells at the earliest stage after fertilization (see p).However nuclear transplan -tation will open the way for cloning on a much larger scale (800).

The Department of Meat and Animal Science at Wisconsin University in the US published a paper in 1990 which said:

"Efficient in vitro systems for maturing oocytes and capacitating spermatozoa, for fertilising and developing the embryos have resulted in commercial...production of embryos. Cloning of embryos by nuclear transfer has been accomplished for sheep, cattle, pigs, and rabbits, with nuclear material sullied by embryos as late as the 120 cell stage in sheep. Embryos have been recloned....Research is needed ......so that the number of clones may be increased to thousands or millions.

"Transgenic embryos or offspring have been produced for mice, rats, rabbits, chickens, fish, sheep, pigs and cattle. ...badly needed efforts to map the genome of domestic animals. "These and other new technologies promise to change livestock breeding drastically over the next decade" (805).

Food from microbes

The trouble with animals is that they are inefficient: almost everything a cow eats is turned into heat keeping warm, energy in moving around, and cells for tissues wearing out such as gut lining shed into cow dung, or skin and hair.Some of the rest is excreted as dung although cows are much more efficient than horses which excrete huge amounts of undigested cellulose in food.

If people could eat grass, straw, hay or protein from bacteria or yeasts (810), our food bills would be much lower.However even plants are not always as efficient as you might think in trapping solar energy and using the power to make proteins, sugars or fibre.

Basically all we eat is solar powered directly or indirectly.The solar energy is stored, converted or transferred in one way or another.How about using another form of stored energy to fuel human beings with good food for us to burn inside our bodies?

Bacteria already exist which eat oil and grow to produce protein which we could use as food.What about bacteria that burn hydrogen to produce energy?

Nuclear power or hydroelectric power can be used to make electricity.Electricity can be used to turn water into oxygen and hydrogen - the same chemical reaction that happens when car batteries are recharged.Hydrogen can be fed to bacteria which use it as fuel to grow.Here then is a potential way of producing food from nuclear power.

Because energy itself is at a premium I suspect we will always find our best results will come from new plants producing most of our dietary needs from sunlight and soil rather than through bacteria directly or through the unnecessary wasteful intermedi -ary of a farm animal.

Progress on plant texture and taste is also needed before we will all be converted to being vegetarians.In the meantime yeasts are also being genetically engineered as future food sources (820).When the world's oil supplies have nearly run out - less than a generation away - there will be a huge drive to produce low cost alternatives to petrol for cars.One well proven alternative is ethanol or alcohol.New ways are being tried to programme E. coli bacteria to produce ethanol (830).

Having considered some of the range of ways genetic engineering is having an impact on what we eat, we now need to look at the most important areas of all: genetic engineering for maximum health, using genes in medicine.