GM Crops: Gene Flow and Fitness in Natural & Agricultural Systems

Chair:	Dr Toby Murcott	Chair
Speakers:	Prof Chris Pollock	Prof CP
	Dr Rosie Hails	Dr RH
	Dr Jeremy Sweet	Dr JS
Panel:	Prof Phil Dale	Prof PD
	Dr Adrian Butt	Dr AB

Chair **Dr. Toby Murcott, Chair**

Ladies and gentlemen, good afternoon. First of all, thank you for coming along on what is, the most beautiful afternoon we've had this year, and very warm welcome to today's open debate on GM Crops, the subject of which is "Gene Flow and Fitness in Natural and Agricultural Systems".

My name is Toby Murcott, I'm a science journalist and I will be chairing today's meeting.

Today's meeting has been organised by the British Association for the Advancement of Science. The British Association as I am sure you are all aware, is an organisation dedicated to the discussion of science, medicine and technology throughout the UK. We are also indebted today to the Institute of Grassland and Environmental Research, IGER, who are hosting today's debate.

This meeting is part of the national GM dialogue that is currently underway throughout the UK. There are three strands to that dialogue. The public debate, looking at the social and ethical issues around GM. The economic study, which is looking at the costs and benefits of the GM, and today, we are concentrating on the science review, which is looking at the science of GM.

The science review is being lead by Professor Sir David King, the government's Chief Scientific Adviser, and he chairs an expert panel from a variety of disciplines and backgrounds which will review and summarise the state of the scientific knowledge and areas of uncertainty over GM science issues.

The open meetings, such as today's, form an important part of the review process. The aim of these meetings is to explore in public the science underlying GM. In essence, this is a science meeting being held in public, so what you are going to hear today is evidence to members of the science panel. A summary will be written of today's discussion and submitted to the GM Science Review Panel and that summary will also be posted on the website which you can see up here behind you. On your seats you have further information which also lists that website. Now, there is also going to be a verbatim transcript, so you can hear my fluffs as well, of today's debate on the website as there are of the previous debates. I have had a look and they are worth reading, and the most important part about the website is there is an opportunity for you to add your thoughts. In doing so, that evidence will also feed into the debate that the 25-strong GM Science Review Panel will have, so if there is something which you don't have the opportunity to say today, please go to the website and make your voice heard there.

The format of today will be as follows. We have three speakers who will present evidence to a representative of the GM Science Review Panel, Professor Phil Dale. Each speaker will talk for 10 minutes, and then they will have an opportunity to be questioned by the panel for a further 10 minutes. Now, Professor Phil Dale who is sitting to my left from the John Innes Research Centre in Norwich, is the only member of the panel who is here today, but also joining us on the platform is Adrian Butt, Dr. Adrian Butt who is the Secretary to the GM Review Panel, who will be asking questions on behalf of the members of the panel who haven't been able to come here today.

Now all the questions and the discussion is going to be about the science issues, there are opportunities for the other issues to be debated both at the other open meetings and on the website, so when we get to the opportunity for you to ask you questions, could I ask you to keep your questions to the science that you are hearing today.

Now, I am going to introduce the speakers. We are going to have the three talks, three 10 minute sessions and then we have an opportunity for you to talk. So I am going to start off by introducing our first speaker who is Professor Chris Pollock, who is the director of IGER and he is going to be talking on Gene Flow in Agricultural Systems and Ancient Phenomenon.

Prof CP **Professor Chris Pollock, Director, IGER: Gene Flow in Agricultural Systems, an Ancient Phenomenon?**

Prof CP Thank you very much. Good afternoon ladies and gentlemen. When I first started my scientific career I was taught how to give lectures. In those days lectures in conferences tended to be about 10 minutes long and I was told to give one point with the evidence. Today I intend to break that rule for the first time and make four points with very little evidence!

What I want to talk about is firstly how we measure the potential for gene flow within agricultural and unmanaged systems, secondly how we estimate gene flow in historical terms, that is how much of it has been going before GM crops were developed, and finally I want to talk about gene flow between agricultural and natural systems. I use the word natural in inverted commas because there is very little climax vegetation left in the UK and there is a continuum between highly managed land, in which issues of occurrence of specific genetic material can be dealt with as part of the agricultural rotation, right through to land which is subjected to almost no management at all. I want to try and tease out what some of the issues are that will determine how genes move, where they move and what happens to them once they have moved.

So if we could look at how to determine gene flow. These were some experiments that were carried out at the institute in the mid 90's, but they serve as a paradigm for equivalent experiments elsewhere. It's very straightforward to measure gene flow. All you need is genetically typed material where you can recognise when a particular trait has moved from one plant to a son or a daughter plant. In this case we used perennial rye grass. The reason we used perennial rye grass is because it is an obligate out-breeder, that is, it will only cross with other plants, so there is no self-fertilisation, and because it is extremely widespread in both the managed and the natural environment.

What you find if you have a central block of donor plants which contain the markers and you surround them at various distances with either linear of circular distributions of recipient plants you can then look at the seeds from those plants and you can get a quantitative assessment of gene flow (that is, which genes move, when and how fast). The data are actually quite interesting. Rates of gene flow are extremely high close to the

donor block but fall off very rapidly with distance. So you can get effectively up to 100% hybridisation very close to the donor block, but in the linear experiments it was very difficult to detect any hybrids at all beyond about 100 metres. However if you arrange the recipient plants in a circle which effectively means that there are more recipient plants the further away that you get, gene flow at one kilometre could be detected, and that gene flow was multi-directional, that is it was affected by the topology but not very significantly. So if you have sexually compatible populations, genes will flow between them. That's the basis hypothesis that you would come out with and there are good population genetics models to allow you to estimate the impact and magnitude of that process. So this first set of experiments showed (I think unequivocally) that gene flow from one population to another is, if you like, the norm rather than the exception, when the populations are sexually compatible. Similar experiments have been carried out with other systems under other circumstances.

Now, you can be quite clever with this business of using markers. You can go back and look at elements of historical gene flow. I need to spend just a minute explaining the logical basis behind these experiments. What these studies did, were to look at two perennial grasses. One - *Agrostis curtisii* - which is not used agriculturally, and one - *Lolium perenne*. What you would predict from population biology theory, is that the further apart populations are the more genetically distinct they are and there are good genetic reasons for that, which are further compounded by topology. The further apart the less chance there is for pollen to move between them, and the less gene flow there will be from these communities. If you look at the *Agrostis curtisii* that is exactly what you find. Populations from adjacent regions were more genetically similar than those separated by a greater distance. Even where there was evidence of gene flow across most of the populations that were analysed, the gene flow was related to the distance.

Interestingly enough *Lolium perenne* the opposite was true. These perennial rye grasses were from old pastures, so the pastures themselves had not been improved, but because of the amount of improved material that there was nearby, these old pastures, if you like, carried the finger print of agricultural improvement from all over the United Kingdom, in fact some of them showed really quite significant marker frequency similarities to the material from the Romney Marsh. This is one of the sites where Stapledon and his co-workers first collected improved rye grass when they began the breeding programme here

in IGER in 1919. So if you look at a conventionally bred crop, and the wild progenitors thereof, you get good evidence to suggest that agricultural practice over the last 100 years has provided a finger print of gene flow. Again, this reinforces the idea that when you have sexually compatible populations, gene flow is the rule not the exception.

So that then really brings us down to the question not of does it happen, because I think the answer to that is an overwhelming 'yes', but what happens when it does happen? What is the impact of that gene flow in terms of natural populations? And here you have to introduce the second element in this debate which is fitness. It's not just a question of moving material from one population to the other, it's a question of how long it lasts and what its impact will be. And again, this particular experimental programme using grasses showed a very interesting effect. If you look at incorporation of novel material, novel "marked" germ plasm into pastures, you can get very high rates of colonisation on bare ground, so you can change the genetic nature of the local population. If, however, you put these seeds into an existing grass sward less than 1% of those marked individuals persist and survive, indicating that there is quite a lot of buffering capacity in natural situations. Poor germination, poor establishment and invertebrate grazing, all act to reduce the rate of gene flow under natural conditions. Thus, there is likely to be a big difference between gene flow, between compatible populations within an agricultural system, which is a naturally disturbed habitat, and the rates of gene flow within the same species between agricultural communities and ones on less managed or natural populations.

However, the key to the whole debate remains the fitness effects of the introduced trait. It's about the likely persistency of this material in the natural environment. The one thing that the GM debate has allowed us to do is to test these hypotheses on a very large scale where GM crops are currently being cultivated. I would like to finish the experimental part of this talk by citing one experiment that was not carried out at IGER, that is some work that's been done on the farm scale evaluations of GM herbicide-tolerant crops that have been carried out across the UK. Here people have looked for the persistency of the herbicide tolerant trait in relatives of oil seed rape, growing in the vicinity of the fields that were used in the farm scale evaluations. Very large numbers of seedlings were harvested from around these fields. All of these fields had herbicide tolerant material in them and all of these species are ones which are theoretically able to cross with oil seed rape. However, in no case did any of the seedlings survive treatment with herbicide, so all of the seedlings

that were tested were herbicide intolerant and none of them contained the trans-gene that was present in the nearby fields.

So what then can we conclude from this brief presentation? I would argue that there are four conclusions. Firstly that gene flow can and indeed will occur between all outbreeders with sexually compatible proximate populations, although the rate will depend upon the breeding system, the topology and the distance of separation. Secondly I would argue that there is very good evidence that this process has occurred in the past.

Thirdly flow from agricultural into natural populations also depends upon predation during establishment and on fitness. And finally, as far as we can tell for non-adaptive traits, that's for traits where there is no major favouring of the trait in the natural environment, the data suggests the rates of gene flow into related species are extremely low. Thank you.

Chair Thank you. Now an opportunity for our panel represented today by Professor Phil Dale and Doctor Adrian Butt.

Panel Okay, one of the things we have to do is present the questions posed by the Scientific Review Panel so the first one is about natural ecosystems. What is a natural ecosystem and how do we identify them?

Prof CP Well as a first approximation in terms of area, you can argue that there aren't any in the UK. That is not quite true, there are salt marshes and small amounts of native forest, but there is a minimum occurrence of truly natural climax vegetation in the UK. The distinction that I would make is in terms of management and there is a continuum of management through from a predominantly arable system in which you get bare ground at least once during the year, through to populations and ecologies that are barely managed at all. And it's under these latter circumstances that I think that the potential impact of gene flow, in terms of whether a trait that genuinely affects fitness is going to be greatest. I think that the phenomenon of gene flow is ubiquitous and fairly easy to demonstrate. The impact is much less easy to demonstrate, and so far in these less intensively managed populations there is relatively little evidence to suggest that agriculturally significant traits that are neutral in a non-managed environment will persist.

Dr AB Chris in agronomic management terms, is contamination, if I can use that word, by herbicide tolerant genes, equivalent to contamination by genes that modify other characteristics such as height?

Prof CP If you look at a conventional agronomy where what you are trying to do is to produce a harvestable product. The essence of management is to look after the plant during the year that you are growing it, harvest the product and then make the land clean for the next cycle of cultivation which will quite often, although not always be a different species. So for example, if you took herbicide tolerance and you said that there was some gene flow into agricultural relatives, what this might then do is to generate volunteers or ferals that are herbicide tolerant and would need a different form of control to the parent material. Now that is qualitatively different from gene flow in say a trait that determined plant height. With the HT trait you've still got to control volunteers but you've had one of your weapons taken away. Of course there are a number of other weapons. This can be seen most acutely in the situation that's occurred in Canada where there has been pyramiding of three herbicide tolerant traits into oil seed rape and a generation of volunteers that require slightly different control mechanisms in order to get clean land for the next cycle of cultivation. So to that extent I think there is a difference between HT and say a trait that affects height.

Prof PD Chris you've discussed the frequency of gene flow and consequence, and that consequence is influenced by the nature of the gene and the nature of the crop and potential recipient of gene flow. Which particular combinations would you be concerned about in terms of agricultural use?

Prof CP You have to take a different approach in each particular case that you are looking at, and obviously the first question that you ask is 'what is the method of reproduction of the crop and what are the proportion of sexually compatible relatives or near relatives out in the unmanaged, or less managed eco system?' So for example in the UK in terms of unmanaged eco systems the cultivation of maize is much less of an issue than the cultivation of rye grass, because maize can only move pollen and generate gene flow within agricultural systems involving maize. There are no wild relatives for it to cross with. Then you have to look at the role of the trait and the potential adaptive significance of that trait within the less managed environment. Again, herbicide tolerance is an

interesting one because it's been worked on a lot, and Professor Crawley's evidence has shown quite clearly that where you are not selecting for the ability to resist herbicide by applying herbicide, the trait is neutral in terms of fitness. So, the question then is 'what sort of traits could you put into crops or plants in unmanaged situations that might alter the balance of fitness within those communities?' The sort of ones that I, in a regulatory environment would be looking at very closely would be ones associated with for example tolerance to pest and diseases.

Prof PD What about salt tolerance or something where you potentially change the sort of biology or the ecological niche of a species?

Prof CP I think there is a difference between biotic and edaphic stress, in that with biotic stresses you have the capacity of the pathogen or the herbivore or whatever to evolve as well, and it's the effect of changes in fitness on the co-ordinate evolution that would concern me perhaps more than edaphic stress.

Prof PD There's another question which many people involved in seed multiplication here will be familiar with. Essentially it is argued that the experience from certified seed, high genetic purity seed, is valuable in thinking about the consequences of gene flow and how we manage it and how we achieve high degrees of genetic purity in the production of GM crops. Now, in the production of certified seed, often you use phenotypic analysis to measure the degree of gene flow. With trans-genes we can measure gene flow with much greater precision. So the essence of the question is, 'is all of that knowledge we've gained from production of certified seed, directly of value in learning how to manage the production of GM crops?'

Prof CP I think it provides a very good and effective base line because the one thing that you can say is that seed and varietal purity has been established and maintained for over 100 years, so it's got to be a base line. However, like with novel technology you learn more about the systems that you work with when you have a greater precision of measurement. Genetic markers, not necessarily GM markers, but genetic markers like specific isozymes have been used in breeding and in gene flow measurements for a number of years in order to improve resolution of process that occur at low rates. I think you have to come back to what, to me, is the key issue about gene flow studies which is not so much their occurrence

and their rate of occurrence but their impact. Under these circumstances it is the impact of the particular trait that you are working with that is more important in my view than the precision with which you can measure low rates of gene flow.

Chair Okay, well, do you have any further questions? No, okay. Thank you very much. There will be another opportunity for the panel to ask questions at the end of the debate. Our next speaker is Dr. Rosie Hails who is an Ecologist from the Centre for Ecology and Hydrology in Oxford and she is going to be talking on The Consequence of Gene Flow in Natural Habitats – Is There Evidence of Enhanced Ecological Fitness? Which I think ties in very well with the previous speakers points.

Dr. Rosie Hails, Ecologist, Centre for Ecology and Hydrology, Oxford, The Consequence of Gene Flow in Natural Habitats – Is There Evidence of Enhanced Ecological Fitness

Dr RH I am going to be talking about the consequences of gene flow. Is there any evidence of enhanced ecological fitness? And as Chris has said very eloquently in his talk, yes genes do flow, at low rates, but they are not so low that we can't measure them, and the rate at which they flow is to a certain extent context specific. For example, oil seed rape can cross-hybridise with one of the wild relatives that we find in the UK, wild turnip, but the rate at which it will do so will depend upon whether its perhaps an isolated plant in an oil seed rape field, or whether we are talking about wild turnip populations which we frequently find along river banks. The rates here [referring to a slide of the isolated plant] are higher than they would be in the river bank populations. So, what are the consequences of gene flow? And again, as Chris mentioned we would be most concerned about gene flow if it was going to confer a selective advantage to individuals in wild populations. And in this context we hear of the term fitness. Now, fitness has a very precise definition in the ecological literature. It is the proportionate contribution that an individual makes to future generations. So in that sense it’s a relative measure. And why are we concerned about it? Well, it’s hypothesised that one potential consequence of enhanced ecological fitness is that populations of wild plants may then become weedy or invasive and this could disrupt ecological communities and even ultimately perhaps result in the extinction of other species.

So how are we going to go about measuring fitness? Well, one measure is via the relative finite rate of increase. Now again, this is a piece of jargon that has a very specific definition. If we take one consistent point in the plants life cycle in subsequent generations, then the finite rate of increase is simply the multiplicative rate between generations. So clearly if this is greater than one the population is increasing, and if it's less than one the population is in decline.

Again, Chris actually alluded to some experiments, there are relatively few experiments where the finite rate of increase or the fitness of transgenic plants has actually been directly measured compared to conventional plants in natural habitats. The experiments of Mick Crawley in the early 1990's were one such set of experiments. They introduced transgenic and wild type seeds and very closely monitored populations in natural habitats and followed them over subsequent generations. Now I am not going to talk about these experiments in detail, because they are already published, and in the public domain, but the essence of their results was that in no case did the genetically modified plants out perform or were they fitter than the conventional plants. But to a certain extent this would be no great surprise to an ecologist because the constructs used here were herbicide tolerant constructs, and in the case of potatoes, they did also look at two insect resistant constructs. But these were the only constructs that were actually available for the experiments at the time.

But which constructs should we be concerned about? Which are most likely to alter fitness? Well, here I would like to talk about a piece of work that's received quite a bit of publicity recently conducted in the States where they have put…they have looked at wild sunflowers which are very closely related to the commercial sun flowers, and they have actually but BT trans-genes into wild sun flowers. Now, BT transgenes produce an insecticidal protein and so it protects the plant from herbivores, and as a consequence, they have found that those wild sun flowers had enhanced fecundity compared to the conventional sun flowers.

When this was actually reported, it was discussed in Nature, they used this phrase 'this was a sign that modified wild populations could prosper and spread'. Well it is, but there are actually quite a number of steps between this result and this statement, and I would just like to discuss that a little further.

So, if we have enhanced fecundity in the trans-genic sun flowers does that necessarily lead to enhanced fitness? Quite often fecundity is used as a surrogate for fitness, but it does actually depend upon the cost benefit balance. There are many examples in the ecological literature, where in the absence of the selection pressure, for example in the absence of the herbivores, there's actually a fitness cost to carry the extra gene. And I quote one example here which is actually looking at wild radishes. I couldn't find a picture of wild radishes so I put some cultivated ones up here. Where they found that even induced as well as constitutive herbivore defences in wild populations incur fitness costs in the absence of the herbivore. So in other words the end result of this cost benefit balance is going to depend upon how frequently herbivores are present in those wild populations, and how frequently they are having an impact on fitness.

Will enhanced fecundity lead to an increase in local populations? Well again, this depends. There is I quote here one example in the literature where Joy Bergulson looked at a genetically modified variety of arabadopsis and in fact it contained herbicide tolerance and compared it to a wild type arabadopsis and she found in fact that there were differences in fecundity between the GM and the wild type, and in this case the GM variety had fewer seeds. The GM variety had a decrease in fecundity. But this did not actually affect the invasive potential of this plant, because this plant is not seed-limited, it's microsite limited. So in other words, in any one generation the number of plants that manage to germinate and grow depends upon the number of microsites that are available. So if you increase or decrease the number of seeds by a small amount you are not altering the recruitment into that population.

However some species certainly are seed limited, and a recent review in the ecological literature examined numerous manipulative experiments where they had looked for seed limitation, and in fact about 50% of those studies that looked for seed limitation did find it and these tend to be in early successional species.

So to conclude then that discussion of the sun flower work, enhanced fecundity may lead to enhanced ecological fitness but this is going to depend upon the cost benefit balance. Enhanced fecundity is actually rather less likely to lead to an increase in local population abundance because it depends on your populations being seed limited. But then there is

this in between situation where enhanced fecundity could actually lead to, even if you are microsite limited, could lead to BT genotypes replacing wild types. However we do know that herbivores quite frequently herbivore populations already contain BT resistance genes, so whether any enhanced fitness is transient or rather more enduring is going to depend upon rates of co-evolution. And in fact one of the problems with growing BT crops in the agricultural field is that you have to manage the rate at which pests evolve resistance to the BT crops very carefully.

So what should we be worried about? I would just like to say where I think we should be focussing our efforts. These are two wild cabbage plants [referring to slide]. The small one is infected with turnip yellow mosaic virus and the large one is healthy. So we can see that there are viral pathogens out there that can have huge impacts on fecundity of the wild relatives of oil seed rape. What is it about this transgenic viral resistance that might be in some way qualitatively different from that we see in conventionally bred crops? Well with transgenic viral resistance we are actually essentially using a pathogen's genes against itself. The way it works, this is my kind of cartoon of how it works. Here [referring to slide] we have a viral pathogen with its genetic material surrounded by a protein coat. We take a gene that codes for part of that protein coat, express it in the plant and that actually interferes with the infection mechanism.

In Hawaii they have had such problems with viral diseases of Papaya that now they can only grow the transgenic variety. So this form of transgenic pathogen resistance can be very enduring which is good news in the agricultural context but could lead to enhanced ecological fitness in wild relatives that is rather more enduring in nature.

So I would just like to end by saying where I think we should focus our effort in the future. We should focus on constructs that are most likely to confer an ecological advantage and for which the rate of co-evolution may be rather different than we observe in natural populations. But even then to actually interpret those observations, we do need to know what regulates and limits populations of wild relatives. Thank you.

Chair Thank you very much. Okay our panel, do you have any questions?

Dr AB Rosie, if a gene did transfer to a wild relative and it led to increased fecundity so there was increased persistence of that particular plant and there was clearly a difference, what is the ecologist's view of environmental harm, would that necessarily constitute environmental harm? It's a difference; it's a change to the eco system. What's the relationship between harm and what might very well be the quite natural processes of change in the environment? How can we handle that?

Dr RH Yes, okay, even if we demonstrate enhanced ecological fitness that does not in my view equate to environmental harm. Environmental harm is only when we get a local population increase to the detriment of other species. So I would say in that there are many different ways in which agriculture can influence local biodiversity, but by that particular route I would say enhanced ecological fitness is necessary but not sufficient for environmental harm.

Dr AB If I can tease that a bit further, what do we mean by detriment?

Dr RH Well yes I mean I think that's a very good question. Say we do get a change in biodiversity as a result, say for example wild turnip becomes more abundant. Now that may be to the detriment of some species but it may be to the advantage of other species so change is not necessarily decline and I think that's quite a grey area there. It would be very hard to actually tease that apart and in terms of risk assessment it needs to be put in the context of all the other impacts of that GM crop and its agricultural management, so I think that's the challenge how to actually piece together all these difference pieces to get kind of an overall assessment of the environmental footprint of a particular crop and its associated management practices.

Prof PD I have a question about herbicide tolerance. Often it is considered not to have any ecological environmental impact in wild habitats because if they are generally wild habitats the herbicide is not sprayed so there is no selection pressure for them. But kind of between the agricultural bit and the wild bit there is a kind of peri-agricultural environment, hedgerows and so on, and could spray drift apply a selection pressure and what is the…how would the ecological impact be assessed in that and I guess part of that as well is it fundamentally different with GM compared with non-GM? So I am just interested in how as ecologists we assess impacts on the surrounding areas.

Dr RH Yes, if we think about that in the context of say herbicide…..in the context of insect resistant crops one particular advantage for field margins might be that if you are spraying far fewer synthetic chemicals it positively enhances bio-diversity in field margins. With herbicide tolerant crops however the associated herbicides are broad spectrum so there is a potential negative impact on field margins. However on the other hand it could create germination opportunities for other annual weeds. I think that's an open question. What is the impact of herbicide tolerant crops and their management practices on field margins? I think it's a very important question because field margins and hedgerows are really important sources of on-farm biodiversity, and I understand that part of the farm scale evaluations will actually be looking at bio-diversity in field margins as a consequence of the management of these crops.

Prof PD But some of the herbicides that are used on non-GM crops they may not be broad-spectrum, but some of them are very, very persistent, like Atrozine so how do we make comparisons?

Dr RH Well absolutely, so the important question is the relative one. What is the impact of the GM crop and the associated herbicides compared to the crop it's intended to replace?

Prof PD How do we know when we've done enough in assessing ecological impact? And how does that fit in with the time frame required to produce a GM variety? And there are quite a few GM crops waiting in the wings to be assessed. So the essence of the question is when is enough enough? And how do we know we have done enough in terms of ecological impact and gene flow and so on?

Dr RH Well I think one of the first things to remember is that current agriculture does have a massive impact on the environment, so it's not as if we are in….we are in a dynamic situation in which we already have declining biodiversity. So therefore I think we have a responsibility to consider all options available for moving towards a more sustainable agriculture. And in some cases that may include GM crops, the use of GM crops in specific ways. So I think that is the first thing. Its not as if we are currently practicing a very environmentally friendly form of agriculture and we are considering introducing something completely different, we are in a situation of declining biodiversity as it stands

at the moment. As far as need to know and nice to know, I would say we already have quite a lot of information on herbicide tolerant…

Prof PD Can you say what need to know and nice to know is, because the majority of the people here won't know.

Dr RH What we would need to know to grant consent for a particular crop to go to commercialisation. Nice to know I would probably define as probably more a pure academic interest. But in terms of need to know, I think we already have quite a lot of information about the herbicide tolerant crops under consideration and their potential ecological consequences in this particular context that I have talked about. In terms of BT crops I think one of the key points there is the rate at which pest populations can evolve resistance to BT, because BT is essentially a selection pressure that is already out there in the environment. So therefore the key question there is managing our agricultural systems to ensure that we don't lose the advantage that BT crops provide us with too quickly. As far as the ecological context is concerned, it is precisely that reason that I would suspect that any ecological, any fitness changes in natural habitats would be much more likely to be transient than enduring because we know that insect populations can evolve means of circumventing these resistance mechanisms. I do however feel there are important ecological questions to answer before we would go ahead with certain aspects of virus and fungal pathogen resistance, and it's not necessarily because its viral or fungal pathogen resistance *per se*, it's because sometimes we are using genes which are essentially much more novel resistance mechanisms, for example coat protein genes and we don't know how quickly viral pathogens can evolve to circumvent those resistance mechanisms. We have much less information on that, and we also have less information on the role of those particular pathogens in regulating the wild populations.

Prof PD Do you see breakdown of resistance as part of the risk assessment or is that a feature that is in common with conventional breeding and if you look at some fungal resistance they often break down quite quickly to conventional breeding.

Dr RH I agree that's a feature that is in common with conventional agriculture, its just the rate at which it happens we can use to actually inform us in part of our risk assessment.

Chair Okay, do you have any further thoughts?

Dr AB Even if we accept that the herbicide tolerance gene doesn't confer a particular advantage or a disadvantage in wild populations, could it remain in the species and at a later date have some sort of ecological significance?

Dr RH Well, I don't think any scientist would say that that was impossible but I know of no empirical evidence that would suggest that that is any more likely than with genes introduced with conventionally bred crops, or crops bred by other means.

Chair Okay thank you very much. I would like to turn to our final speaker please. Our final speaker is Dr. Jeremy Sweet who used to be from the National Institute of Agricultural Botany in Cambridge, but I have been told it has now become NIAB and there is no other name for it, so now I am to introduce Dr Jeremy Sweet of NIAB.

Dr JS **Dr Jeremy Sweet, NIAB**

Good afternoon ladies and gentlemen and thank you for inviting me. My talk is about 'Gene Flow and Co-existence in Oil Seed Rape and Maize'. I ought to explain I think what is meant by co-existence in this context. The co-existence basically means if GM agriculture becomes accepted and we start to grow GM crops in Europe, will there be a requirement to segregate these from non-GM and if so how are we going to do it? In other words what is the feasibility of establishing a separate supply chain and production chain for GM and non-GM crops, and the basis of understanding this obviously has to be an understanding of the crops themselves and how the genes move. Now the two crops I am going to talk about are maize and oil seed rape. These are both open-pollinating crops with the ability to disperse genes quite widely from crop to crop, and they are also about to be commercialised or already commercialised as GM crops in Europe. So in maize, we have a crop which releases pollen from the male flowers, which will go to other maize plants to pollinate the female flower or pollinate its own female flower.

There is less of a problem with seed dispersal in maize. Maize seed doesn't seem to persist in the ground through the winter, it rots and dies, and so this pollination is the main way of dispersal of the genes from crop to crop. Whereas in oil seed rape, as well as pollen

spreading from plant to plant, we also have a situation where they produce a rain of seeds which falls to the ground and escapes being harvested. Those seeds will persist in the ground and grow up again later, so you can get GM seeds persisting and coming up in subsequent years in fields. And there is a small potential for oil seed rape to disperse genes to plants like wild turnip and for these in turn then to pollinate other rape plants and for the genes to move that way.

So let's first of all look at maize. There's been some interesting studies done with maize both looking at movement of GM markers and also looking at blue maize. So if you look at the movement of genes either from a transgenic or a blue maize into a yellow maize, non-GM you can get cobs that look like this [referring to slide]. The one on the left obviously is 100% pollinated with the blue. Whereas the others are successively less. And based on these, you can make measurements of the amount of out-crossing that has occurred.

If you first of all look at the dispersal of pollen from maize, some quite interesting studies have been done in different parts of the world. This is a Canadian study and basically it shows that when you get up to 50 metres, 99% of pollen has deposited and at 100 metres 100% of maize pollen has deposited, so that you are talking about dispersal of pollen over that sort of range. Now having said that, there are factors obviously which can move small amounts of pollen much further than that. If you get hurricane-force winds or you get certain climatic conditions which are going to lift maize pollen up into the atmosphere you can get dispersal, but generally you get that sort of decline. These are the average types of decline that you get. Then you have to look at the out-crossing that will occur. This is an experiment that we did at NIAB where we took isogenic lines of maize, one GM and one non-GM, and we looked at the out-crossing and it produced a curve which you will see in many other scientific papers on maize out-crossing with a typical decline from about 4% or 5% where the crops are close to each other and a rapid decline down to very low levels at about 20, 30 metres. And this is a typical situation that you get with adjacent crops of maize. So in fact the ability to restrict gene flow between maize crops is fairly straightforward.

There are a number of factors though which have to be considered very carefully. First of all, maize produces pollen ahead of it having its female flowers receptive, and so therefore

its time of flowering is quite critical and if you have an adjacent maize crop where its female flowers are receptive at the time that the GM is dehiscing you may therefore get higher levels of out-crossing. So time of flowering is quite critical.

Things like crop height can be quite important. Maize for example grows twice the height of sweetcorn so therefore you are likely to get a bigger throw of pollen from a nice 6ft to 2 metre high maize crop than you would from sweetcorn. Distance, as I said, is interesting. But what is more important perhaps is the intervening crop space. Some interesting work in Germany has shown that if you have a ripening field of corn in between two maize fields, you get more atmospheric convection and more thermals and higher levels of cross-pollination than if you had a grass field in between. So there are other factors which need to be considered.

You also need to think about the relative size of the GM crop versus the non-GM crop. You can get an element of swamping. If you get a very high proportion of GM crops being grown against a small area of non-GM then you may get higher levels of out-crossing occur just because of the pure volume of pollen that is being produced by the GM and being pushed onto the smaller recipient crop. And we need to think about landscape features. Do you get channelling of wind down valleys, affects of wind breaks and that sort of thing. And obviously wind and other climatic factors are important.

The other thing is to think about the type of crop that you are growing. With forage maize the whole crop is sampled. The cob and the grains are only about 50% of the crop, so if you get a 1% out-crossing occurring, you in fact end up with only .5% GM crop because its only the grain that is receiving the trans-gene so you get this reduction effect as opposed to say grain maize where 1% cross pollination means 1% in the seed.

The interesting one is sweetcorn, where obviously you get pollination of this type occurring but the problem is that you market it not by in bulk but by cob, so therefore if you pick up a cob like this one, and happen to bite on that piece there, you could be getting significantly more than the 1% threshold for GM which is suggested at the moment. Whereas if you bite here, or here, you get no GM at all. So there is then a problem as to how you set thresholds for sweetcorn cobs.

To move onto oil seed rape, I said that oil seed rape has this problem of seed as well. When you sow a crop of oil seed rape, you are already sowing it into a field which has probably a seed bank of oil seed rape from previous years, and this can be extremely important. We have looked at GM rape and looked at the persistence of the seed in seed banks in the soil and you see here 4 different rapes. A conventional, an IMI-tolerant, that's a non-GM herbicide tolerant, and two herbicide tolerant types. And we looked at the decline in numbers in the seed bank. We've now done it for 4 years, we actually have data for year 4 and it's not a minus figure as suggested there, it's round about 100, but what you can see here is in fact the decline of the GM and the non-GM and the herbicide tolerant was all approximately the same. They are all behaving in much the same way so there appears to be no inherent ability of GM rape to persist in the soil more than non-GM. And this is from the same programme, this is some data from Rothamstead which is a slightly better curve, and this is the sort of tail that you can get. You can get quite a rapid decline depending on soil type, and then this low level that persists for several years. The rate of this decline here is dependent on the number of factors. Its dependent on the soil type and also on the type of soil cultivations you do to encourage germination and depletion of the seed bank. And in light soils we get this very rapid fall off, whereas in heavier soils the line will come across this way more, and you get better persistence.

But the interesting thing is how important is this seed bank population? Well first of all people who have studied oil seed rape in seed banks have found that you get this persistence of a low level, of about 100 plants per square metre persisting for several years. It could be up to 10 years. If 1% of those seeds germinated that would give you 1 volunteer per square metre. Now oil seed rape is sown at about 60 to 100 seed per square metre, so 1 volunteer would be approximately 1%. We then looked at NIAB at what that means. If you have 1% of GM volunteer coming up in a field, what does that mean in the harvested seed? And we found that it varied according to variety. In the variety Apex it gave you 0.9% in the harvested seed. In Pronto, which is a restored hybrid it gave you 1.2% and in Synergy with is a varietal association with low male fertility it gave us 2.4%. So there is a problem there that if you do get volunteers coming up, GM volunteers coming up in your subsequent non-GM crop, you could end up creeping up over the threshold levels.

Pollen from oil seed rape. Pollen from oil seed rape can disperse over very long distances. This was some work done in Scotland where they put out male sterile plants and found pollination occurring up to 400 metres away from the nearest fertile plant source. We did some studies at NIAB looking at cross-pollination levels, and again, you get the typical leptokurtic decline curves with a very rapid fall off with distance into the crop in fully fertile rape. But in rape with a low male fertility you get this higher level of out-crossing occurring, so again, it's important to know what sort of rape you are dealing with when you are trying to isolate from GM sources. And we are also a little bit concerned about the scaling up. This was looking at two of the farm scale sites where we are looking at 10 hectare fields, and we did find at one site that we were getting quite high levels right out across the fields in patches, so you do have to think quite carefully about what this means.

But just to finish then, this is the summary of a paper that was produced by Jan Ingram from NIAB for DEFRA in 2001, where he looked at the threshold levels that could be achieve and what sort of isolation which was needed, and you can see that for oil seed rape to achieve a threshold level of 1% add mixture, you can grow the crops practically alongside each other. Whereas if you want ½ % you would have to have a bigger area of isolation. If you want 0.1% then you have to have 100 metres. With the varietal associations he concluded that he couldn't give any information or there was no good data on how to get down to these lower levels of threshold. And for maize and sweetcorn again he gave these recommendations, that for grain you would need approximately twice the level of isolation that you have for forage maize for silage. So I will end on that, thank you.

Chair Thank you. Thoughts from our panel?

Dr AB Jeremy, yes, coexistence for maize and oil seed rape, is it feasible?

Chair I think that’s a 'yes' or 'no' answer isn’t it?

Dr JS Yes, I just first of all, for those of you who are particularly interested in this, this was the coexistence study that was done by the European Union which looked at maize, grain production and oil seed rape seed production, under a number of different scenarios. If you are interested in this I can give you the reference for it, this is on the web, and that I

think explains how, in certain scenarios you can have coexistence and in other scenarios you can't. So the answer is not 'yes' or 'no' , it depends. It depends on what you are trying to achieve and what the situation is. I think realistically it's going to be very difficult for GM oil seed rape to coexist with non-GM on the same farm because I think you will get a gradual build up in the seed banks, you will get certain levels of out-crossing occurring and it's going to be very difficult to manage, and I think that is something which farmers will have to think about, whereas with maize I think it is quite feasible and quite manageable.

Prof PD Doesn't that depend on whatever threshold is agreed upon eventually?

Dr JS Yes, I mean at the moment the European Union are suggesting a threshold of 0.9% for crops for production and there are also recommendations for thresholds for seed production, which are 0.3% for maize and oil seed rape, 0.5% for sugar beet. These levels can be achieved but they will require very careful management. For seed crops it does mean that we have to have very effective isolation of seed production.

Prof PD Jeremy you talked about pollen gene flow and talked about volunteers and so on, I was wondering about these figures here [referring to slide], does that include volunteers or is that just gene flow? Is that just pollination?

Dr JS That's purely on cross-pollination. This is a table for cross-pollination, and why I made that comment about oil seed rape, is this would suggest that you can actually grow GM and non-GM oil seed rape alongside each other. You may be able to for a year or so, but after a while you are going to find that oil seed rape seed crops up everywhere. We looked at a combine harvester leaving actually a GM rape field, this was in the early days before we got too sensitive about these things. We found 6 kilos of seed in that combine harvester. It then went into a field of barley and harvested the barley, and that barley flushed out the rape seed and it all dropped into the ground. Now if you start doing that repeatedly on the farm you very rapidly start to have oil seed rape spread all around the farm and occurring in seed banks, and it becomes quite difficult to manage.

Prof PD You can imagine defining protocols that will cope with isolation distances because you can see that, and you could police it. How easy would it be to define protocols and police

protocols for seed handling, cleaning out combines, seed drills, and all of that? How would that be manageable?

Dr JS I think that's going to be much more difficult. I mean, it's being done under the current scimac procedures, because that is the requirement that was placed on the farmers at that time. Whether farmers will look at the value of a GM crop and decide that that value includes them spending a lot of time cleaning equipment and messing around I think will be for farmers to decide. But it does add quite a bit of cost to the production of a GM crop if you have to carry out all these extra measures as envisaged in scimac for example.

Prof PD Now all of this is okay if farmers comply with whatever protocols and rules are laid down, and say with isolation distances more manageable. Is it going to work if there is going to be a proportion of farmers that don't comply with the rules, and how do we police that?

Dr JS I think that's quite a difficult issue.

Prof PD Isn't it just by thresholds, increasing thresholds?

Dr JS Yes, there will be stewardship programmes, and things like scimac which are introduced and it will be a condition of the technology that farmers sign up to these, and it should also be a condition that these stewardship programmes are inspected an monitored and if farmers are not complying then they are denied access to the technology. That is the way I understand that these stewardship programmes and things like scimac will work, but whether this will work or not I don't know.

Chair Sorry, could I just ask you for the benefit of the members of the audience who don't know what scimac is, could you just explain that please?

Dr JS It is the supply chain initiative on modified agricultural crops, and it was an initiative set up by the industry to develop guidelines for the production of GM crops.

Chair Thank you.

Prof PD We have a lot of experience with high erucic acid rape seed, and that's often given and kind of quoted as a bank of experience that we can draw on. Maybe you could just explain what high erucic acids are and why there are isolation procedures and how well that works, and also how much high erucic acid rape seed there is in the UK and how much of a…

Dr JS High erucic acid rape is an oil seed rape which is produced for in particular industrial purposes, the high level of erucic acid means that the oil is non-edible and so the production of those crops is segregated from food production oil seed rape. There are isolations established for High erucic which I think are 100 metres, and I think there is also an isolation requirement of 4 years in crop rotation. Now, this has not become a particular problem in terms of food crop production of oil seed rape because the number of erucic acid crops has always been quite low, and usually fairly well managed and maintained in the production system. I think where the concern arises is that if oil seed rape….if GM oil seed rape becomes very widely grown, becomes say more than 20% 30% of the area of oil seed rape, then it becomes much more difficult to manage these sorts of things. If you are just talking about a few crops here and there around the country, it is much easier to manage than if you are talking about it becoming a mainstream part of agriculture.

Dr AB Co-existence of course requires that you can control the supply chain to quite a high degree, and traceability is an important feature of that. What I would like to know is what measures are currently available to trace seeds in existing seed supply chains and are these appropriate for tracing GM seed. To facilitate the process for example could GM seed be dyed so it was a nice visible marker, or could there be some other phenotypic marker that would be useful which could be recorded at the point of registration of the new variety? I mean what options are available currently?

Dr JS I don't see the problem really being in seed production. I mean I think we have a very high quality seed production system in the UK and in Europe. The levels of seed purity are pretty good and the supply chain through from seed to farm has a high quality. I mean NIAB is involved in testing this, and we are involved in OECD inspections of seed, and actually the number of seed lots that fail each year are pretty low. We are now beginning to start to use some of the tests that Chris was talking about to use genetic tests now to look at purity of seed stocks and this is being done more and more, and of course that can then

be extended into GM seed crop production or non-GM seed crop production. So I don't really see the issue to much in certified seed. It may be convenient to put a marker on and that can be done. For example oil seed rape components in varietal associations are marked. The male sterile is white seed and the other one is purple seed I think. So you can pick those out, so there are already markers being used. The difficulty is in the crop production and in farm saved seed. One of the difficulties I think is going to be particularly in saving seed of oil seed rape if you have also grown GM rape on your farm. And that I think is going to be quite problematic particularly if you are trying to achieve a very low threshold and I think this is where we have a problem in that its going to make farm saving of rape seed in particular very difficult, and there will need to be testing done of farm saved seed, for the farmers to have confidence that it's a low enough threshold so that when the crop is then harvested it will meet the 0.9% level of the market.

Prof PD Can I ask another one about thresholds? A basic question. Why do we need thresholds? Is it anything to do with the safety of things, for example environmental safety?

Dr JS Well, we have thresholds for varietal purity in seeds, so that a farmer knows that when he buys a batch of seed it's that variety and not another one and also it doesn't contain off types or dead seed or whatever. For GM seed, there was a feeling that a threshold was needed but the reason for it was in fact a political one, because the EU had decided that the product threshold would be 0.9 and if you are going to produce say oil seed rape at 0.9% you have to have seed with a considerably lower level than that to allow for the fact that contamination will occur during the growing of the crop to allow for pollen coming in and seed contamination and so on. So there was a group of us who got together in Brussels and pondered over this, and we came to the conclusion, that, in order to allow enough margin for the farmer to achieve the threshold of 0.9 we would have to set the seed threshold at about 0.3 for oil seed rape, so that allowed him effectively about 0.6 to play around with in growing his crop and that's how we achieved the threshold. Very unscientific I know but that's basically how we did it, because we were basically worked into a corner. The EU said that 'politically we will set a level at 0.9 and therefore we want scientific advice on how you can achieve that and what is required for seed'.

Prof PD So it's principally about defining a product rather than about safety and environmental impact?

Dr JS Well the assumption is that if GM products are commercialised they are safe and therefore we are not talking about food safety issues, we are talking about the requirement, if you like, to satisfy society over where you draw the line between what is GM and what is not GM.

Prof PD And what are the consequences to farmers, to the consumers and so on of levering that threshold down, and down, and down?

Dr JS If you lever it down far enough you kill off GM which is what obviously some people are trying to achieve.

Panel But in the sense of achieving lower thresholds it presumably has a cost?

Dr JS Yes, I mean the lower the threshold the harder it is to achieve and the more expensive it becomes to achieve it.

Chair Okay, well thank you very much for that. I would like to ask our other two experts to return to the platform please. We are now going to open the debate to the floor, it's your chance to grill our experts. So, do we have any questions please?

Josie MacDonald, Farming and Livestock Concern:
I am very disillusioned by the standard of science behind this. I have got oil seed rape growing in my garden and I haven't got a crop within 8 miles of it, and I have realised that this is coming from bird seed, which might be imported. So how do we stop this transfer when we are importing from America, Canada and other countries? I am also concerned with the effect of seed dropping into the soil, but apart from that, part of the plant rots in the soil, and those genes are released and can be picked up by soil organisms and this is not being looked into. Having about 14 files on this from information collected round the world, I cannot find a good peer reviewed piece of research on the safety of it.

Chair Okay well let's take those two points. First of all shall we look at the idea of oil seed rape is apparently growing in this ladies garden, because it's come from bird seed imported from other parts of the world? How do we deal with the issue of imports?

Dr JS Well first of all the dispersal of oil seed rape by seed is not a new phenomenon and it occurs all over Britain, along motorways, motorway verges and so on because it's being dispersed by man mostly. So the reason that it's in your garden is because you put it there and the reason it's been occurring in many other parts of the country is because people are putting it there. Yes, I can understand the concern that that may be GM but I mean that is an issue that we have to confront. We are not talking about particular food safety issues, but we do have to accept the fact that once GM oil seed rape is commercialised it will be everywhere and that is inevitable, because conventional rape is everywhere, there is no reason why its going to behave differently from conventional rape. So once we start growing GM rape it will become as widely dispersed as conventional rape.

Josie MacDonald, Farming and Livestock Concern
So this is a fait accompli more or less?

Dr JS I consider it a fact.

Chair Okay lets turn to the next point, the idea of plants rotting in the soil and some of the trans-genes that are introduced into the plants becoming available to soil organisms and maybe we will take an ecological perspective on this, so Rosie Hails, do you have any thoughts on that?

Dr RH Yes, I mean I am very much a terrestrial ecologist, I haven't got any particular expertise in gene flow in the soil, but yes I mean plants will decompose in the soil, and this is again equally true of conventional and trans-genic plants. There has been some research, Chris you probably know more about this than me, on the rate of horizontal genes transfer between plants and soil bacteria? Can you say something about that?

Prof CP Yes, I'm aware of one very well-executed study that looked at horizontal gene flow and founded under laboratory conditions, although it has to be pointed out that the organism that was the recipient was selected very, very carefully to show very, very high rates of recombination, so it was an organism that was if you like a laboratory model, and was particularly adept at swiping pieces of DNA from other bacteria. They then looked for the same process to go on in the natural system, and found no evidence of it, so its one of these

things that is theoretically possible, that there has been a reasonable level of study to look at it, and nobody has found any evidence of it occurring to a significant extent under natural circumstances. And of course many of the genes that are the subject of trans-genesis do themselves come from soil organisms and are present in the original organism in the soil as a matter of course.

Chair Do we have any further questions?

Mr. Howard Evans, Retired Forester:

Can you tell us whether the small particles of genetic material which you transfer in genetic modification work are they in fact have a simple Mendelian type of transfer within plants, and if that were the case, do you choose things which are recessive or dominant? Because if they were recessive it would seem the flow would be greatly lessened?

Prof CP The whole process for generating commercial GM varieties or potential commercial GM varieties from the original activity that created the transgenic plant ensures that there is stable incorporation of that trait into the DNA of the plant. Either into the chromosomes that are in the nucleus or, to a limited extent and mainly for experimental purposes, the DNA that occurs in chloroplasts and mitochondria. Whether the trait is a Mendelian dominant or a recessive is dependant upon the mode of action of the trait. So you could have some GM traits that are inherited as a dominant trait and some that are inherited as a recessive trait and obviously the agronomy of the trait is going to be the determinant of whether that is valuable. In terms of the phenotype, that is what the plant looks like in the field, if there is gene flow and it is a recessive trait then you will need two copies of the gene in order to demonstrate the phenotype. So for two traits with similar rates of gene flow, the phenotype will be less abundant for a recessive trait, although the frequency of the gene in the population will be the same. There is a very strong interest in experimental laboratories in non-nuclear transfer, because this offers a rather effective way of preventing potential distribution through pollen. This is because the chloroplast in plants tend, although not absolutely exclusively, to come from the maternal parent. So the genes that are carried in pollen don't contain chloroplast DNA. Chloroplast transformation is an intriguing target but I am not aware of any cultivars, at or near market that have been produced by this technology. But your summary is absolutely correct.

Chair Yes, please go ahead….

Mr. Howard Evans, Retired Forester:
If I may, in the American material that you show where there appeared to be no plants whatsoever carrying the trait for the herbicide resistance. Do you know whether that was in fact a recessive material that had been transferred for the herbicide resistance?

Prof CP No, you only need one copy of the HT gene, to get the phenotype.

Chair So that's a dominant?

Prof CP Yes

Chair And could I just add, for those of you who are interested in the issue of chloroplast DNA, that was dealt with at the Belfast meeting that we held last week, and the transcript will be up on the website relatively soon, so if you are interested in that you can follow that up there.

Prof PD There are no characters that are in commercial production where the gene has been put in the plastid. There are some experimental lines. You are right in suggesting that pretty well everything, I think every trans-gene is dominant at the moment, but as Chris has said, it is possible theoretically to introduce recessive genes but they are more difficult to work with. And all of the ones so far are Mendilian, they behave in quite a regular fashion.

Chair Now before we move onto our next question, I know that many of the audience here are experts in this field, but if there is anybody here who feels that it hasn't been explained properly, please make themselves known and I will endeavour to get a clearer answer from everybody concerned. Do we have any more questions?

Jonathan Harrington, Private Crop Consultant and Member of Crop Gen Panel
Normally I get a Boo from the audiences I speak at. I get a lot of objections when I go to public meetings like this. And one of the questions which is asked of me is fear of the change in the environment, something that the speakers dealt with. But two of the crops that have been in trial in the last three years, namely maize, which has no wild relatives,

and sugar beet, which doesn't actually go to seed at all, would appear to many members of the public to offer a much lower risk than oil seed rape, which has already been explained can disperse pollen over a wide area. Would any of the panel like to comment on that, and if there is a risk in terms of environmental pollution or danger, it must be vastly less with maize and with sugar beet than perhaps with either, in this country anyway, with any or many other crops?

Dr JS First of all with maize, well I think all of the speakers have mentioned the fact that maize has no wild relatives in this country, so therefore any transgene produced in maize as far as we know will remain in maize, it won't go anywhere else. Sugar beet is an interesting one. First of all sugar beet does produce seed, unfortunately, in this country, and is one of the reasons why, in parts of East Anglia, we have a huge weed beet problem on some farms. And there are issues of seed production. For those of you who are not familiar with sugar beet or fodder beet, seed production occurs in Southern Europe where they grow two year old plants, which grow up to flower and seed and they cross-pollinate them and they produce the seed, that seed is then sold into the UK, and is grown here. Now, if there are problems with the seed production, particularly if genes come from outside the beet crop, from wild beet, then you can get what is called annual beet, or bolting beet, and this beet goes to flower in the first year and becomes a weed beet. It produces seed, the seed sheds to the ground, it persists in the ground and it comes up in subsequent sugar beet crops. So there is an issue of first of all how we produce GM sugar beet in the seed producing areas to try to restrict the gene and keep it contained purely within the seed crops and how we also produce the GM beet in a background where we don't have any bolting and any flowering beet, and the breeders are looking at this very carefully and the seed producers and are trying to produce as high quality as possible with the minimum number of bolters by having very effective seed production, very effective screening for the bolting allele and by close monitoring of crops. But there is an issue there and it does need to be looked at very carefully.

The other interesting thing, just quickly, is that beet does have a wild relative, throughout Europe, which is the *Beta maritima,* the sea beet or wild beet, and so potentially GM beet can transfer genes into wild beet and this is being studied quite extensively across Europe.

Chair I know Rosie you wanted to make a point on that.

Dr RH I just wanted to make a very quick point really about putting everything in context. If a crop does cross-hybridise at very low rates with wild relatives, that raises certain questions, I think that we really must answer in risk assessment, but that doesn't necessarily mean to say that we should shut down the possibility of growing that crop altogether, if there are other biodiversity benefits to be had from growing that crop. For example there has been work recently published by Alan Dewar and colleagues at Brooms Barn which has shown that with GM sugar beet if you actually alter the way in which you manage the crop you can get significant biodiversity benefits. So just to put that into a little bit of context really. We have got to look at our environmental impact assessment in the round I think.

John Tanner, Department for International Development:
It's a question for Dr. Sweet. I am intrigued that these threshold figures you talk about seem to be arbitrary, I think that's the word, I don't know if you actually used that word but they are arbitrary. You suggest also that they may be used as non-tariff barriers to trade. Do you want to make any further comment on that comment that you made?

Dr JS Well, I would draw your attention to the fact that this is a scientific meeting and therefore I couldn't possibly comment on these things, except for saying that there was no scientific foundation or basis used for the setting of what was first of all 1% and now has changed to 0.9% threshold. I mean it's not based on food safety. And it's not based on any other standards or whatever they use in certified crop production. It is based on political and sociological grounds.

Prof PD There are distinct parallels with certified seed and then again there are genetic purity thresholds and you could argue those are about defining a product. A farmer buys certified seed, he expects…he or she expects seed of a particular genetic purity and there are certain parallels with that.

Chair Okay our next question

Phil Morris, IGER:
I'd like to raise the issue of the relationship between the impact of GM crops and their non-GM equivalents. For example, one can generate herbicide tolerance through a non-GM

route. Plant breeders are constantly breeding for resistance to environmental stresses through a non-GM route. If these are considered to be problematic, what is the relationship between the impact of GM and non-GM, for the equivalent traits. Should we be considering the traits rather than the mechanism by which they are produced?

Chair Thoughts?

Dr RH Absolutely yes, we should be considering the traits rather than the mechanism. It's just that at the moment the way the debate has developed we have a completely different regulatory system for GM crops compared to everything else and that's what makes the debate. That frames the terms of the debate really.

Phil Morris, IGER:
Should we be changing the regulatory system?

Dr JS Well, just to comment briefly on that. The Canadian system of regulation is based on novelty, so if you introduce a novel crop regardless of what its origin was or whatever, for example if you introduce kiwi fruit into Canada for the first time, that would be treated as a novel crop and they would look at it to see whether it harmed you and was safe and all the rest of it, and having done that they would then licence it and then allow people to grow it. So the Canadian system is based on novelty not on the production system that was used. And it would be much more logical if the rest of the world did that. Rather than being hung up on system. The first GM crop that we looked at at NIAB was a chrysanthemum where the gene had been vectored from another chrysanthemum to change the flower colour. But, because it was a transgenic technique that was used, that material went into quarantine, and there was all sorts of who-ha and isolation requirements. And all it was, was a gene from chrysanthemum, put into chrysanthemum.

Chair Questioner again please?

Question from the floor:
Could we be careful about the word transgene? Because there are two forms, at least two forms of genetic manipulation. One involving real transgenes, ie genes that transfer across

genera and genetic manipulations that involve manipulating the expression of endogenous genes which doesn't necessarily involve a transgene.

Dr JS Sorry yes, perhaps what I should have said is that it uses a non-conventional or close to conventional breeding technique to transfer the gene. In other words it's a bacterial vectored gene.

Chair Phillip Dale has a brief point to make on that.

Prof PD It's just following the point about product or process. In the UK, novel foods are regulated in terms of the product, so kiwi fruit is not GM, that is regulated because it was novel to the European population. Anything that is imported like some novel nuts and various things that are not consumed in Europe have to go through the regulatory process, so for food it is novelty that is regulated, rather than process. For environment it is process that takes the lead. It's just the history of the way regulations have evolved in Europe.

Chair We have another question here please.

Mike Theodorou, Institute of Grassland and Environmental Research:
I think there is concern in the GM debate, not only because of the genes that we are transferring from one crop species to another, but also because of the marker regions that we use to identify those genes. So, for example, antibiotic resistance markers that get transferred alongside the genes of interest. And as with the questioner, I think our first questioner earlier on about the fact that plant biomass is degraded in the soil and there is the potential to transfer from one, well in that case, plant species to bacterial species, many of these crops are produced for livestock, and they are eaten and they are digested in the rumen and the rumen is in the ecosystem that contains a huge population of micro-organisms that are exchanging genes all the time. So what assurance can we have that things that we put into crop plants and don't end up in bacterial species, antibiotic resistance genes for example, in the rumen and then beyond move into the human population.

Chair Okay I will turn to the panel on that in a moment, but would just like to add that the meeting in Belfast we had last week looked specifically at this are, so I am sure our panel

can add something more to it, but if you are interested, when the transcript is available, which will be shortly, I suggest you go and have a look there, there's a lot of information. But anyway, I know Chris you are interested….

Prof CP Well I would say is that most of the antibiotic resistance markers that were used came from soil bacteria in the first place and will have formed part of the natural diet of these ruminant animals since their evolution began. Secondly, again, there has been an extensive programme of screening to see whether there has been horizontal transfer of antibiotic resistance and so far there is no compelling evidence. However as a result of public concerns, the best practice guidance for GM production that the EU are introducing will prevent the use of antibiotic resistance markers moving into new commercial GM varieties in the not too far distant future. I can't exactly remember which year it is, Phil will probably know. 2008 is it?

Prof PD I think it's 2006. Because there are two. There's one for experimental use and one for commercial use, and I think one is for 2004 and the other is 2006. Anyway if you want that kind of information then talk to me afterwards…

Prof CP There's also an analysis that estimated the relative antibiotic load of animals that were fed on GM versus the normal industry prophylaxis involving routine administration of antibiotics to cattle and to poultry in the UK and there was a very significant difference between the load.

Josie MacDonald, Farming and Livestock Concern

If that gene transfers into the gut of animals or humans, I am particularly concerned about cattle. Will it change the function of bacteria, or is there a possibility of that in the cattle system which depends entirely on bacterial digestion as the cellulose and part of the normal diet of the cow.

Chair Chris please…

Prof CP I think if we had a significant likelihood of the rumen digestive process being modified because of contacts with antibiotics, that is the generation of antibiotic resistant rumen micro-organisms that would affect the output, that would have already happened because

of the prophylactic use of antibiotics in animal husbandry. If I can draw your attention back to the way in which the Scientific Debate has gone already, the essence of the argument is not about gene movement, it's about fitness and the selection pressure that you impose on the natural population. Thus, if you are continually administering antibiotics as part of animal husbandry, which is routinely done in Europe, then that is much more likely to select antibiotic resistant bacteria than the small amount of DNA that would go in through the feeding of GM animal feedstuffs. To my knowledge, and I'm not an expert in this area, there is no indication as yet that this latter process has had any measurable effect upon things like the efficiency of rumen digestion or the nature of the animal products that come out. I have considerable concerns about the routine addition of antibiotics in animal husbandry but, as far as I know, the derivation of novel organisms has not been one of the results.

Josie MacDonald, Farming and Livestock Concern

I wasn't referring to antibiotic resistance, but a retro virus from cauliflower mosaic virus or something like that.

Chair Okay Phil yes, you want to make a point on that?

Prof PD As Toby has mentioned there will be quite a lot on the website from the Belfast meeting, but there are kind of two ways of approaching this. One is looking at the likelihood of gene transfer. There have been quite a lot of experiments. The rumen is quite an inhospitable environment for gene transfer, but those kind of studies are there. The problem is proving a negative, and that is often the difficulty with much of this. The conclusion if it occurs it is extremely rare. So that's the first bit of evidence, or the first way of approaching it. The second is to look at the context in the sense that ruminant animals are eating DNA from all kinds of sources, and Chris has already touched on this. There are thousands of tons of DNA going through ruminant animals around the world and that DNA is from all kinds of sources. Many plants contain toxins and if they don't express the toxins, like potato contains a toxin gene in the cultivated potato it's switched off, but the gene is there, so there is an opportunity for it to transfer. Animals that are eating Brassicas or Cruciferae they are eating millions and millions of cauliflower mosaic virus particles. And so all of that is happening and the antibiotic resistance genes are in, as Chris has said, in soil. Most of them are from soil micro-organisms Streptomyces so all of

that DNA is going through. And the significant question is 'well what is different about GM compared with that sort of context of DNA going into the ruminant animal?' and that is where the kind of risk assessment tends to focus. So, there is quite a lot going on in that risk assessment, but as I say, much more of the information will be on the website from the Belfast meeting.

Chair And could I just add, if people don't have easy access to the website Adrian Butt who is Secretary to the GM Review Panel has just confirmed that if you write to them, they will send a transcript to you. Any more thoughts?

Michael Abberton, IGER:
I would like to ask the panel to what extent what they said previously would apply equally to the production in transgenic plants of pharmaceuticals for human use?

Chair Again, this was touched on a little bit last week, but let us see if any of our panel care to go there?

Prof JS Well, I think the first thing that will obviously be looked at is which plants are used for pharmaceutical production, and how can we prevent pharmaceutical gene products getting into food crop plants? There has been quite a lot of concern that some of the earlier crops for pharmaceutical production, particularly in the States, have been things like maize. And there has been concern that some of the genetic material is moving into food maize. So I think that there are very good and sound reasons why we should strive for segregation between food crops and pharmaceutical crops. We know that pharmaceuticals are biologically active and have the capacity to be harmful, and therefore there is an advantage in segregation. In the case of GM the assumption is that once a GM crop is de-regulated it's not a human health problem, so we are talking about two different situations here. One is where there is potentially a human health problem, and one is where there isn't, and so therefore there are very strong reasons and strong grounds on why we should try to segregate. Having said that, there is concern I think that we do not use food crops for the production of pharmaceuticals, where it can be avoided and there are a number of alternatives that can be looked at. Or, if you have to use food crops you use the non-sexually reproductive parts of plants and you make sure that when they are going any sex it's done in complete isolation where the seeds and the pollen cannot escape, so that you

have control over the situation. So, they do need to be looked at differently from GM food crops in that it is imperative that there is segregation and effective segregation and that has to be foremost in the mind of people producing pharmaceutical crops.

Prof PD I am involved in a collaboration on developing a project with Guys Hospital on this, and it does raise quite a lot of significant challenges in how to manage it. Clearly the potential benefit, if it all works is very considerable. The production of HIV vaccines and TB and various other kinds of vaccines. Essentially the bottom line is if the risk assessment shows that it is quite unacceptable to release these into the environment it will be done in containment, but that depends on whether the yield is high and whether the value is high to determine whether that is feasible. The problem with avoiding food crops is that some of the vaccines we want to be edible and if we don't choose something that is edible then we have a problem. So that is part of the reason for the interest in edible crops and inserting vaccines. But as Jeremy said, there are various possible strategies for managing risk in terms of making plants sterile, possibly labelling plants in particular ways like maize or whatever it is and make them a different colour or marking them in a way that would make them quite unacceptable for food. But there are some very significant challenges in managing that.

Chair Okay, we have another question, but before we take that, can I just draw your attention to the feedback forms that are on your chair. We are very interested to hear what you make of this meeting and also, probably more importantly, it is yet another way you can get your thoughts fed into the work of the Science Review Panel. So, could I ask you to have a look at these, and please fill them in and hand them in on the way out. Another question please.

Susan James, Interested Member of the Public:
I think it was Professor Pollock who mentioned a change in procedures, or something, to accommodate public concern about GM technology, I would like to know why you think the British Medical Association is so concerned about antibiotic resistance in particular in this context and why have they called halt to the farm scale trials?

Prof CP Some time ago the BMA expressed some concerns about GM foodstuffs which did, to some extent, concentrate upon issues associated with the potential for developing antibiotic resistance. Those concerns were debated extensively within the scientific community and

they are still an issue of some controversy. Many people I think felt that, as I have alluded to earlier, the main causes of antibiotic resistance and its spread are over-excessive prophylaxis in two particular sectors. One of them is the animal production sector and the second is the medical sector. So whilst it would be true to say that these opinions have been expressed, it would be equally true to say that there is a significant amount of disagreement within the scientific community about the value of those criticisms. The farm scale trials of course don't put material into the food chain, and won't put material into the food chain, but they do involve GM crops that have got antibiotic resistance markers. Were it to be shown that the concerns of the BMA were justified, then that would be another reason for undertaking the sorts of steps that Professor Dale and I alluded to, in order to generate GM crops without the use of antibiotic resistance markers. I guess that the only other thing that I can say that would tend to offset the BMA's concerns is the fact that HT crops have been entering the human food chain in North America in substantial amounts for a number of years. There is no evidence of any increase in the prevalence of antibiotic resistance that's not directly attributable to the two causes that I indicated earlier. That is excessive prophylaxis in animals and in hospitals.

Chair Do you want to come back on that? No? Okay, do we have any more questions?

Anita Shaw, Techniquest, Cardiff:

I wanted to ask Rosie Hails about when she was talking about the viruses that you can confer resistance in plants by putting some of their coat protein into the plants? Given that viruses are successful because they are able to mutate so quickly, what's the point of putting that into a plant given that it may mutate and therefore the whole crop is not going to be viable?

Dr RH Why would the crop not be viable? Because the viruses would co-evolve?

Anita Shaw, Techniquest, Cardiff:

Yes, basically if you are going to put the bit of virus into the plant, then the virus is going to mutate which means that it would be able to get into the plant anyway because it's not resistant.

DR RH Right, okay, so you are talking about the whole process of co-evolution, that was one of the themes of my talks. Well kind of the short answer is they do it because it works, because it does actually produce very enduring viral resistance and that's you know why they are able now to grow this transgenic variety of Papaya in Hawaii for example. That's just one example, whereas before they have had huge problems with I think it is called ringspot virus. And also you know they other benefit side of this is that you know if you control these sorts of pathogens in this way then you can cut down on the synthetic chemicals you can use to ordinarily control them. So, that's the motivation behind these sorts of transgenic plants.

Dr JS Can I just make a comment on that? Cross-protection in viruses has been known for some time. I mean there was the classic work that was done years ago where you put a mild form of TMV into tomatoes to make them resistant to the sever strain, and there was always concern that in fact that might cause mutations in the virus, but I don't think they ever particularly did and it does appear in fact that if you look at wild plants and the relationship between wild plants and viruses you do have this co-evolution of viruses and wild species and the development of virus-induced resistance in plants. And you have a dynamic there, and so it is something that's occurring in nature, and I guess what we are trying to do with genetic engineering is to simulate that in a different way. Instead of actually inoculating the plant with the virus you are putting in a bit of viral protein to induce a similar sort of reaction. Now obviously there are consequences in doing that which you have alluded to, but it is something which relates very much to what is happening in the wild anyway, where viruses are challenging each other, and challenging the induced resistance that's caused by other viruses. And it's a dynamic that has been going on as long as plants and viruses have been around.

Chair We have a couple more minutes left so we will come to close shortly, so if you have any burning questions please get them in soon.

Josie MacDonald, Farming and Livestock Concern:

To Professor Pollock. There have been no complaints in the US and Canada of any ill effects on consumers from this, you do not have an adverse reaction reporting system which we have normally when we licence new products. Because if a product isn't labelled there is no point in reporting that it is the cause of your trouble. You will never be able to

prove it. The other thing I would like to say is that in my farming days, I benefited a lot from naturally improved crops, grass etc., barley and naked oats that were produced at this centre. We have increased our food production four fold since the last war crossing plant genes with the same species, selecting from the best. Why are we going into this, that so far has produced no real advantage regarding yield, lack of sprays and nutritional benefits? And if these sprays as EU tell me are now going to be examined for residual and synergistic effects, 800 of them by the year 2008, what are you going to do, when I am pretty sure, glufosinate and glyphosate will be banned?

Chair I'm not going to ask Chris to take the whole rate of that responsibility on his shoulders. I think those are important questions. But Phil Dale is very keen to make a point here….

Prof PD You are right about in the States not having segregation labelling, but there is a very effective litigation system there, and at least one has the impression that if there is an effect of them then it would have been detected and somebody would have sued somebody about it. On the question of naturalness, it's an interesting debate about what is natural. And if you look at the history of plant breeding from Stapledon, there was polyploid, there was induced mutation, there was wide hybridisation and a host of other things. Induced mutation, one of the most successful barley varieties every used was Golden Promise and that was produced by mutation. Now, its an interesting debate to discuss you know what is natural and what isn't natural and is hitting something with radiation or chemical mutogens and causing all kinds of genetic changes and damage some would say, is that more or less natural than GM? As I say, I think the natural argument is quite an interesting one, and I think that many of the things that have been done, if you look at it in a kind of ideological…from an ideological perspective, many things that have been done in plant breeding have been quite unnatural, but we you know…food supply has increased and plant breeding has been very, very successful.

Chair I am going to leave that rather large point for our final question here….

Tony Gordon, IGER:

Just to put the record straight, the lady on my right asking the question, implied that IGER may be producing plant varieties using genetic manipulation, and we are not doing so.

Chair I think that's a fair point. And our final question please…

Ian Panton:

Can I just ask two questions please? One is on bees as pollinators. I understand that the Welsh beekeepers came out with a policy decision last week that they would expect to be compensated for any genetic pollution of their product. So my first question please is, what do the panel think about bees as pollinators? And the stance that has been taken by the beekeepers that they wish their particular purity of their product to be respected.

The other thing is I understand from Dr. Sweet that as far as oil seed rape is concerned it is sewed at 60–100 seeds per square metre. I was wondering therefore why I understand that the farm scale evaluations are being signed off at 150 seeds per square metre, and in fact as Dr. Butt will know, there are in fact some releases at 250 seeds per square metre. I wonder if we could have a comment please? Thank you.

Prof CP Well I can answer the latter point it is because there is a variability in the germination percentage of some of the material used in the farm scale trials, so sowing rates were adjusted to give similar germination rates between the GM and conventional half fields.

Chair And the subject of bees?

Dr JS Yes, I mean this is a tricky one. I mean the beekeepers are perfectly entitled to want to monitor the quality of their honey and to decide you know what it is sourced from. I think it raises a number of different issues. First of all there is this issue of how much pollen is in honey, and we were discussing this a bit on the train coming up. The difficulty you have on setting thresholds is you talk about say 1% and then you have to say well 1% of what? In honey you have a particular circumstance. You know, what are you talking about in terms of pollen as a percentage of honey and then perhaps transgenic DNA as a percentage of honey. And so again the beekeepers of Wales, or wherever, will have to decide on a threshold level, at which honey is either GM or non-GM, and once they have decided on that then they will have to try and market their honey according to that standard. So the difficulty they will have is to decide on how you set this threshold. I mean it's always struck me as slightly curious that you can have organic honey when the bees may be foraging from exclusively non-organic farms. And if you buy organic oil seed rape honey,

then you have a complete contradiction in terms, because, as far as I know, there are actually no organic farmers in this country growing oil seed rape, so therefore how can you have organic honey from oil seed rape? So I think that the beekeepers will have to think very carefully about how they want to achieve these standards and how they want to establish them and have a very clear perception of what it is they want, and then take that forward. But you are entering a minefield. I mean this whole area of thresholds is a minefield, and I think the beekeepers have to tread very warily when they get into it.

Chair And there we have to leave it. And so I would like to say thank you very much to our experts, Jeremy Sweet, Rosie Hails and Chris Pollock. Our Panel Phil Dale and Adrian Butt and thank you very much indeed. Don't forget you have an opportunity to get your thoughts in on the forms here and also on the website and thank you for coming. I hope you can catch the last of the glorious sunny afternoon. Thank you very much.