The Royal Society of Edinburgh Discussion Forum on GM Gene Flow: Scale and Consequences for Agriculture and the Environment

Chair: Professor Andrew Miller, RSE General Secretary

Speakers: Dr Geoff Squire, Theme Leader: Management of Genes & Organisms in the Environment (Scottish Crop Research Institute)

Dr Ricarda Steinbrecher, Director (Econexus)

Dr Mike Wilkinson, Reader in Plant Genetics (University of Reading)

Professor Tony Trewavas, Professor in Plant Biology (University of Edinburgh)

Panel: Dr Brian Johnson, Terrestrial Wildlife Team, English Nature;

Professor Michael Wilson FRSE, Chief Executive, Horticulture Research Institute

Professor Philip Dale, John Innes Centre

Chair – Professor Andrew Miller, RSE General Secretary

Prof.Miller: Ladies and gentlemen, could I first welcome you very warmly to this evening meeting which is to discuss gene flow from GM crops. The first thing I've got to do is - I'm just waiting to see the statutory safety arrangements on screen. There they are. If the alarm sounds then there's two exits, that one over there if you are sitting nearest that door or one at the back and your exit there, I'll just give you two minutes to see that you pop across to the George Hotel. Some of you might automatically anyway! But you mustn't stop to pick up anything on the way. That's my statutory duty finished.

Can I really welcome all of you and the interest you have shown in coming to this meeting on Gene Flow and I would like to thank particularly the speakers and panellists who have come from quite a distance and the speakers tonight who, at rather short notice prepared papers in advance which I hope you have all got by now.

Secondly, I would like to thank the sponsoring bodies, the Scottish Executive, the British Association and the Royal Society of Edinburgh for financial support, and thirdly the staff in the RSE here, Dr Marc Rands, Research Officer, Dr Roisin Calvert, Events Manager, and their staff who helped us to get moving tonight with something for us to eat because I knew that most of you would be travelling from some distance. Kirsty Black and Catherine Henderson is an important member here, she is going to make a 3,000 word report on this meeting so you might see some of your ideas reflected later when that comes out in a week or two's time.

This meeting is part of the consultation arranged and organised by the UK Government to examine the possibility of genetically modified crops being grown in the UK and used to produce food. At present there is a moratorium on the cultivation of GM crops for food in the UK but this is due for review this year, 2003. Some fuel trial evaluations of GM plants have been approved in the UK and they also are due to produce their first report in the middle of 2003.

The consultation has arisen because of expressions of public concern and because of the emergence of strongly expressed views both for and against GM crops for food. Our question tonight is, can science help to get at the truth about GM crops? This is a scientific meeting. There's many other aspects of the problem of "Should we be using GM crops for food?", social issues, commercial issues and so on. Tonight we are concentrating on science. That's our remit. We have to produce a report from this meeting on a scientific account of the state of our knowledge on GM foods.

If I could have the first slide please, I will just explain the context of this meeting in the light of the wider consultation in this public debate. The Steering Panel is really the umbrella body conducting the science debate and there are two other review panels. One is looking at the economics, the impact of GM on the UK economy, either helping it or hindering it, and that's being run by the Prime Minister's Strategy Unit. This is the Science Review Panel, which is UK-wide and chaired by the Dave King and Howard Dalton, with advice also from the Food Standards Agency. We will feed into the Science Review Panel. Three members of the Science Review Panel are here tonight and you will hear them later as they question our speakers. That's the way the information will flow from this meeting. It will go onto a website. There will be a transcript of this meeting so everything that you utter will eventually go up on the website, as well, of course, as the Report prepared by Catherine Henderson. Information will go from here up to the Science Review Panel and then finally the Steering

Group will collate information from the three panels and a report will go out later, about mid-2003.

The Royal Society of Edinburgh has organised this meeting tonight. We were invited by the Scottish Executive to organise this meeting as part of the open meetings activity and this meeting is special, first because it's regional, it's Scottish, and secondly because it's devoted to the science underlying one specific area of public concern about GM crop production, namely Gene Flow, the title of the meeting, Gene Flow - scale and consequences for agriculture and the environment. So I'm delighted that between 80 and 90% of you here tonight are scientists and we really want an emphasis on science from this meeting.

The RSE agrees that scientists do have a responsibility to address areas within which their work gives rise to public concern and we do not see this meeting as self-serving for any interested party, be they scientists, industry, NGOs or Government. As a non-expert on GM myself, I am a scientist but not an expert on GM. From reading the speakers' papers and the panellists' questions, it seems to me that there are two broad possibilities on gene flow that we might decide as it were, in the light of science. Either: At least some of the public concerns are valid, so then we have to go on to ask, "What are the current scientific views on these concerns and what are the levels of certainty or uncertainty about these scientific views?"

On the other hand, we might decide, and I doubt it but we might decide, that the science shows that there is absolutely no need for concern by the public. That has been maintained in some quarter and that may be what comes out of here tonight. But if it does, and if there is no need for public concern, we should be asking ourselves "why are the public concerned?" Have they been misled? Has there been a failure of communication? So whichever is the case, we do have an issue here tonight. Note that GM applications are of many different types so that there is unlikely to be a single generic answer to the either/or that I pose, but case-by-case responses are usually necessary and in science usually we will be getting down to specifics and giving our views scientifically on specific cases of GM.

What can the science produce? Well, it can describe the possibilities for GM that are well-understood scientifically, and also try to give some indication of the confidence levels there.

It can indicate uncertainties and the consequent risks of the GM and, of course, the possible risks of not using GM. And thirdly, we might suggest research. What would we like to know, but at this moment we don't actually know? Science can do a lot. We must make sure that public policy is based on sound science and we can, of course, debate for ages what sound science means. I take it to be science that has gone through the process which is established and accepted by the scientific community in the normal way. There can be difficulties there. You may have heard that in Australia there was recently a nearly total eclipse of the sun and the media decided to make a public issue of it and to explain it to the public. There were excellent programmes showing how the eclipse took place and how the public could view events on the sun surface, just as the sun was coming out of the eclipse. One viewer text-messaged into the TV channel said "it was excellent but I've got one criticism. You showed this live eclipse on a Wednesday, a week-day when everybody was working, and many people couldn't see it. Next time please arrange it for the weekend." So that gives some idea of what people think science can do. As scientists we wouldn't see it quite like that.

So now it's over to the speakers. They will speak one after another with no break, Dr Geoff Squire first, then Dr. Ricarda Steninbrecher and then Dr Mike Wilkinson, then Professor Tony Trewavas. They will go unbroken, no questions, ten minutes each and not a minute more! Then there will be a panel from the Science Review Panel in London to question the speakers. When that's finished after half an hour then it's open to all of you and the whole of the second half, an hour and 15 minutes of this meeting will be for you, the participants, to speak to the speakers, question them and make your own comments. So please Dr Squire … thank you very much.

Dr. Geoff Squire, Scottish Crop Research Institute

Dr.Squire: Good evening. **[Slide 1]** I'm from the SCRI Dundee, and in sending the presentation down, it changed slightly in format and bits of it don't quite come through but the main points are there. Issues of concern have been stated **[Slide 2]** and I take the gene flow to be pollen mediated movement of genes and individual mediated movement of ferals in this case. My remit was to deal with crop to crop, as part of that I include the feral populations that arise from crops. I won't mention or go into any detail concerning liability which is somebody else's matter of concern and so a job for the panel. That gene flow, in some way, will interfere with the habitat functioning of the system and will, by outcrossing or by ferals growing within the crop, cause impurities in yield. **[Slide 3]** And I wanted to just remind ourselves what the system was. A number of essential processes. If any of these major points and major processes cease to function and that's the end of it. As a species we aren't very good at managing the system, in many parts of the world we've failed. **[Slide 4]** We have to look at a range of scales, fine soil structure, micrometres, right through to landscape. We can't just assess one particular scale and this image is to remind me, I think, perhaps more than anything, that this is the crucial bit that we can't mess about with too much or get wrong. **[Slide 5]** These are details of 2D and 3D images from work of colleagues on fine soil structure. If we interfere with this too much, this is the bottom line and that's it essentially. I think we have to assess all aspects of gene flow and risk assessment to do with terrestrial systems in the light of what it's going to do to the soil. A particular species, if you like, that concerns us most and that the public are perhaps most aware of and worried about, is oilseed rape. **[Slide 6]** Quite an old crop, it reappeared, mostly one species, some term it oilseed, has definite functions. Its characteristics here is that it out-crosses quite freely. It's pollen goes and crosses out to individuals of the same species and it leaves feral descendants in large numbers.

So, **[Slide 7]** this field of oilseed rape here will contain the crop that the farmer sowed, it will contain feral plants from some previous crops, maybe the one before that as well, and a few wild relatives, if you're very lucky, because they aren't very common. I'd like to mention the white ones there, the white flowered ones.

[Slide 8] If you then go to the field a year later to give an idea of the extent of the feral problem, then in this kind of small plot 10,000 plants give you getting on for a 1,000,000, probably rather than 100,000, shed seeds; 100 feral plants one year later, typically, and maybe 1,000 or 10,000 in the seed bank, so its become quite prevalent. If you measure the numbers, quite a large amount of seed gets left behind.

[Slide 9] On a regional scale we see that a single field leads to quite large areas being covered. These four tiles from our 500 square metre study area, 1,2,3,4…4 different years showing the sequential and gradual coverage of the arable area as oilseed rape was planted in each year, so that's the first year, the second and third and the fourth, and there's quite substantial clumping in groups of fields here with these out-of-field cell populations arising also. But this is the kind of meta-population network, each yellow field has in it, or will have in it, some feral descendants. **[Slide 10]** But will it disturb the habitat?

[Slide 11] The main point of impact is other arable plants. If you bring something new, in terms of a plant, into a habitat, the main point is competition. In general, there are a large number of very active plants out there, weeds, which are valuable to the food web, but they don't want, particularly, oilseed rape to be in there with them, anymore than they want anything else. It has quite a hard time getting established. **[Slide 12]** Here are some examples of the kinds of seed, if you were to isolate these from the soil you could easily tell them apart. And how do we assess the impact of feral oilseed rape arising as a deposit from a crop or through gene flow? **[Slide 13]** Three examples of field patterns in the seed bank, the size of the blob is an indication of population size and from these we derive properties, species area relations, species abundant relations, typical ecological descriptors and look at the influence of oilseed rape on these. And we find very little influence indeed. **[Slide 14]** If we look at the influence of oilseed rape, as a new plant type in the trade space here, feeding through to herbivores and predators. Perhaps more influence there. Oilseed rape is quite attractive to a range of organisms. But there is also quite a lot of work at many sites and this doesn't include the farm-scale evaluation sites at all. Really, if you are thinking about introducing feral oilseed rape and any hybrids of this type into the system then the effects so far appear to be very, very small indeed. **[Slide 15]** No substantial effect. It fills vacant spaces in the seed bank, it might alter the seed bank's composition slightly and there might be some transgression of effect to the food web. This is our present understanding of oilseed rape.

The second main area is impurities **[Slide 16]** and here I think there is slightly more to the story. **[Slide 17]** Our workers looked at distance and frequency, persistence over time. We haven't looked at the impact on food quality but clearly that is one of the outcomes of our kind of work and also there are issues of perception and preference which perhaps aren't amenable to scientific analysis.

Going back to this graph, the four tiles that I showed earlier. What we tried to do was to work out the way genes move from single fields of different types into other fields and into the feral populations. **[Slide 18]** And the story is really, condensing much information, many years work, is that gene flow from a feildfalls off very, very quickly, by orders of magnitude, within a few metres, a few tens of metres, and then spreads out over the environment. It has a very long tail as wind and insects carry it a long way. The work of Caroline Thomas and Gavin Ramsey here has demonstrated, in a real context, that gene flow happens over a long distance. It might be a very rapid fall off initially but then it moves out into the environment very substantially. It depends on the context. The values you get, this is a slide pinched from Gavin's talks, it depends on where you are. Gene movement from one block of the grey block to a red block, two types of oilseed rape, depend on where you are. The relative size of the blocks, whether you grow it from a little block to a big one or from a big one into several little ones and distance dependence varies accordingly.

[Slide 19] Before I go to the next slide, this is an example of Gavin and Caroline's work around the GM sites over the last two years. These are two kilometre squares, and these are ordinary oilseed rape fields, and these are GM oilseed rape fields and the dots, here, are measurement sites. There's a measurement grid in the environment. We are looking at this process using the farm-scale evaluation sites as a marker, a very convenient marker, looking at the way genes reach these sites and move over this region and the results will be published in due course.

In the soil, ferals and hybrids tend not to disappear that quickly. **[Slide 20]** There's again a very rapid decay over time, maybe again one or two orders of magnitude over time, practically in the first year and then quite a long tail as resistant individuals in the seed bank remain alive to germinate later. Our very extensive experiments and modelling on this givecurves that show decay rates of feral oilseed rape in the seed bank, and for up to six years, with, there can be quite a substantial degree of impurity within the harvested yield as a result of seed crop earlier in a previous crop.

Conclusions then regarding impurity. **[Slide 21]** It's not preventable and that isn't just our conclusion, it's the conclusions of several groups including European groups. They've looked at this and these will occur with low frequency of gene flow over several kilometres. There is a high range of insect vectors. We are unearthing that a number of insects, not just bees, are involved in spreading pollen around generally. It's a regional process. It depends on where the fields are and typical estimates of whole field cross-pollination which are uncertain, are that beyond a few metres, and for quite a few kilometres, you are going to get something of the order of one in a thousand seeds that are going to be 'impurity' if you like, and contain genes from some other crop nearby. Perhaps more important than genes flow the emphasis has always been, I think in the press and elsewhere, on the pollen of the bio-gene, but the residual in the field itself is probably more important. It probably contributes 1 in 100 or 1 in 1,000 itself to impurity. It can be limited. Our calculations show that something like 1 in 1,000 (0.1%) is simply not practical. 1% might be, it depends on how things go.

Very final conclusions then concerning gene movement out from crops and I'm not talking about GM crops as such, any crops of this type. **[Slide 22]** Ecological effects – all the indicators are that ecological effects of oilseed rape coming into the system and leaving ferals or hybridising are very small compared to the massive effects that occur through other agents. Although the impurity will be difficult to manage, it will be there and be hard to manage. It will require more rigorous standards of husbandry to keep it below 1% if that is a value that is ever accepted. I haven't mentioned GM and I haven't mentioned the farm-scale evaluations. I am talking about income of a particular plant species and its hybrids. This conclusion might be modified if the plant concerned brings with it or is associated with a change in field management. It's field management that is more important than the plant itself in terms of ecological impact. Thank you very much.

Dr. Ricarda Steinbrecher, Director (Econexus)

Dr.Steinbrecher: Good evening, I would like to thank the organisers for inviting me here. I am looking forward to this evening's discussions. I didn't bring any computer graphics. I have some overheads…

My task has been to review the horizontal gene transfer from Genetically Modified crops to other species or organisms. Through evolutionary studies we know horizontal gene transfer happens across species boundaries and even human boundaries and now the question is, what is the importance of that for genetically modified crops? Whilst gene flow from pollen might look at the concerns of trying to prevent genes going to nearby crops, and talking about containing a problem we might know about, horizontal gene transfer in itself might produce a problem. To which extent we do not know because so far the emphasis has been on looking at different components of whether it might occur or might not occur, we haven't looked very much at the consequences yet. **[Slide 1]** This overhead is just to see in which areas we would need to look. Basically we are looking at micro-organisms mostly because that is the most likely transfer. We are looking at bacteria, protozoa, fungi or yeast and viruses.

Here on the right-hand column you can see it's all transferred into gut micro-organisms and this can be micro-organisms found in bee's which have been fed with pollen or it can be farmed fish, or humans and there have been events which I'll come to later which actually looks as if it can readily happen, but basically this is the section of gut micro-organisms which are potentially capable of picking up the transgene and this would be gut organisms of earth-bound organisms like earth worms, nematodes etc.

On the left-hand side you see the micro-organisms which would come directly into contact with the plant, so it could be pathogens, symbionts or saprophytes… I don't want to go any further into that. This is just to show what a broad section it actually is that we might have to look at in order to see what the possible consequences might be.

[Slide 2] Horizontal gene transfer – there's three main mechanisms. I only want to focus on one of them, which is transformation which basically is the transfer of a gene via free DNA to a recipient cell. Just to recap from what I wrote in the paper, and I am trying to emphasise once I go through it, what are stepping stones and what are hurdles, which actually make it more likely or less likely that horizontal gene transfer occurs. Basically, in this top section we are looking at the availability of the DNA - will it survive, will it not - and basically free DNA in soils, in the gut and also in processed food, processed feed and silage.

There was the understanding, not too long ago, that DNA would not survive any of these procedures, like going through the gut or being silaged, but studies like Schubertt & Doefler in Germany who fed mice with the M3, M13 phage, actually found that some phage DNA, could be found in the faeces. Others tested silage and it was found there big enough to contain some genes actually in the 20k region still, which is very large. We also know it from processed feed but also in 1999, or was it 2000, I know Neilsen found that DNA actually is capable of surviving in soil for over two years. Now, that doesn’t mean that necessarily horizontal transfer can occur, because there is a difference between the physical survival of DNA and the biological activity of DNA and about the latter we know actually very little, so there is more research which needs to be done.

Now the next stage is exposure to bacteria. I've outlined earlier which areas could be meant, whether its gut or whether its soil. Now the major next step is the competence of cells that are able to pick up the DNA and in 1994 (Lawton Buckenhaber) wrote a review and had identified 42 different species which were capable of developing natural competence and could pick up freeDNA. It was clear that that list was just a very small amount, probably, of those bacteria around which are capable of developing competence and we know in the meantime that more has been added, like (Rita Pooley) has forwarded research adding to the organisms which can achieve competence. It’s a very complex mechanism, it’s even that somebody did some research recently on whether lightening can have an effect on it and indeed it can. There are so many different variants in it but again we could just take it as read that this can happen.

I think the most important point for the question of horizontal gene transfer from transgenic crops is actually coming up now which is the capacity of a cell to bind the particular DNA because that is quite often size-dependent as well as homology-dependent. Sometimes they need the 20 base pair homology; there are certain mutants strains which can do it with much less; but from here binding and uptake, we can have recircularisation if there is a place of origin, if it’s originally a plasmid form, or recombination which then can lead to expression which then, if there’s selection force, a negative selection force would lead to plant death, positive would lead to amplification; neutral, wellthe bacteria would remain where it is. Of course, degredation is part of the possibilities.

Now what actually is interesting in terms of horizontal gene transfer from trans-genes, which is the genetically modified genes, is that a lot of the steps here are made very easy. Homology, a lot of trans-genes actually have bacterial origin and so therefore if, for example, one would look at the hurdles so far, this gene would be very clearly a trans-gene. It’s got a promoter in front, it's got condensed genetic information, in this case the *pat* gene, okay it will have some terminal sequences but basically it is obvious to anyone that its not a plant gene because for one thing the promoter is different but also plant genes would have had introns in it and bacteria can't obviously use that. So the likelihood for a trans-gene to be usable by bacteria is much increased now. Therefore the evidence we have that, for example, gene transfer from plants hardly happens to micro-organisms, basically that data doesn't have any relevance to this topic any longer because we are talking about the different type of genes available now.

Now the likelihood has jumped up drastically for it to be transferred and possibly used. In this case we have also not only that the bacteria could use it, since there are no introns, we also very often have a promoter in front which is from, in this case, the cauliflower mosaic virus promoter, which works in the plant but also is capable of working in many other organisms such as bacteria and fungi, so we basically have a situation where we have increasing likelihood of the transfer, yet we do not know anything about the consequences. No tests have been done with that.

I wanted to briefly outline in relation to Part B of our submission on our papers… viruses. That with transgenic plants which contain viral elements we will need to have in mind that trans-genes might recombine and actually they have been shown to recombine quite happily with viruses, and can give a different advantage to different components, to different viral infections. Some viruses will infect the plant and propagate, otherwise they might end up in the plant by the insect, but will not spread. If those viruses now would get a hold of the trans-gene which is highly adapted to that original plant, then the trans-gene would give the non-infected virus potentially quite an advantage compared to its parental lines.

But if one looks at infectious viruses then that advantage might not be given because it would have to compete strongly with its parental lines. Of course relationship bears on this as well, a high degree of relatedness helps in the combination. I end it here and thank you.

Dr. Mike Wilkinson, Reader in Plant Genetics (University of Reading)

Dr.Wilkinson: Epileptics be warned, I've got a number of slides and I'm renowned for going quickly. **[Slide 1]** I'm going to be talking about the problems of detecting gene flow in gene crops to wild relatives. **[Slide 2]** If we look on a global sense, you don't have to take all this in, I'll be asking questions later perhaps, but Norman Amstrad looked at the 13 most important crops round the world and when you talk to him he says that if you look in a global sense then gene flow is a real problem with all but groundnut having the possibility of hybridisation in some relatives or other, and groundnut doesn't because it flowers underground.

[Slide 3] In the UK it's a little bit more simple. Raybould and Gray, going back to 1993, reviewed 30 crops. This needed a little bit of updating, but in essence of those crops 7 of them have no wild relatives in the UK which can cross-hybridise, 11 have the potential for hybridisation and a further 12 have a strong history of hybridisation, and therefore, when we talk about gene flow to wild relatives we have to consider the crop and the context as I'll explain a bit later on.

[Slide 4] In the United Kingdom… I apologise for this slide, obviously something went wrong with my tabulation… the first wave's going to be maize, oilseed rape, possibly sugar beet, and possibly potato. Of these, oilseed rape many wild have relatives with which the crop can hybridise, sugar beet has one wild relative which is a member of the same species, potato has three relatives but none of which will hybridise.

[Slide 5] Now when we are talking about trans-genes and movement into a wild population and subsequent spread, it's actually quite a mobile approach, it's not just the hybridisation itself. The trans-gene must stabilise by a process called integration, then it must spread between populations so that it becomes abundant within the species and in the area of consideration, then in some way this must change fitness which leads it to change in population size, population density or distribution of the species and then this change can have effects on all the other organisms be they herbivores or predators or parasitoids of the herbivore and this in turn can change community structure.

[Slide 6] Now if you are going to do a quantitative type of approach of looking at this process, you have to think of it as a linear process and you start at the beginning, you start at hybridisation.

[Slide 7] Okay, so why bother quantifying hybridisation? **[Slide 8]** Well, first of all hybridisation affects the likelihood of subsequent of these consequences or factors within the pathway. **[Slide 9]** If I give you an example, if we are worried about a GM crop in some way affecting a specialist parasitoidof course it doesn't just jump on to the parasitoid a whole series of prerequisites must happen first. **[Slide 10]** First of all you must have the hybrid, the hybrid must then self-fertilize or back-cross leading to the trans-gene perhaps stabilising. The trans-gene must then spread within that population into other populations and then that must affect, in this case it was insect-resistance perhaps that would affect depressed herbivore numbers and the depressed herbivore numbers in turn may depress the specialist parasitoid that fees on it. Okay so we need to think of it in terms of a progression and of course everything depends on how many hybrids you have in the first place.

[Slide 11] Second reason for quantifying hybrids is that the number of hybrids you have determines how effective measures are to stop hybridisation happening in the first place. There has been a whole stack of different measures posed but the most crude and least effective method at the top, isolation distance, down to perhaps the most effective methods down right at the end which use technology itself.

[Slide 12] Okay, so if we want to provide estimates of hybrid abundance and other exposure terms, we have to relate it at the level at which decisions are made and that's the national scale which makes things a little bit more tricky. **[Slide 13]** Okay, so we've been trying to do that with oilseed rape and what we were trying to do is estimate F1 hybrid formation between crop and this particular wild relative, across the whole of the UK. First of all, when you do that for any particular crop you have got to identify what the recipients are, then you've got to quantify local gene flow, then long-range gene flow, and then you've got to combine these together. Sounds easy but in actual fact it's quite tricky. **[Slide 14]** This is obviously rape and **[Slide 15]** the closest relative we found with which it could hybridise with is something called

Brassica rapa, otherwise known as bargeman's cabbage or wild turnip or something in French presumably.

Now, *Brassica rapa* actually grows in three different contexts. **[Slide 16]** It has two major ecotypes but three different contexts. It occurs occasionally as casuals of disturbed land, more commonly in Scotland than in England. It occurs infrequently as a weed, it occurs quite frequently as a volunteer, but infrequently as a weed across the UK, and quite commonly has stable wild populations in riverbanks. When you are estimating hybrid frequency you have to consider each of these separately. **[Slide 17]** Here it is as a weed. And the thing about *Brassica rapa* grown as a weed is that it's surrounded by the crop, so that makes hybridisation far more likely. **[Slide 18]** In fact, if you take seeds from these plants you get between 9 and 93% of seeds off the *Brassica rapa*, are actually hybrids with the crop, and the average is about 60%.

So surely then that means that hybrids are going to be everywhere? **[Slide 19]** Well, no because again we have to consider the context. In this case *Brassica rapa* as I have already said is an infrequent weed and secondly they have consider the crop rotation and the methods used for weed control. **[Slide 20]** We see *Brassica rapa* in its true sense as opposed to volunteers and actually largely restricted to Yorkshire and Humber region with the frequency outside this area we have estimated a ½% of oilseed rape fields, so it's not very common.

[Slide 21] Also, when we look at the hybrid survival we have to consider the fact that the hybrid seeds actually show very low dormancy whereas the *Brassica rapa* plants are very dormant so that means in the year following the hybrid seed set, most of the hybrids will germinate but only a small proportion of the wild seed, the *Brassica rapa* seed, will germinate. So we have to consider this because in the next year weed control is extremely effective. **[Slide 22]** In fact next year if you look at what happens there's obviously grain, next year is cereal usually followed by cereal… but the key thing is that in this year you can use a broad leaf herbicides which are extremely effective at controlling *Brassica rapa*. So the next time you get reasonable numbers of *Brassica rapa* again is not until you can oilseed rape again.

Okay, so how do we look at them? So what we've done there is we've looked at that at the geographically explicit level and we're trying to estimate the number of hybrids across the UK. **[Slide 23]** It's a bit more tricky when we're looking at wild *Brassica rapa*, and again I'd just remind you that we're looking at local hybrids and long-range hybrids. **[Slide 24]** This is a rubbish photograph, and you will notice that here is the *Brassica rapa,* a natural population growing by the river Thames here and this is oilseed rape. This distance between those two is about half a metre. **[Slide 25]** If you collect seeds from these plants you get about between 0.4 and 1 ½ % of them are hybrids but again that is an over-estimate for the reason I mentioned before. When you actually look at the hybrid plants its much, much lower.

We have now estimates of how many hybrids you get when the two come together but that only gives part of the question. **[Slide 26]** How often does this happen? In other words, if we want to know how much local hybridisation there is we have to know how often the field is next to the recipient population. So one of the things we have done…you can cheat. **[Slide 27]** You can use satellite imagery. Now satellite imagery is really good because it can use the appropriate masks, it can identify oilseed rape, and there they all are. Now one of *the Brassica rapa* only grows by rivers so we overlay the river systems, all now you have to do is pick on a few willing volunteer students and send them out to visit every time there's an oilseed rape field next to a river, and I did that, and I wasn't very popular for a long time. And in this particular area we only found two instances where all three elements came together. We are now in the process of doing that for the whole of the UK using a similar but not the same sort of strategy because otherwise I'd be lynched. **[Slide 28]** This is a sympatry liklihood map, in other words a map of where all three elements come together and quite clearly here the river bank oilseed rape and oilseed rape and the river, of course, all come together, mostly in this area, mostly in east England. You will notice that Scotland is actually sadly lacking in riverbank *Brassica rapa*.

Right, okay. **[Slide 29]** So we are now in the process of estimating the total number of hybrids per year by combining these two things together. **[Slide 30]** OK, just the conclusions then. In essence the number and distribution of hybrids that we get determines the scale, speed and possibility of any subsequent ecological change, therefore it's important to measure it. The hybrid numbers in a country determins the feasibility of correction measures. If we only have ten hybrids per annum in a year then something that reduces hybrid frequency by ten to nine is going to be extremely effective. If we have 10 million and it only reduces hybrid frequency by ten to the minus three, then it's obviously less so.

[Slide 31] It’s important that we have error estimates in any estimate of the number of hybrids which we are having incorporated into our work and hybrid frequency estimates should be followed by measures of other parts in the pathway. Okay that's it, thank you very much.

Professor Tony Trewavas. Professor in Plant Biology (University of Edinburgh

I'm largely going to read this out because I'm going to save time. **[Slide 1]** The old saying that *vox populi; vox dei*, as every philosopher knows, cannot be trusted in scienceand that's why we are here tonight, and I hope that while the public may be concerned, we know that that concern can quite often be misplaces, but science is quite clear as far as I am concerned, concerning the crops on trial in the UK the debate, at lease in the public is really about values, feelings and beliefs and I wish people would be, in many cases, more honest about the political beliefs they hold about this rather than trying to corrupt the science.

Assessments will always made by coast-by-coast basis, and approval of one GM crop does not provide blanket approval of all. A most important thing to state. In risk assessment relative risk is crucial. Comparison is made with what we do now and is accepted as safe from a history of experience. And in most cases, as far as I am concerned, you have to compare your GM crop with a conventionally produced crop and if the trait is the same in both, so far as I am concerned, the risk is no worse between the two. There is no absolute safety for anything in human life but we do act as though there is, unfortunately, who regards their motorcar as unsafe. **[Slide 2]** We have all eaten genetically engineered food all of our lives. Conventional plant breeding, let’s remind ourselves, uses natural mutants, that is natural genetic engineering. Why wait for nature to do it. As we replicate by GM what nature has already done, insert dwarfing genes, for example, which we could do, is there really any difference? Induced mutation, radiation used on this number of crop samples to speed up mutation rates enormously, that data was issued by the International Atomic Energy Authority, year 1999. Estimates suggest radiation modifies up to 10% of the genome, 80% of the world’s wheat, it is estimated, has changed genes from radiation induced muto genesis, we basically have no idea what genes were modified by that process and yet is anyone agitated about it?

Genes obtained from weeds for pest-resistance. This is frequently being used in cereals and cereals have hardly any species barrier, so far as I can see, with embryo rescue you can cross almost anything. In comparison, GM it is much more targeted, quicker and more accurate, at least we do know what they are doing, in part, when do that and, quoting Bob May, we share 50% of our genes with a banana and with some people you can see it rather directly.

[Slide 3] Gene flow from the same crop, just to reiterate a few things, the figure from detailed studies by Rouch and others in Australia. I think this is the most detailed summary I have seen from gene flow to the same crop and I am going to leap ahead and just show you these two pictures and then come back**.** **[Slide 4]** This is the first of these, the whole experiment involved over 6.5 million seeds, individual seeds measured. What you see here is a single field on this side here of GM oilseed rape measuring the movement of that trans-gene to an adjacent field of rape. You notice it goes up for a distance of about 3,000 metres but these are 190 separate samples taken through 63 fields and each little bunch is given a frequency with which you find a transgenic seed. You see the maximum here is about 0.2% and if I go onto the next one **[Slide 5]** the data over the whole 63 fields averaged here you find the maximum contamination, if I can use that word advisedly, because it is perhaps a simple way to put it, the maximum trans-gene movement per field is only 0.07%, rather lower than the figures we have been given before. This is the spread up to three kilometres probably by bees, thank you Gavin Ramsay for telling me that, I always thought it was possibly wind. Varietal purity, seed certification and/or product segregation is not a problem if that is generally true because they only guarantee 99.5% purity anyway. And as regards organic regulations, the EC level for non-GM description is only 0.9% GM in the sample. So you see that the present trans-gene movement, at least in rape, is considerably below that.

[Slide 6] Gene stacking of herbicide tolerance in volunteer hybrids has been reported in Canada arising from two GM rape and one conventional HT rape within close proximity but any mixture of cultivars, one crop growing in close proximity, will give rise to similar problems. Cross-resistance to herbicides is well known and reported many years ago. The problems, therefore, of this kind are not unique to GM crops and more of a nuisance than a problem and of course much more easily detected now we have easier markers of GM crops. And to quote from Mike Crawley's experiments, all current GM crops or equivalents do not survive in fallow fields, an observation, of course, first made by Laws in 1900 and he looked at the survival of wheat.

[Slide 7] Introgression, these features must be there and I won't read those out because they have already been dealt with by other people, but with current herbicide tolerant and pest-resistant GM crops, as far as I am aware the only things on trial at the moment, intergression at a low rate can occur from oil seed rape into several closely related weeds like wild turnip or sugar-beet int0 seabeet, so should we be concerned?

Well, I think the following is important. Current intergression hybrids do not survive, that is my reading of the literature, that is their fitness is weak and I don't find myself surprised by that observation. Herbicide tolerance is not considered to be of genetic value outside the farming environment and thus will be quickly lost.

[Slide 8] Weeds are a seed, of natural mutant variants and it often seems that we have forgotten that weeds are not a uniform genetic population. Herbicide tolerance is already present in weed populations insofar as I am aware in all weed populations as indicated by the speed of resistance development. That is we now in fact have some 15 herbicides worldwide in which we have weeds resistant to them but this herbicide resistance develops in a very short period of time and the conclusion from that has to be the gene was already there. Pest resistance is already present in weeds and indeed we have used it in crop breeding and in most plants as indicated by the rapid spread of exotics transferred from their normal environment when pest pressure is removed. Most weeds must have resistance to pests of one sort or another or they will not be a successful weed. Thus present GM traits are not novel.

No evidence that genes inserted by GM transfer more vigorously to weeds. Of course bear in mind that might change in time and at least three crops are marked with resistance to herbicides from conventional breeding. Atrazine-resistant rape has been available for well over 20 years, maize resistant to aledazolidone, I'm sorry I got that wrong in my script, and soya bean resistant to sulfonylurea. No known problems have emerged with the use of these particular crops in terms of the weeds and there might be many reasons for that.

[Slide 9] Traits which could increase weedless potential are those that increase tolerance to drought, cold or dormancy. However, crops with these traits are already currently used and they do not currently lead to increased weed problems. I do emphasise currently. In the UK an estimated 1,000 crop cultivars are introduced every year for conventional breeding mainly for pest resistance but other unique traits which may have resulted from the breeding are of course never tested for if they are not immediately obvious. In many cases I have to estimate that we understand very little about conventional plant breeding even though we assume it is safe. One of the impacts on bio-diversity currently the herbicide tolerant trait, has been introduced into many different lines of rape and therefore they may not be a worry.

[Slide 10] Avoiding gene flow has already been mentioned by Mike Wilkinson. Isolation of crop, use of crop that produces sterile flowers, another possibility that propagates vegetatively, use of terminator technology, production of sterile seed is essential if you are going to actually have vaccines or pharmaceuticals in the plants. In fact it is very difficult for me to see how this will ever get out into the open, it will have to be contained in greenhouses.

[Slide 11] Transformation via the choloroplast genome. This is a technique that has been pushed particularly by Daniell & Dhingra and I put down here the advantages of chloroplast GM compared to nuclear GM at present. Chloroplast traits in most crops are maternally inherited - in most crops, I emphasise that word, not necessarily all. The pollen does not contain chloroplasts. I worked on pollen for ten years. I have never seen a chloroplast in a pollen tube, in fact it couldn't get in because, it’s too big. Much higher expression is achievable with a trans-gene when used, with BT protein, for example, 100% kill of target insect was obtained with that product, and thus in fact no resistance development was at all possible. Interesting to see how that was managed in the field.

Single sites for incorporation of gene. Incorporation uses homologous recombination because you are dealing basically with a prokaryote type genome. There is no gene silencing, which has caused complications with nuclear genes. Multi-gene constructsts and whole operons are expressed in chloroplasts. Systems for ready transformation are present. Potato and tomato are the major ones transformed, together with tobacco. Cholera vaccine and biologically active growth hormones expressed in chloroplasts. That's already been done and that can be valuable in certain parts of the world. Marker gene removal methods at present using CRE-lox. However, seed spread is still possible and birds can carry seeds long distances. **[Slide 12]** I put in finally this is of benefit to the use of herbicide tolerant crops, because this never seems to be referred to, we only talk about the difficulties rather than the possible benefits.

Had we not originally gone contrary to the laws of nature, by ploughing the land we would have avoided the problems as well the time-consuming efforts to solve them. We would have missed all the erosion, the sour soils, the mounting floods, the lowering water table, the vanishing wildlife, the compact and impervious soil surface. The benefit here is from the development of no-plough or no-till technology and while it is used a great deal in the States, it seems we use very little in this country. Unfortunately I think organic has diverted attention from what is an extremely valuable and environmentally friendly technology. All of Faulkner's claims have been established by measurement and indicate superiority of no-till agrictulture over organic and conventional ploughing technologies. Ploughing is the most damaging soil treatment and no-till agriculture most easily introduced with HT crops to avoid weed problems, and organic has no choice but to plough to mineralise nitrate, blah, blah, blah. **[Slide 13]** There's a list there which the Chairman is not going allow me to say, but these are the no-till benefits compared to a till agriculture. They are enormous and they are often not put down on paper like this so people can actually see the real benefits. Thank you very much.

Chairman

Well thank you very much speakers and now if I could please ask the speakers to now come on and sit, the four of you, over to your right, over there, and the three panellists on the Science Panel also come up and sit over here. I am sorry I have to rush the speakers but you do have the full papers in your dossiers and they have been on the web since a few days ago.

Now what's going to happen is that the three panellists, Professor Wilson, Professor Dale and Dr Brian Johnson who are on the UK Science Panel, they will question the speakers and that will go until just after 8.15 and then the discussion will be open to you in the audience and so who would like to start off?

Professor Michael Wilson, Chief Executive Officer, Horticulture Research International

Prof. Wilson: Yes I wonder if I could sort of kick off. In the presentations, three of the speakers, Mike Wilkinson, Tony and Dr. Ricarda referred to the containment or the reduction of gene flow through chloroplast transformation as a possible strategy. So we are here to propose containment strategy, but we also have to consider this in the context of horizontal gene flow apparently and the transformation competence of our gut flora. I wondered if any of you have any evidence of gene flow from chloroplast DNA in general, which is bacterial type of course, into human or for that matter herbivorous animal gut flora, because as a horticulturalist I am concerned if I am telling people to eat more greens and this might be a higher risk.

Prof.Trewavas: I know of no evidence whatsoever. I mean, apart from these experiments which were not produced by DEFRA but were funded by DEFRA, which showed that the bacteria in the gut can indeed take up DNA, and in fact the DNA is finally degraded and the bacteria go all the way through the human gut. I would have thought that if this event has happened, there are, I believe, sequences of about 100 bacterial genomes and yet I do not know of any case where anyone as pointed to a chloroplast gene in any of these bacterial genomes. So if the event happens, it must happen rarely. That's my view.

Chair: Any other comments from the other speakers?

Dr.Steinbrecher: There’s a few articles on this from different points of view, and the problem is that not much research has been done into flow from chloroplast into the micro-organism population. There is data from mitochondria, for example, which is also a plastid, back into the chromosomal DNA, which also can happen. There is quite a number of data available, but I think the problem would be greater now. If we really want to know the answer we would have to have the experiment of putting a gene into the chloroplast which might be of use or interest to the micro-organism and see whether it transfers. The problem is…. that these experiments, as far as I know, have not been conducted. So I think yes, it is crucial if we wanted to follow that line, that we might be, maybe, prevent gene flow via pollen, then we should re-investigate the rules on gene transfers.

Professor Phil Dale, John Innes Centre

Prof. Dale: Could I follow that question? There are millions of tons, I guess, across the world, of DNA going into the environment through human digestion and we are even digesting our own cells from our digestive system, so we are digesting human DNA, through animals and coming directly from the environment. Now some of these genes code for pretty nasty things like toxins, virus toxins, plant toxins and so on. Even if our crops don’t express these genes for toxins …or don't express a very high level of toxins, like alkaloids, the genes are still there. So all these genes, and some of them coding for really nasty things like ricine and so forth, are dropping into the environment. So what special features are there about GM that raise these concerns? We know that bacteria can pick up genes and express them even without a promoter, so I don’t see how the argument that a promoter is sitting next to the sequence carries any real weight.

Prof.Trewavas: Are you asking me that Phil or not?

Prof. Dale: Well I'm asking Ricarda but you can come as well if you want.

Prof.Trewavas: Well it’s got to have some sort of promoter surely? I mean if it doesn’t have, …I mean there are there are plenty of good bacterial people here who can answer this better than I can but surely without a promoter you are not going to get any successes?

Prof. Dale: If it expresses from an endogenous promotor, so it finds itself next to a promoter.

Prof.Trewavas: Precisely. So we will have to gain an endogenous promotor from somewhere

Dr.Steinbrecher: Could I just have clarification now, where you are talking about ricine in the form as it is in plants so that it can be taken up by bacteria, as the plant gene? Is you're your question or …?

Prof. Dale: Well there are masses, lots of genes from different sources, that's the essence of what I'm saying.

Dr.Steinbrecher: I was trying to point out earlier that the plant genes…

Prof. Dale: Yes but there are bacterial genes for toxins in the environment…

Dr. Steinbrecher: Certainly, certainly…

Prof. Dale: … that are quite able to be picked up and then expessed.

Dr. Steinbrecher: I understand that, I completely understand that. My understanding is that if you, for example, look at gut micro-organisms or at soil micro-organisms, it is the magnitude, now in the plants, of the genes present. But also it is that we do not have actually data collected. We know that there are certain limitations, for example, for gene transfer among microbia, for example in gene exchange, and some of this exchange happens, some hasn't… I don't know why it has or why it hasn't … I don't think that data really is available. I think the concern is more about trying to do the experiments and then seeing whether…our assumption that it is harmless, is right or not. Does that make sense? Because I feel that we have so far not tested a lot of the transfer to micro-organisms, for example. But on top of that, if you look, for example, at Bt, the *Bacillus thuringiensis* toxin, which is of course available in the microbial population as a bacterial gene. In the plant it has been altered, it is shorter, it's already in the toxic formula as a pro-toxin so it has been changed, so therefore you can't say it is exactly the same gene. It's worthwhile looking at it. If it's harmless, great.

Prof. Dale: Well, my point is really just trying to get the context in which we are making these evaluations. And you know, it’s tempting for scientists to say, well let’s take a reductionist approach and understand this, that and the other. But it’s important to accept that all of this DNA, from many different sources, is already dropping into the environment and we have to try and explain that away in terms of impact.

Dr. Steinbrecher: It is also a question of meeting points, in terms of contact and availability, that is another problem.

Dr. Brian Johnson, Terrestrial Wildlife Team, English Nature

Dr. Johnson: Well my only comment on that discussion is that given my extraordinarily varied and excellent diet, I’ve probably been ingesting huge quantities of very odd DNA indeed in my life. But I wanted to change the subject really to clear up what might be some confusion in your minds about hybridisation and its occurrence, possible occurrence, between GM plants and wild relatives. You may have noticed in the presentations that the paper from Mike demonstrated spontaneous hybridisation between oilseed rape and wild turnip and Tony who was saying that in fact introgression hybrids do not survive and may lack fitness. I would like to ask this question of you both really, and that is that I’ve just returned from an international congress about this subject and the consensus there is that spontaneous hybridisation between crops and wild plants is actually very common worldwide, probably more common between oilseed rape and *Brassica rapa* in Europe where *Brassica rapa* is a much more common weed, especially in places like Denmark, and between sugar-beet and its wild relative, sea-beet, and with grasses as well. The interesting thing about many of these hybrids, is that they are fertile and they do back-cross into the wild plant population so can you please clear up what seems to me to be a rather confusing picture?

Prof Trewavas: Well, let me say first, my reading of this situation, and I'll be taking this from Michael Wilknison's papers, so I'm not trying to blame you, that's just my interpretation. But so far as I am concerned the progressed hybrid is not a super-weed and that is it doesn’t seem to have any special property which makes it….

Dr.Johnson: That wasn’t my question. My question was, do these hybrids actually form..

Prof. Trewavas: All hybrids form, I think in my talk I did say that, there’s been wild turnip and oilseed rape and seed-beet and sugar-beet for example, I recognise that.

Dr.Johnson: Do they survive is my question.

Prof Trewavas: Well, perhaps that was a bad use of words in the sense that, yes they can be there and yes they can do something or other in terms of back-crossing. My interpretation of the literature is that they are not within the province of this thing which is commonly called "super-weeds". In other words, they have always been produced and you have fields of rape and you have some colonies of the *B. rapa*, let me get this right, yes that’s the right one. This phenomenon has always occurred but it has not been a serious issue in terms of generating a resistancy to the gene

Chairman Mike, would you like to… ?

Dr. Wilkinson:Yes, I think it’s important we distinguish between rural and wild here. In the weed populations, in particular in Denmark, there is irrefutable evidence from the Danes that there are cases of hybridisation forming a stable introgression but that’s a rather special case. In one particular case they were we looking at an organic farm which had been recently transferred from a conventional system, in which case they were getting volunteers of both *Brassica rapa* and *Brassica napus* all together and in those cases you do get widespread hybridisation and integration. As a weed, in the conventional sense, even in Denmark, the number of F1 hybrids you get is very low. But you still get introgression at a very low level. In the UK, as a weed, it is so rare, and it is so limited in its distribution in terms of number of fields, and in its geographical distribution, that the total number of F1 hybirds is very low. As far as the wild populations, these have been around since the time of Hooker who was arguing then that they were native, there is some debate as to whether the river bank rapa's are actually native, they have been subject to introgression but there is much less frequency and there is no clear evidence, at the moment, but I think that might change soon, of stable introgression, although it has almost certainly happened.

Dr Johnson: Can I sum it up by saying that you do actually agree that gene integration of crops and wild plants is a real phenomenon and that the real issue is does it matter?

Dr. Wilkinson: No, I wouldn’t agree with that. I would agree that it happens. I would not agree that therefore we just dismiss it. Because if you look at *Raphanus raphanistrum*, it will hybridise with oilseed rape but it's at such low levels that we just ignore it. The amount of hybridisation is critical in making these sorts of decisions. The reason why oilsseed rape is so interesting is because it has an intermediate hybridisation rate and therefore we have to consider the later stages.

Chair: So the answer to the question 'does it matter?' seems to be "it depends"?

Dr. Wilkinson: Yes, absolutely, context as well as crop.

Chair: Can I just ask, can people hear at the back, Okay? Any more questions please from the panel?

Prof. Dale: I have a question for Geoff. I, like you Geoff, am really fascinated by the gene flow question and its potential impact and the nuts and bolts. If you remove your inquisitive, scientific hat and think of it in terms of making these decisions about commercialisation, do you see there are significant gaps in our knowledge that we need to bridge, we need to fill, in that commercialisation decision. If I can tag another one that’s related to it. What characters, this is for Tony, would you be particularly concerned about in terms of gene flow? I think Tony, you said that the ones we have now, you are not particularly concerned about. Which in the future would you be concerned about that we need to think about?

Prof.Trewavas: My concern, so far as I am concerned, if you are putting in a trait by genetic manipulation that you can already produce by conventional plant breeding, the risk, so far as I am concerned, is identical with that of conventional plant breeding. Where we must be concerned about is when you start to introduce traits which you cannot put in by conventional plant breeding. But those obvious ones, on which you must get immense constraint, have to be pharmaceutical products and vaccines, because those will directly affect our health if they get out into the environment. Even if you get gene flow into weeds the possibility of changing things radically is definitely there. So those are the ones I feel must be very highly constrained and I think I said in my talk, constrained in greenhouses probably rather than out in open fields because I think it could be a very difficult thing to handle.

Dr.Squire: The issue of what's missing I think is important, but it's probably more important putting something like gene flow into the wider context because we have to compare how important is this compared with a range of other potential threats. It seems to me that the things we need are fairly mundane in the UK and elsewhere. Perhaps most importantly, there are two examples. One is to what extent have pesticides generally reduced the numbers of plants and animals that the system is in danger of not functioning, irrespective of GM or gene flow. So where are we in relation to proper working with the system and I think that needs a thorough look. Secondly, I am not certain we know whether the wider food web in the arable scene is resource limited, by the plants that form the basis of the food web, or consumer limited, by the other organisms that feed on those plants. There are some quite crucial issues that we don't fully understand. Another related one is how does the diversity of plants in the arable system influenc the soil functioning. So there are some quite big issues there. Now these are broader than GM and gene flow and I would address these and GMs in this broader context. Comparing GM with the massive potential impacts that there are coming or are here. Mundane but fundamental I would say.

Prof. Wilson: Could I move us back into intracellular gene flow and considering the comment that Ricarda made and trying to again accommodate two issues, that was viruses and recombination or, if you like, gene flow inside the cell. To date there must have been trillions of plants planted which contain the 35S promoter from Cauliflower Mosaic Virus and other sequences from plant viruses, from the trials starting in '86 through to today. If there is any evidence, I know of none, of gene flow to wild type viruses or changes in the viruses occasioned by having grown those plants, above and beyond the natural recombination and evolution of viruses themselves. Because I think the record is nine different viruses in one plant and most viruses, 96% of them are RNA viruses, and RNA has no proof reading, so there is a huge area of frequency and possibility for evolution in any case irrespective of gene flow and these other issues that we are discussing…. so I just wondered if you have any data on that point?

Dr.Steinbrecher: I did that paper together with John and John is the expert on viruses so…

Chair: Dr. Latham?

Dr. Steinbrecher: Dr. Latham

Dr.Latham: Can you hear me okay. I mean part of the question is, has anybody actually looked for recombination between the 35S promoter and viruses. You may be aware of somebody who has but I am not aware of anybody who has done that. Certainly not who's published research. And then the second question is, the 35S promoter is one of the least likely candidates for horizontal gene transfer to viruses. So that, in a sense, that is extremely small compared with the transgenes which are put into transgenic plants to make them resistant to viruses. And also a large part of the issue with horizontal gene transfer to other viruses of virus genes which are expressed in a transgenic plant is that the incoming virus will acquire a transgene if it recombines with that transgene which is adapted to the host. Now so far as we know the 35S promoter is not host-specific and works in all known hosts and so there is no advantage that we know to acquiring this transgene. There's no selection process. That circumstances may change, because we don't know very much about most viruses and that includes 35S promoter, but the issue is largely, has anybody actually looked?

Prof. Trewavas: Yes, it doesn't seem to be very widely known but, thank you Gavin Ramsay again for the information, in fact none of the oilseed rape in trials in Scotland actually uses 35S, but uses the robisco promoter, is that right Gavin?

Dr Ramsay Yes

Prof Trewavas: Okay so that one goes out of the window as a concern straightaway. Secondly when you produce a virus-resistant crop by conventional plant breeding does anyone know what the virus resistance is caused by? What is the actual mechanism, what is the manner in which these crops become virus resistant, because to my mind if you can't answer that question then in fact an ordinary virus resistant crop produced conventionally is as hazardous if you want, as anything you produce by GM, you simply don't know.

Chair: I suggest we get the responses out from Phil and then I really would like to open it up because it may well be that there's more people in the audience here who could answer that question than here so Phil first and then Ricarda?

Prof. Dale: I just wanted to make the point that it's known now that there are quite a number of viruses becoming integrated into the plant genomes during the natural life cycle and I'm just wondering to what extent that should influence our thinking about putting trans-genome in?

Dr Latham: As far as I know, the viruses are not integrated as part of their life cycle, are para-retro viruses and they have a DNA component and they have an RNA component, But I am not actually aware they actually integrate into the plant genome.

Prof.Dale They are integrated into the chromosome

Dr Latham: Yes I understand that they may have got there by accident, and some examples have been uncovered quite recently. Examples where there have been found viruses which integrated into chromosomes and the question is, should we have already seen the consequences of that in terms of horizontal gene transfer. I think I suspect it's what you are interested in. And the answer is that we can't answer that question because we haven't addressed it in a sense. And so the viruses which we're talking about which have integrated into part genomes are not RNA viruses, they are viruses with a DNA component and therefore we are talking about a restricted group of viruses which is the para-retro viruses, as I said, that they are not one of the most common plant viruses.

Prof. Wilson: Could I just add a footnote to that. The viruses that integrate are badna viruses. Bananas have been in the news recently, and most bananas have badna virus DNA sequences integrated into them. In Uganda, bananas are the principle component of a staple diet. In Uganda, HIV is also extremely prominent and many of us are aware, it is not to do with gene flow but it's to do with some of the other issues that permeate public discussion about GM and virus transgenic plants, particularly the Caulifower Mosaic promoter specifically, but these things could activate genes, create new viruses, create cancer and all this sort of stuff. But it's very significant that in Uganda where an integrated plant para-retro virus and an animal retro-virus are together in the diet, and nothing has happened.

Chair: Now what I would like to do is open up things to you in the audience and I think maybe we could continue for a few minutes on this question of viral integration and viral sequences into plants and then possibly the effect on the plant viruses after they have been integrated into the plant host itself. But could I really encourage you to take part, with questions that may be in your mind or more importantly, as most of you have quite a bit of experience who are sitting here, if you want to make comments. Because as a kind of layman to GM I have been hearing lots of confusing messages and I don't really envy Catherine Henderson preparing her 3,000 word report on our conclusions here. But it would be a big help now, and for the rest of the meeting, if we could get real input from you. Whether it's questions or whether it's comments. So could we start off at the back please. Thank you. And I would like you to identify yourself and where you come from as well.

Derek Paton from Dundee

Mr PatonPD: Good evening, I'm Derek Paton from Dundee. I am currently professing quite vociferously against the imposition of GM ingredients in food. I'm hearing repeatedly from spokesmen of the Scottish Executive who are repeatedly saying that there is no GM in the food chain. We've heard different here tonight from certain commentators. I have objected to the fact that one of the halves of the current farm scale trial fields is not under any form of monitoring. That is beyond the 50-metre buffer strip that exists in a GM trial field.

Chair: Now that's a specific point so I would like to focus on point by point.

Mr PatonPD: By the way I'm here at the behest of ISIS, the Science in Society…

Chair: So could I take that point please, that you're making a criticism of the field trials. That the trials are not being conducted properly. Could you we have a response for that please? Thank you.

Dr. Squire: On the issue of whether there are any measurements of gene flow from the GMs to the conventional side of these trials, the answer is that there is, throughout the UK. So the information you have is not quite correct. In Scotland in particular there is an ongoing programme, as I indicated, of much wider measurements of gene flow to nearby fields and feral and wild populations. So estimates of gene flow are made to the conventional field beyond the 50 metres.

Mr Paton: Could I just reply to that? The fact is there's no monitoring carried out on the crop beyond the 50 metres of these trial field, and reports have come from New Zealand, for instance, where pollen has travelled a matter of miles. I feel that…

Dr.Squire: I'm sorry you're wrong, you said that again. There is monitoring of cross-pollination beyond 50 metres in those fields and in Scotland to much wider fields. So what you're saying is not correct. Sorry.

Chair: I'm sorry, that's you done, you've had your two minutes. Even in the hour that we've got, there's only going to be about 20-25 questions if we're lucky, if everybody is very concise and succinct we may get that number in. So I will just ask people to be very succinct with their questions and then I am sure you will get succinct answers from the speakers and the panel. So thank you very much for that question and that was the response. Any more questions please or comments?

Dr Bruce: **Dr Donald Bruce from the Church of Scotland**

Donald Bruce from the Church of Scotland, Society, Religion and Technology Project. We did a big study on GM ethics several years ago. The two questions the public might well be asking, beyond the more scientific discussion, would be "is the gene flow that can be predicted, going to be ecologically significant" and "what about transfer to things like gut bacteria in humans". Where are we on both of those two currently?

Chair: Thank you very much for that. Who wants to start on the question?

Dr. Squire: Just very briefly on the significance as far as plants and invertebrates and so on. It is significant with respect but very small, so there has to be an impact but it will be very small compared to many other impacts in the system, I'll pass part of the question on….

Chair: The human gut, did you want to speak to that?

Dr Johnson: I would like to address that because I think it is a very important issue and it's right the public are concerned about it. The actual rate of hybridisation is not of great significance if hybrids are exceptionally fit. Because an exceptionally fit hybrid could in fact multiply through integration. So such a plant would become very many plants. There's some interesting experiments being carried out in the United States where they looked at the increasing fitness of plants and watched the way they multiply in fields. You probably know that invasive species, alien species behave in much the same sort of way. The interesting question scientifically is "what do we know about how the existing transgenes that are being used in wide scale agriculture, affect ecological fitness" and the answer to that is we don't know. So far as I am aware there are only three studies that have been carried out in that area. All of them are very new and all of them have only measured the impact on fecundity. And that's not the same as ecological fitness. In one of those studies they found the fecundity is unchanged. In another, the fecundity was significantly increased when the transgene is added to a wild relative of the GM crop. Now it doesn't necessarily mean that that crop will be more ecologically fit in a genetic sense. What it does say is that there is a risk that it could happen. It will not tell us the size of that risk, nor its ecological significance. We've got a long way to go before we understand it, especially with those genes that I think Tony sees as a particular risk.

Dr Wilkinson: I agree with most of what you said there but not entirely all of it. Yes, it is true that the amount of work that has been done so far on fitness has been limited. And there has been quite a lot of work on demography, particularly Rosie Hales' work and it's ongoing. It's not in the public domain but that is fast coming to fruition as is some of the work we are doing. However, one of the things that you have consider when you are talking about ecological fitness is the presumption that something which is fit is bound survive. That is not the case. Founder effects are immensely important. If you look at the history of invasions in other countries and other continents, you will find that quite often the Founder event is unpredictable. So just because you've got one Founder event with increased fitness, doesn't necessarily mean you are going to get a spread of the trans-gene. It depends on luck aswell.

Prof Trewavas: I've read the five papers produced from the study commissioned by the Food Standards Agency, when they came out, and it was over a year ago. And the Food Standards Agency described the results as insignificant. I agree with that conclusion having read through the papers. It was quite clear that bacteria can take up DNA through ingestion. You can pick up parts of the SPS which people are fed with and if you look at ileostomist, that's those who have a false stomach, you can certainly pick that up. By the time those bacteria have gone all the way through the gut, that DNA has been degraded. It has not in fact been incorporated into bacterial DNA or transformed DNA

Dr Latham: the study suggested that the bacteria were living in the gut. It's irrelevant whether they come out again at the other end….

Dr. Steinbrecher: I still owe Phil a bit of an answer from earlier because I couldn't quite think fast enough there. Concerning the question of the importance of the weight. Which gene might be problematic and which not. I completely agree there might be some genes where we don't even need to worry about with horizontal gene transfer because it's everywhere. But some genes we might want to. Like as I feel like with the *pat* gene, but that is a different issue. So now I think the study which you were referring to, the Netherlands study, which shows that bacteria were able to pick up genes from genetically modified soya is not so much relevant in terms of asking what is the consequence of that particular event.

What it was trying to show is that horizontal gene transfer happened, which so far had no proof whatsoever. It actually had been a bone of contention for a long time. So I think the significance of that finding was not so much in the question, "what would the result have been", because we don't know what part or where it was integrated. But the question is now no longer "will it happen?" We now know, yes, it does happen. So really we need to focus on the consequence and some genes we will not need to investigate further. But I was looking at a study which showed that if you have genetically modified plants resistant to glufosinate ammonia, for which the *pat* gene is the resistance gene for that. These plants will then produce the non-toxic form, the N-acetul-L-glufosinate ammonium which is called NAG. Now that gets transferred back by gut organisms into the toxin L-glufosinate amonium, to 1%-10%. There was studies done by Agribo, actually in the gut. *E-coli* has a gene which is able to do that, which has been used in other genetic modifications, so therefore, the whole complex between the *pat* gene (phosphinothricin acetyl transferase) and NAG and the whole system, we just know too little about in order to even answer "what are problems". But some genes I think need more looking at and others we do not need to worry about.

Chair: Right, final comment on this particular topic for the moment.

Prof Dale: The *pat* gene is in streptomyces, it is in standard soil microorganisms

Dr. Steinbrecher: No, that's the *bar* gene here in the UK. The *pat* gene is from a mutant in Cameroon. Yes, it's highly more active.

Chair: Right, let's move on. We have a question in the middle here please, can we have the microphone.

Dr James Gilmour, (British Crop Protection Council)

James Gilmore, (BCPC) I would like to address the more general ecological context and pick up a point that John Dale was making earlier on. What puzzles me in this whole debate is why the concern about this gene flow from transgenic plants? In terms of potential ecological impact, and if we stick with oilseed rape, we've changed the oilseed rape we grow in this country very dramatically in the last 20 years. It used to be very high in Erucic acids and very high in glucosinolates For our own reasons we changed the crop we grew. We removed most of the Erucic acids, we dropped the glucosinolates levels to a very low level and we now call them double lows. In terms of potential ecological impact, forget about the crop, we are looking here at the hybridisation of the wild relatives. Changing the glucosinolate levels has a very great potential ecological impact in terms of its influence on the micro-flora and micro-fauna that inhabit those. Now that was all done by conventional plant breeding and yet the ecological impact is potentially very great.

So far as I am aware, nobody… no one has looked at that and nobody who is presently so concerned about the gene flow from transgenics was ever concerned about that and is still not concerned about that and yet that effect is very much greater than anything that's going on at the moment. So what is it? I am very concerned as a biologist to know, what is it that's so special, so different, about these GM transgenes that we all should be concerned about them and we are not concerned about these others.

Chair: That's a very key question, so speakers and panellists, do you want to respond to that?

Prof Trewavas: Well, what is a concern depends upon the number of activist groups that decided to make political capital out of it. That's quite simply what the answer is to that particular thing. It's a political question, it's not a scientific one. It's like so many things in biology, like the gut bacteria. If it's a problem, we've always been eating DNA, and gut bacteria have always taken it out. Why are we specifically now saying that there's a major difference between the two? Well I suppose, one answer is that people say you can take a gene from almost any organism and express it in another, so maybe the genes you are now ingesting may be different, and that might give rise to a consequence. But after all it's only a stretch of DNA which we are actually talking about in that regard. So I think in that context you have to recognise the political aspects of the debate which has been induced here and in fact this is not a real reflection of the changes which have gone on in agriculture. It is because certain groups use campaigns as a means of maintaining their organisation, but without campaigns there is no organisation.

Chair: But the fact still seems to be Tony, that that was an interesting scientific question. Thank you for that prompt answer. First Geoff and then Phil

Dr. Squire: I agree, the rise of oilseed rape in the 70's itself and the change in glucosinolates are quite important There are ecological of that from those varieties and …it's an important issue. I think that the particular thing that scientifically is valid in the present instance, and I agree with your point entirely, is not so much the GM-ness of the oilseed rape but what you do with it. And that is you’re potentially changing the herbicide profile, the timing of it, the nature of the herbicide, the range of individuals that it might kill, and that potentially, as other changes in herbicides over the past 50 years, could have proven ecological consequences.

Dr Gilmour: Chairman. That’s an effect in the crop. That is not an effect in the wild relatives in the wild community.

Dr. Squire: I accept that but that’s where the present experimental issues arise, but it’s also a concern if in the feral relatives of those plants become herbicide tolerant and remain so for several years and become amplified the next time you use that kind of herbicide.

Prof Dale: I think your comment gets really much to the heart of the issue. We debate process rather than product. We can produce glycosate tolerant dry grass. Just being done, conventional breeding. Nobody mentions this about it. I've debated this many times and it becomes political and we are not here to talk politics. But I think that this is the basic problem, that we’ve got hooked on this particular bit of technology and unfortunately we are missing the potential impacts of other aspects of agriculture. Now you can commercialise oilseed rape with it's Atrozine resistance. Nobody asks any questions, by conventional breeding. Atrozine is very persistent. Has all kinds of potential environmental impacts. And so I think in this debate we have to recognise in the scientific process, we have to recognise this and hopefully something sensible will come out of it at the end, that we really should or are talking about product rather than process.

Chair: Can I take it that the three hands that are up, as well as John who's next, that they are on the same question or is it a new question? I want to stay on this same question just for a few more minutes and the question really is "there's been many analogous effects observed with conventional plant breeding, what's so special about GM?" Do you want to answer that John?

Dr Latham: There are two answers, in my opinion, to your question. One is that when people who are concerned about the environment, for instance, and who are scientists, are not unconcerned about the impact of conventional farming. Farming has an enormous amount of impact on our environment. Now, the issue with GM crops is that you can introduce traits which cannot be essentially, …or you can induce plants to do things that they could not otherwise do. In the case of the glufosinate resistance, you are introducing a transgene which turns glufosonate into another chemical. But that other chemical accumulates in the plants, it's not a normal process of biological transformation where in a normal biochemical pathway the chemical is taken from A to B to C to D to E and back into carbon dioxide by the metabolic processes of a plant. If you introduce such a transgene into a plant, you are essentially introducing a new biochemical step which is not normally borne by that plant. And in the case of gluphosphate resistant crops, the product of that transgene accumulates in the plant and this is why Ricarda is concerned about horizontal gene transfer of that gene into gut bacteria because….

Chair: Sorry…you have to finish your point soon.

Dr Latham: Okay, its coming… So if you have a crop. If people eat a crop which is accumulating a precursor of a toxic chemical and then you eat it and you turn that precursor back into the toxic chemical, that's something that would not normally happen.

Chair: Okay, so we'll find a response on this I think back to the original question.

Dr Gilmour: That's true as far as the crops are concerned. We're not concerned about the crop that we're going to eat, we're concerned about the wild relatives growing in wild, natural communities. They are never going to be sprayed by these wretched herbicides….

Chair: I must say I am a layman myself I wonder if we should know a lot about gene flow from conventionally modified crops. Look let's stay on it a little bit longer. Two more from the table

Dr Wilkinson: This exact questions was raised last week at the gene flow conference in Amsterdam which was a conference full of ecologists and they were essentially, rather reassuringly, when asked what kind of transgenes in constructs they were worried about, none of the first wave were identified. However,

Chair: First wave?

Dr Wilksinson: First wave transgenes, so herbicide tolerance, even insect resistance, wasn't really top of the agenda. However, what was higher on the agenda were the things that will affect stress tolerance and plant architecture. So some second and third wave transgene constructs really…

Chair: Yes, that's a good point and finally…

Dr Johnson: I think the short answer to your question is that using transgenic techniques you can arrive at traits which are not possible to arrive at using conventional breeding unless you are prepared to take hundreds of years to do it. So, for example, if you wanted to put a very specific insecticide, like Bt protein, into a plant and you wanted to use the process of mutational breeding to do so, you would certainly not see the results of your efforts in your lifetime. Now my concern is, and the consensus of that Amsterdam conference was, that there wasn't concern about that transgene, I did not see that at all. What I read into that particular presentation was that there was evidence presented that the Bt transgene, if it were transferred, in this case, into wild sunflowers would be able to increase their fecundity. This is because some of the main pests that, if you like, keep that weed in check are lepidoptera and that transgene is a specific insecticide for those insects. So you could do things with those transgenes that are very difficult todo with conventional plant breeding. The same could be true for stress tolerance, drought tolerance, salinity tolerance, if it were introduced inadvertently into weedy rice, for example. If you put salinity tolerance, and I'm talking about big time salinity tolerance, you know, not tweaking here but big time salinity tolerance so that rice could be grown in very brackish water. If that gene were to get into weedy rice, which is already a serious agricultural weed in many parts of the United States and South East Asia, you would have a problem.

Chair: Right, well I think there are one or two people who want to speak on the same question. By the way, I thought we may have a wee break for a minute because it may be when we get to the end, some of you may not have been able to ask the question you want to ask, or have not been able to make the comment or the point that you would like to make because of time. So can I draw your attention to the website address at the back here. Anything that you put into there, I think they said actually something as long as it's not rude, it will be kept on that website and fed forward and taken into consideration. So we will continue for a little bit longer.

Prof. Wilson: I wonder if I can just pick up that point about the biochemical pathway. I think an extra gene, one protein, one new intermediate created. If you take Tony’s statistic that 10% of 30,000 genes are mutated when you are breeding a plant. What on earth are all those enzymes and biochemical pathways doing and what on earth is being accumulated in the plant and who’s assessing it. We’re doing this on a hit and miss basis. It seems to me there’s one rule for one and for another.

Prof. Dale: I think this question about whether GM is different, this is really important. It is different. That’s why people want to use it. But mutation breeding is different. So the question is different from what? If you look at mutation breeding, the products are different from GM. You can’t produce polypoid plants by GM. That has unique features. You can’t transfer a chromosome by GM, because you’re transferring a whole string of genes. You can’t recombine thousands of genes by GM. So each has unique features. Now the question is whether GM is innately more dangerous? So is to move a bacterial gene into a crop that codes for a toxin innately more dangerous than transferring a deadly nightshade toxin from wild potato into a cultivated potato. I think kind of that illustrates, and it’s essentially the product that is important, and that's what we should focus on. You can do irresponsible things by conventional and GM.

Chair: Thank you very much. Ricarda do you still want to comment?

Dr. Steinbrecher: I do not want to take attention away from the importance of looking at foods derived in other ways, or crops, but I think the focus is GM here tonight. And I wondered whether somebody might have an answer to a question I have. Will plants, especially wild relatives of feral plants, have an advantage if they, all of a sudden, have an increase of 20% or so lignin? I know about ready-round up genes, the Glycosate resistant genes put into plants, will have that effect on soya and will have that effect on corn. So therefore gene flow, (I am not talking about, for example, horizonal gene transfer into micro-organisms now, I am talking about gene flow via pollen), will pass that on to relatives to whomever. Does it make a difference? To those of you who are ecologists, does it make a difference in their capacity to actually defend themselves…?

Chair: I wonder, why don't we turn the tables and give them a rest here. This is a wide reservoir of expertise so can any of you address the question that Ricarda has posed?

Professor Tom Meagher, Professor of Plant Biology, University of St Andrews

Tom Meagher, University of St Andrews**,** and as it happens, about a week ago I looked at the Weed Science Society of America's web page on herbicide resistance and it happens that in the UK there's something like 23 different naturally occurring herbicide resistant varieties that occur in agricultural systems. So to some extent it's not a question of whether some of these sorts of genetic effects are going to get into weed populations. They already have and the fact that they have has nothing to do with GM but rather has to do with the fact that herbicides are being used in agricultural systems.

Dr. Steinbrecher: I was talking of the side effects of one of these introduced genes and whether you know if lignin actually gives an advantage to the plant?

Prof. Meagher: That I don't know but actually….

Chair: Is there any ligni around? Can you speak about lignin?

Dr.McRoberts: **Dr Neil McRoberts, Farming Systems Research Co-ordinator at SAC**

Dr Neil McRoberts, Farming Systems Research Co-ordinator at SAC. The direct answer to your question Ricarda, Mike Jager who's currently at Imperial College, when he was at the University of Wageningen in the Netherlands, had a research group address that question. And they found some evidence that relative growth rates in plants which express resistance through accumulation of secondary metabolites like lignin, growth rates tended to be lower in plants that were more disease resistant so there's a trade-off between growth rate and disease resistance in weedy species.

Dr. Steinbrecher: Thank you.

Dr. Squire: It's an interesting comment Ricada. Is it a very recent finding? Is it referencable? … the finding that glyfosate resistant plants have more lignin?

Dr. Steinbrecher: Yes, it is, I have the references.

Dr. Squire: I'd like them because it seems….a change of that magnitude is quite substantial unless it can have been caused by compoundable or secondary effects on growth. But a 20% change in lignum content in a herbaceous plant, just seems very, very substantial indeed and I would question that amount.

Dr Clair Halpin, Division of Environmental & Applied Biology, University of Dundee

Dr Halpin I am Clair Halpin from the University of Dundee. I work on lignin and in fact I have worked with some new projects over the last ten years and tried to manipulate lignin and I would be very interested to know how you could get a 20% increase by targeting a single gene. But in fact people have looked over the years to try to manipulate things like borage digestibility by impacting on lignin and it really isn't as simple as you would think. Plants vary very widely in the amount and composition of the lignin that they make and it's a whole bag of things including the architecture, the way particular tissues in plants are organised, that would affect whether, say, an insect would be able to attack something with more or less lignin. So I think it's far too simplistic to worry about whether an increase in lignin would have a massive effect on the fitness of the plant. Certainly most of the data would suggest that subtle changes to lignin may be economically or agriculturally valuable, but when you make big changes to lignin you do seriously affect the fitness of a plant in deleterious ways.

Chair: Well thanks very much, it's very useful to hear from people who do know what they are talking about.

Prof. Wilson: I was going to make a very similar point in that it was very important for the GM Review Panel to look into these sorts of claims specifically and I alluded to one earlier about the Cauliflower Mosaic promoter in cancer, and all these sorts of things. This is exactly the sort of issue that the science panel should be digging into and resolving. I'm very pleased that Claire's in the audience, I was delighted to see her.

Dr Johnson: I think that question raises a very interesting issue and that is. If the changed lignin content, and I know nothing of this paper, but if there is a change in the lignin content and its a pleiotropic effect of that transgene in the plant, we know very little about what would happen if that transgene were to be in the genetic background of a wild plant. You might get completely different pleiotropic effects, we just don't know. The evidence so far seems to suggest that transgenes behave very much the same as they do in the cultivar, if they get into the wild plant. There's a very recent paper by Neil Stewart for example in the United States that demonstrates the Bt gene, if it is transferred into *Brassica rapa*, behaves very much as it does in *Brassica napus*, oilseed rape, but that may not always be the case.

Chair: Thanks, now we have a question. Is this a question or a comment?

: **Professor Wayne Powell from the Scottish Crop Research Institute**

It's a slighlty different comment. It deals with gene flow between crop plants and their relatives. Clearly this is not new. And I think if we look at what's gone on in recent research in the United States on the domestication of corn, maize and hybridisation between *Teosinte* and progeny corn to produce modern varieties, it's clear that the changes have been on regulatory reasons. So in terms of domestication and on ecological issues, it's those changes that have been profound. And this affects plant architecture. So I think in terms of manipulating genes, it goes back to the statement I think Tony and others have been making, it refers to the trait, the type of gene that has been introduced. So I think there's a whole lot of scientific evidence surrounding those issues.

Chair: Does anybody want to comment on that from panel or from the speakers?

: **Professor Steve Blackmore, Regius Keeper, Royal Botanic Gardens, Edinburgh**.

What I would like to comment on in relation to that is I think there's a very great need for great care and precision in our terminology when speaking of these things. Because I think the point Wayne has made is very important. But if we are not careful to distinguish in the process how we arrived, we may mistake ourselves into looking at traits in far to a simplistic a way, and assuming that age rate, salinity tolerance, frost tolerance, whatever that trait is, has a common underlying basis. And as we heard earlier, in the technologies of genetically modified organisms, it's not necessarily the same gene by the time it's transferred. I think it's critical to this discussion that we have the clarity and the precision about this thing. So in those terms I would strongly disagree with Tony's view that the risks are going to be the same if the trait was the same and suggest you don't really mean that.

If the precise DNA that's exchanged was exactly the same, then I think we might be able to get closer to an agreement. But I do think that's critically important in this debate and I would not go so far as to say that the process doesn't matter. I think the process is critically important and I think unless we get very careful precision into that it would be very hard to carry the wider public with us. If I could just add one other point, I would say …and then I can stay quiet, we talked about scale earlier on in terms of presentation. One aspect of scale that wasn't it touched on was time. And when we look at what's happened in genes through evolutionary time, we realise the importance of time is incredibly important in selecting and seeing what survives and what doesn’t survive. So it’s very difficult exploring the effects of genes in an experimental, short time frame when we actually know that some of the most profound and important things that happen are really quite a long, even geological timescale. So somehow a real challenge to this is to build time and the equivalents to time, into our experiments.

Chair: Tony, did you want to come back on this specific first point:

Prof. Trewavas: The reason I designated traits is because I think that’s what selection works on. I mean the reality of the mechanistic basis, down to the ground level of DNA, is surely that each individual may well be different. You cannot guarantee that they will be the same. The event that gets selected for, for example in frost-tolerance, is whether that seedling is frost-tolerant, if it goes below zero. So the actual reason for the set of genes which has one individual compared to another, or even a different species, I think, makes no difference in that term. That's why I argue for traits. I recognise obviously there is a difficulty when you are characterising traits in that way. They tend to be operational definitions as much as anything. And frankly we do not know what most of those traits actually mean from conventional crops, let alone anything that we produce by GM. It makes it so extremely difficult to pass comments upon this, but I will add in terms of herbicide tolerance. I mean this is a very clear example here. If you look at the genetics of herbicide tolerance in weeds which have developed. Certain weeds have single gene herbicide tolerance and to the same herbicide other weeds will have polygenic tolerance. So clearly the mechanism is different, but to the farmer it makes no difference. If the things are herbicide resistant he's got to use another herbicide.

Prof. Dale: One of the features of the process being different is that it enables us to analyse the insertor gene and the surrounding effects with a precision that is impossible in conventional breeding. So we know exactly the sequence, we know we can map where it’s gone to and the genome and so we can map it with precision. We can also ask very detailed questions about lignin content, unanticipated effects, and it will be interesting to us to ask question do conventional plant breeders ever analyse plants with the same precision? They don’t of course. In many of our wheat varieties there is a fragment of Rye, a Rye chromosome, so that maybe there are several thousand genes which are probably having quite a lot of unanticipated effects on that wheat. Okay, they're having one major effect, but quite a lot of unanticipated effects. That is true of a lot of conventional plant breeding but we never ask these kind of questions. So I think one of the features of GM is that we can ask and answer many of these questions and that is both an advantage and a disadvantage. It gives us the expectation that we must ask all these questions and generate masses and masses of data.

Dr Wilkinson: Can I address the time exposure, because I think that's quite important, a really valid point. We have to take into account, though, that we are talking about an agricultural release here, so on a commercial scale, a commercial lifespan of a GM cultivar will be finite, in terms of years. We don't know how many years a particular construct will be used for, but for example it won't be a millennia. Therefore, in terms of evolutionary context, then we have to then work out whether the gene will get out there in that timeframe. So you're absolutely right. Will the transgene get out, but once it's out then I absolutely take that point. But we are dealing with a finite timeframe of exposure.

Professor Tom Meagher, Professor of Plant Biology, University of St. Andrews

Actually the herbicide tolerance is a good case in point, and following on what Mike just said. One aspect of the way that the scientific community could inform the GM debate would be to develop a better understanding of the dynamic nature of agricultural systems in the first place. Because I think there's a perception that somehow agriculture is a sustainable system that's being modified by GM, which is absolutely not true. In fact weeds are evolving all the time whether there's GM in the system or not. Just the management the practices that are imposed and other technologies. And I think that one of the actual positive contributions that GM may have made in this is to heighten our awareness of the dynamic nature and the fact that introduction of novelty is necessary to the sustainability of agricultural systems.

Chair: Still on the same issue?

Dr Ulric Loening, University of Edinburgh

That of pleiotropy and dynamic systems, yes. I am a long-retired molecular biologist and I like Mike Wilson's comment just now, he was one of my students at Perth. I hate to raise a fundamental issue here but Brian used the word pleiotropy for the first time this evening and everything we know about genes from 4, 5, 50 years ago, from Waddington, to human genome project now is that genes are pleiotropic. And we seem to have forgotten that when we talk about individual gene transfer. Especially Tony's comment that it's the product that matters.

It's the process that matters. And if we are not very like bananas, most of us Tony, then what that tells us is that the individual gene is not the important element. We share those because we have a common metabolism. And I would just like to see that stressed, that what we are actually on about, is one of process and epi-genetics rather than genetics and this has got lost from the public and even from the human genome project. People were surprised that we only have 30,000 genes. Some of us weren't surprised and you shouldn't been. So I think that's very important. Just to add, it goes to the previous point, it's not true that the public have not been concerned with the other processes of agriculture. Of course there's been a vast movement. We've landed up in…I nearly said this country… it landed up in the House of Lords with a big debate which led to the Agriculture Act of 1947. And got it wrong. And we don't want to get it wrong again here. So this is very important, that we should look at the process, the epi-genetics, just as much as the individual treatments.

Professor Peter Wilson, Royal Society of Edinburgh

Thank you. I think the general theme that's come out this evening is that a lot of people are happy about many things but there are many unanswered questions about gene flow, for one. So my question is a simple one. When plant breeders are selecting the species that they are going to breed or improve or modify or whatever you like to call it, why don't they in the next decade or so, deal mainly with those plants important in the world which are mainly vegetatively propagated. The banana, I think you really meant a plantain Michael, the plantain of Africa is one such. The cassava plant, which is a major carbohydrate plant in the tropics is another such. In this country the potato. Now all these plants can be sexually propagated but under quasi-experimental conditions and not in the field. And in the field they are propagated vegetatively. Fruit crops on trees is another example. If only the scientists had picked on these for their first decade or so of genetic modification, wouldn't we have escaped a lot of the problems we are dealing with tonight?

Prof. Wilson: Can I just… I think the reason that they didn't pick on those, Peter, was because the technology and the cost of the technology was driven by industry and the seed industries particularly. And you don't sell those vegetatively propagated crops in that way. However it's true that the public sector, particularly the Difaid and the aid-programme funded researches, very much focused on those crops, particularly because of their relevance to the developing world. And GM varieties of those crops with valuable traits to improve and food security and environmental impacts are certainly in the pipeline.

Dr Johnson: Can I just add something to that. I think the point you have just made is extremely important. One of the genetic isolation mechanisms that's missing from Tony's list is 'first choose your plant'. It's as simple as that. For the American companies to choose commonly grown food plants as a vehicle to produce pharmaceuticals seems to me to be crass commercial stupidity, let alone scientific stupidity, and you're absolutely right. First choose the right plant. So the decision at day one should be "which plant am I going to try alter and why", and that's absolutely right.

Chair: Ok just wait a second, we're staying on this question a little bit longer.

Dr. Steinbrecher: It's just that you were wondering whether that would have saved us from that big debate and I think yes, from a certain component of it, especially the ones we were talking about. But it might have still had questions around it being a food, but that's not the debate here so we might have had a different debate definitely.

Chair: OK another topic please

Professor Dave Atkinson, Vice Principal, Scotch Agricultural College

I wanted to follow on the theme that Peter Wilson just introduced in terms of wider agricultural issues. I think one of the issues that concerns most people, is in terms of quantitative measurement of the gene transfer process, because this clearly links very much to the question of does it matter. And that's actualy the theme I'd like to see the panel comment on. Clearly to those people who want to grow organic crops close to GM crops, the quantity that moves matters. To those people who want to grow, let's say, specialist varieties of oilseed rape next to other ones, the quantitatives matter. And if one is actually going to have to involve weed control, then the quantities matter because they then start to have the sort of widescale ecological impact that Geoff Squire alluded to in his talk.

So my question to the panel is a fairly simple one. What percentage of a presence of the transgene in non-GM crops do you think is the one that matters to agriculture? And I would like to just marginally complicate the very tidy message that the panel has addressed in terms of gene flow with pollen, and to point out that anyone who's actually driven up farm roads around where people grow oilseed rape. Or driven around farm roads close to oil crushing plants will be aware that in fact an awful lot of plants escape from uncovered lorries as they actually move around. And so pollen transfer is actually quite a major process. Now so far as I know it's not that well modelled because clearly being a very stochastic process, it's quite difficult to model, but I would actually like to roll that into the question. So in a sense the question is, what percentage should we be worried about, what percentage should matter in agriculture?

Chair: You just want a figure then, just have the panel give you one by one…

Prof Dale: It's impossible to answer in terms of figures. It depends is the answer. The organic thing is not a scientific issue in my view. The gene flows from Erucicacid oilseed rape, conventional to seed rape seed, that is all laid down. It's done by analysing the product and working out what frequency, what tolerance you will allow without affecting the food crop. Herbicide tolerance and so on, you can do similar kinds of calculations. Those are the kind of scientific questions. The issue about what we in Europe would accept is very much a political, ideological. It's a matter of practicalities and ultimately it comes down to, again this is not a scientific answer, to what the consumer will pay for because ultimately the consumer will have to pick up the bill for isolation distances, just as they have to for oilseed rape, for Erucic acids and so on.

Chair: If you could really just got to stick to oilseed rape because you've simply got to focus on something (we could jump to all sorts of things with more time)..

Dr Johnson: The actual percentages of course aren't fathomable, that's really a political decision, it's a commercial decision. I think what concerns me most about this issue of what we will tolerate in conventional crops is how many transgenes will we tolerate in commercial crops. Because of course if you put in a percentage which, for the sake of argument, is 1% and in the future that is made up of 10 transformations, each of which confers a different trait, then you will get gene stacking occurring. Hybridisation will occur and you may or may not have either an ecological or agricultural problem. Now it's that area of risk assessment which is at the moment relatively unexplored because there are no plans to introduce, for example, more than one herbicide tolerant oilseed rape to the UK.

We have seen what has happened in Canada where we have seen that transgene stacking is a reality, but it is an issue that is concerned not with the level in the crop, but the transgenes that are actually there, because they can be there at very low levels. I would remind you that 1% of a transgenic crop in an oilseed rape field is actually tens of thousands of plants. So there's a scale effect here. We're talking about percentages, but we're actually talking about very large numbers of plants in contact with each other

Prof. Wilson: Well I think Bill said it all regarding separation distances and labelling of seed. The point on gene stacking of course, there are now crops being developed with multiple genes. The golden rice for one and the golden mustard another. And so there are multiple genes going into these things and there will come a time when they when they want to put in resistance to herbicide or drought or salinity or whatever simultaneously. So long as they go through the normal regulatory process and they are assessed and judged to be safe, personally I have no problem with it.

Dr.Squire: As I said in the talk, it will be difficult to achieve 1% populations, or amounts of gene flow and persistence will tend to rise above that. But for the crops and food purity I think it’s not so much a matter of science, but that even very low amounts of gene flow are important for altering the dynamics of semi-natural populations, much below the levels we’ve seen. And so levels we are seeing in terms of ferals and gene flow are quite high really, in terms of altering ecological processes. The issue here in our arable system is that it isn’t the plants that are invasive or that they develop by themselves. It’s that the management system makes them rise or fall. The actual amount of gene flow isn’t so important as how we interact with the trait that’s exchanged and so some weeds have been crops in their time, they are now major weeds achieving very high populations. And I think we've made them, or created the actual environment for them that's brought them up. And we can modify the weeds, the arable plant, up and down according to managment. So gene flow is crucial for semi-natural and wild populations but for arable systems, it’s how we interact with them that’s really crucial issue, not the actual percentage.

Chair: So do you think, since you said 1% is going to be difficult, that the European Union statement of limits of 0. 5% unauthorised stuff, because its banned, is really going to be impractical?

Dr. Squire: I think 1% is the sort of figure that our calculations, and the French as well have done similar calculations, for widespread commercial use where you get contamination in the founder seed, the sown seed, through volunteers and through gene flow occurring during the cropping. Small scale trials or early releases should be able to achieve much less than that. It’s in the commercial field that you’re going to have difficulty getting below 1% in terms of contamination.

Dr Steinbrecher: I mean a percentage I find also is really problematic, if it's about co-existence of different farming systems. It’s a different question or different relevance than in terms of ecological impact or maybe safety impact or horizontal gene transfer. It’s I think something which really needs much more debating, but I would not have any kind of answer to it.

Dr Wilkinson: Crop to crop, I think pick a number, frankly…I think it is purely a political issue, I think, and there's a little bit of pragmatism in there, inasmuch as in one crop 1% might be doable but a self-incompatible crop may be different. But I think it's going to be a political decision, coupled with what we can actually manage to enforce and detect.

Chair: Well I think that last half sentence is important. Its not going to be very useful if you all sit here and say "you know, pick a number" and so on. I think we've got to link it to what is feasible and what we think is feasible.

Prof Trewavas: The number is already there, they're already fixed. 0.9% is what the EC says that below that it's not GM. And let's remember we're dealing with oilseed rape. What does it produce? Oil. I mean chemically it is identical between non-GM and GM. To answer the first question we ever had - "What does it matter if it's in the food chain?" I mean it's only oil, you can never detect the difference. If you could you would get a Nobel Prize. Yes, I think that is a critical point that we have to deal with with in this respect for rape.

Prof. Dale: Regarding principles… that the lowest level you can detect, the levels of analytical detection, are about one GMC in a thousand. Okay in rarefied labs you can get better than that. So that's about the lowest you can do in the lab. As you increase up to your 1%, it will cost less to do it. It's pretty well impossible to get to 0.1% because of the practicalities of sampling and growing and moving seeds around and so on. 1% is considered to be reasonably achievable but that will cost. There are figures that have been worked out on the cost of that and it could potentially be up to about a 10% increase in cost of growing the crop to get that threshold down. And that is principally the cost of analysis to verify the level that you have.

Chair: That's achievable but requires resources. Now this is on the same point is it? A new point? Same point… Anybody on the same point?

Dr Richard Ennos, ICAPB/School of Biology, University of Edinburgh

I just wanted to make a point. Why are people concerned about gene flow from genetically modified crops? Well, what we are trying to do with the crop, in many instances? We are trying to make them resistant to wild organisms in the wild. And we do that taking out genes with powerful effects and we put them into our crop and they interact with wild organisms and the idea is to kill those wild organisms. Therefore it seems to me that necessarily any of the genes that we are going to put in are of a large ecological effects. If they weren't large ecological effects there would be no use in putting them into the crop in the first place and we wouldn't invest great deals of money in doing this.

That's the reason why people are concerned about that. They are also concerned if those genes get out into the wild populations that there can be knock-on effects and it's very difficult to predict what those would be. As I see it those are the reasons why people are concerned about this and to me rightly so. The other thing about hybridisation that we've been talking about, hardly any hybridisations are occurring. Very low percentages of hybridisation are occurring. But we must remember that most evolution takes place as a result of very rare mutations. They occur very rarely. But if you have natural selection, those individuals will increase rapidly in frequency. So it seems specious to me to just quote a level of hybridisation and say we can ignore it. It depends on what the genetic make-up of those particular individuals are and how they will respond to natural selection in the wild. So I just wanted to make those points.

Chair: Thanks… The first point, does anyone want to respond. I think we dealt with quite a bit earlier because there are a lot of natural insecticides in the wild and purity ought to respond to that. The second one about individual mutations having a huge impact because of they are naturally selected, anybody want to comment on that?

Dr Wilkinson: I think you're absolutely right. A rare event can be ecologically and evolutionarily very significant. I think the importance of knowing the rate of hybridisation is the do-ability of prevention and hybridisation in the first place, largely. So if you have a hybridisation in a frequency of, say, 100 plants in the country, then something like terminator technology will probably be fine over the life span of the cultivar being planted but if we're talking about a million then maybe it won't be.

Professor John Dale FRSE

So far this evening we've been concerned with gene flow largely from one species of Brassica to another. I would be very interested to know how significant that is going to be even if there were a significant gene flow, on the natural environment. What I would be very much more concerned with is if there were significant gene flow from Brassica to a member of another plant family.

Chair: Who wants to respond to that?

Dr Wilkinson: I can talk about Brassica. In many ways I think that's a very valid point. I think the key question is how important is *Brassica rapa* to the habitat that it occupies and also *Brassica oleracea*. How important is *Brassica oleracea* to the habitat that it occupies. I don't think the data is complete on either of those but it's a valid point.

Dr Johnson: Can I just make one comment on that? That is that the importance of these species ecologically may not be solely concerned with the functionality of the eco-system. I would remind you that some wild plants, and some of them are fairly scarce including some scarce Brassicas such as the Lundy cabbage, have extremely rare invertebrates feeding off them, that are absolutely specific to them and therefore it's important to distinguish between that and their functionality in the eco-system. They may not disrupt the eco-system, if they go wrong, even if we remove them. They could have an effect in reducing the number of species there. We have a statutory duty throughout the UK to maintain our natural biodiversity so that is a consideration.

Chair: Sorry just on this point?

Dr.Squire: Yes it is in a way but it's also related to the previous point. It's true that these chemicals, the GM types, that are say insect resistant or fungal resistant, have these deleterious effects potentially. But at the same time we can do far worse carrying on spraying the chemicals that we do spray on, which very largely affect non-target organisms, detritavores and the herbivores as well as the intended victims. There are massive effects of chemicals which cause major ecological disturbance.

Dr Squire: I'm not saying your point is invalid, but somehow we've got to find a system that allows much grater flow and flux to the food web, while preserving our crops and maybe this is one way. Certainly the present system is not sustainable.

Chair: One thing I do want to do is stick to finishing at 9.30 and so I think there's time for one more question.

Professor Joe Perry, PIE, BBSRC Rothamstead

I'd just like to comment on the impression I think that Dr Johnson gave about the knowledge in the scientific community of selective advantage and its importance. I'd like to point out the study by Professor Michael Crawley FRS, published in Nature in 1993 and the follow-up study in 2002. Both of which showed little selective advantage for oilseed rape hybrids in the wild, and also point out Rosie Hales' excellent article in Trends and Ecology in Evolution in 2001, in which she showed, I think fairly convincingly, that herbicide tolerance probably confers the least selective advantage. But there is a hierarchy of risk going through insect resistance to viral resistance. I think this point is quite important because I know that ACRE considered the topic of selective advantage of fitness in some detail before they ever gave permission, or advised the government to give permission, for large-scale field trials. And I think it's important that the public realise that there is quite a lot known about this area and that the decision to go through large-scale field trials was not one that was done lightly. Tony has already mentioned the work of Laws, I'd add to that the work of Grenchley and finally maybe quote Les Firbank, the co-ordinator of the farm-scale evaluations, who said quite clearly at the start there will be no super weeds. And indeed that there is no evidence that there have been.

Dr Johnson: Can I come back on that because I think it important that I do defend that position. Those figures that you quote are not concerned with wild plants from hybrids with GM crops. They were concerned with the fitness of the crops in the wild, which we all know is pretty close to zero most of the time. What I'm concerned with is the transfer transgenes to wild populations when that transgene finds itself in the genetic background of a wild plant. That is not the issue that I addressed Joe, and you know that.

Chair: Ok, did you want to come back on that?

Professor Perry: No.

Chair: Look, I think you're tired by now. I would like to just finish by thanking the speakers on the panel again but also thanking all of you. It's been really very important I think that the Government held this open consultation. We have been allowed to say what we want as scientists. You've been allowed to say what you wish, to the scientists, ask questioneds that you wished and if, as I say, you didn't get the time at this particular meeting, and indeed if your one of these people who tends to think more clearly in your study, there is the website. Please continue as scientists to put in comments and questions, concerns, on one side or another into the website. Because when we are given an opportunity, as scientists, to speak to government, to say what our concerns as scientist are. And they are often very different from the concerns of the public. I think we should definitely take the opportunity. But you certainly took the opportunity tonight and a lot of you have made a bit effort to get here tonight and many of you have travelled. I'm very grateful to you for that. I think we just have not had a quite minute in the 2 ½ hours of the meeting, so thanks again to the panel and the speakers and thanks very much to all of you.