NEW ZEALAND SCHOLARSHIP 2004

BIOLOGY

QUESTION ONE
Compare and contrast the possible outcomes of releasing into the environment, plants genetically modified for herbicide tolerance with those of plants genetically modified for insect resistance. Your answer should include both the **ecological** and **evolutionary** outcomes of such releases, and evaluate the likelihood of these outcomes occurring.

Sample of assessed candidate work – Outstanding Performance - Performance Descriptor 1

One of the major fears that consumers appear to have in regards to crop plants genetically modified for such things as insect resistance and herbicide tolerance is the idea that these plants could somehow 'escape' into the wild and cross with wild relatives, creating 'superweeds' that would be resistant to any human efforts to control them. Although one of the conditions placed upon scientists regarding GMOs is that they be modified to be unable to survive to a certain level in 'natural' ecosystems, the fact of the large geographical range of plant seeds due to factors such as wind and insects means that contamination is always a real threat for those growing GM crops.

Whether or not GM crops would have any major effect on the environment if they were released would depend to a large extent on whether or not they would be better adapted to survival than wild competitors. Because agriculture is such an old practice in many human societies, many major changes have occurred in crop plants species due to factors such as selective breeding: wheat, for example, is thought to be an allopolyploid cross of three ancestral species that probably would not have evolved to the form we find it in today if it had not been for human manipulation. In this sense, the fact that many crop plants have been bred over an extended period of time for factors that make them easier to harvest and with greater yield means that they would possibly be ill-equipped to survive in an environment that did not feature human manipulation of reproduction and of the presence of other species (such as weeds).

> Directly addressing what the question has asked for.

> Good example of integration of knowledge from other areas of biology.

However, the resistance that some of these plant varieties have to insects such as caterpillars and moths (may varieties of GM crop plants have a resistance gene taken from bacteria) would possibly provide these plants with a competitive advantage over wild species if they were released into the environment. According to the competitive exclusion principle, no two species can coexist indefinitely with the same ecological niche – so if crop plants were released that had similar niche requirements to plants existing in the wild, it is possible that the major advantage of resistance to insects would effectively allow these crop plants to dominate the ecosystem, perhaps reducing diversity and disrupting natural food chains.

> Evidence for evolutionary impact – selective advantage of insect resistant crops. Also application of knowledge from other areas of Biology.

Also, the fact of resistance to insects itself would be likely to have an effect on the ecosystem if the GM plants were successful: although insects are undoubtedly pests in agricultural situations, they play an important part in maintaining the stability of natural ecosystems: any

> Evidence for ecological impact – food webs of insect resistant crops.

major replacement of wild plant varieties with bt crops modified for insect resistance would be likely to reduce resources such as food for wild insect populations, hence reducing their numbers considerably and perhaps causing the extinction of some species. (Interestingly, a Lamarkian view of evolution would postulate that such insects would develop resistance to the bt toxin in response to need for this. Certainly, diversity would ensure that some insects would be better adapted to resistance to such toxins: perhaps natural selection would give rise to resistant insect populations – which is always a worry in the development of things such as pesticides in agriculture, which sometimes have to be updated).

Evidence for evolutionary impact of insect resistant crops – selection pressure on insect populations.

As for tolerance to herbicides, it is unlikely that his would confer any particular advantages to GM plants released into the wild (unless of course **pleiotropic** effects of this tolerance somehow gave the plants an adaptive advantage in some other sense). Because, as stated earlier, crop plants may be naturally maladapted to survival in the wild due to thousands of years of selective breeding, it is unlikely that they would be better equipped to survive than wild varieties of plant, seeing that herbicides, unlike insects, do not have a place in natural ecosystems.

Evidence for evolutionary (selective advantage) of herbicide tolerant crops; excellent analysis.

As for the fear that GM crops plants would somehow be able to cross with wild relatives, giving rise to 'superweeds', there is certainly a mechanism by which – in theory – this could happen. If any of the crop plants released did have close enough relatives in natural ecosystems, for hybrids to be formed (certainly, some varieties of crop plants would have wild relatives), the rare event of somatic doubling could potentially result in a fertile polyploidy being formed from a sterile hybrid. Such a hybrid would potentially express both the phenotypic traits of resistance to insects or herbicide tolerance of the GM crop plant, and the environmental adaptations of the non-GM, 'naturally occurring' plant. However, because such events as these are extremely unlikely to occur (in theory) – as compared, for example, with bacterial transformation, which so easily allows resistance to antibiotics to be passed from one bacterial species to another – the risk of 'superweeds' actually establishing themselves, creating havoc in both the natural environment and that of agriculture, is probably extremely low. However, precautions must still be taken to ensure that such events do not happen.

Evidence for evolutionary impact (gene flow) of both crops. Good integration of knowledge from different areas.

One other concern to do with GM crops is the idea that they could effectively 'contaminate' non-GM crops such as organic ones. The threat of this occurring is potentially far greater than the possibility of the formation of a 'superweed' (and some studies have shown that contamination of this sort has in fact already occurred with some crops) – the issues to do with this possibility, however, are more likely to concern consumer opinion (as a lot of people do not want to eat foods produced from GMOs) and certain ethical issues involved with the process of genetic modification itself.

Overall, there are certainly ecological risks associated with releasing GM crops into the environment that could possibly have evolutionary effects (such as insect tolerance of these plants developing – an example of an insect species using plant toxicity to its advantage is effectively seen in Monarch butterflies and caterpillars, which accumulate the swan plant's toxins and are effectively protected from predation as a result – while also having almost total monopoly over the swan plant). Plants with resistance to insects would be likely to have more effect on natural ecosystems than those with herbicide tolerance, although if this tolerance was somehow passed on to wild plants, they could effectively become very efficient weeds. Polyploidy resulting in a hybrid between wild plants and GM ones is theoretically possible, although the probability of this occurring is likely to be low. It is also important to remember that evolution (except in the case of polyploidy) takes a long time to occur, and effective measures for limiting possible problems in this area could probably be developed before any major catastrophe occurred. However, an ecological effect would be likely to occur much more rapidly, so it is of the utmost importance that risks are constantly evaluated and attempts made to minimise them as much as possible.

Evidence for evolutionary impact (pest resistance) of insect resistant crops.

Good summary.

General Comments

Although this candidate did not address the impact on chemical usage, this answer demonstrates considerable breadth and depth of understanding. It is coherent with statements supported by specific evidence. There is appropriate and accurate use of biological terminology. All material presented is relevant and directly addresses the question. The ability to select relevant material and structure the answer to the question is evidence of perception and insight.

QUESTION ONE continued

Sample of assessed candidate work – Performance Descriptor 3

The growing of GE crops is one of the most argued issues in agriculture today. GE crops could bring massive improvements to agriculture and could even prove to be more environmentally friendly than traditional agricultural methods. However, the risk that weeds and insect will simply evolve to cope with new technologies is a very real one and could lead to an evolutionary arms race between pests and scientists with the GE crops. GE crops also pose a more immediate threat to the environment, not so much themselves, but what farmers will do with them. Instead of herbicide resistant plants reducing harmful herbicide use, they could simply increase it as farmers try and rid themselves from the weed once and for all. Considering that 70 million hectares of GE crops were planted last year these issues must be addressed and addressed quickly.

Gentically modified (GE) crops are those in which a gene from another organism has been placed to enhance some aspect of the plant's performance. The two main aims of GE research in crops is to provide crops with tollerance to herbicides and the ability to produce toxins which kill insect pests. They can also be engineered to be drought, cold, or salt resistant. To analyse the effects of commercial growth of these crops one must look at herbicide resistant plants separately to insect resistant ones.

Not relevant to question.

Herbicide resistant plants have been hailed by some as the cure to our current agriculture vs. environment woes. Before the advent of these crops, certain crops had to be protected from weeds by herbicides that were often bad for the environment and bad for the person applying them. However, crops can now be engineered so as to have resistance to environmentally safe herbicides. This is done by finding a plant with this herbicide resistance, identifying the gene responsible for it, then physically isolating the gene with restriction endonucleases. Then the gene is spliced into the plasmid of Agrobacteriun tumefaciens (for this delivery mechanism). The bacteria is then allowed to place the DNA into cells of the recieving crop as it would normally place its own genes. The cells with the gene are isolated and then are grown by cell tissue culture into full plants. In evolutionary terms, this process has a massive problem. Because only a few cells are grown up into whole crops, the genetic variation of these crops is virtually non-existant. Thus what will cause the death in one plant will cause the devastation of the whole crop.

Not relevant to question.

Although it has been claimed that herbicide tollerant plants will reduce herbicide use, many people believe that quite the opposite will happen in actuality. They believe that farmers, seeing the chance to improve crop yields will douse their plants exhaustively in herbicide. This use will increase as the herbicide's effectiveness decreases. The extensive use of herbicides is simply not good for the environment. It leaches into streams where it can reach dangerously high levels and there is also the problem of spray drift to non-crop areas. The problems created by overuse of herbicides are very real and are inevitable with this technology unless strict restrictions are put on herbicide use.

> Weak attempt to describe ecological impact of herbicide tolerant crops; needs elaboration. What are the impacts? Idea not developed.

The exhaustive spraying of an area leads to another problem that will only present itself a few years down the track and is really an evolutionary one. Weeds that are growing in an area that is intensively sprayed are under intense selection pressure to develop resistance to the herbicide. A similar phenomenon has been documented with bacteria all over the world developing resistance to antibiotics. Already farmers have found that each year they spray with a herbicide it becomes less effective and this causes many simply to increase the dose of herbicide so accelerating the process. There is a very real danger that an evolutionary arms race between GE crops and weeds (or insects as I will refer to later) will develop, making farmers more and more reliant on GE crops.

> Why? More elaboration needed.

> Some evidence for evolutionary impact (weed resistance) of herbicide tolerant crops. Needed to explain why herbicide becomes less effective.

Another danger, if a less likely one, is that the genes from the GE plant will be transferred into a weed. The weed would be able to resist certain herbicides and could be very hard to eradicate. This could cause major ecological problems as the weed could outcompete native plants and drive them to extinction. The transfer of genetic material could occur via a virus or via bacteria. Plants with close weed cousins are deliberately not released in an engineered form because the transfer would be too easy. The transfer via virus or bacteria is unlikely, but with 10 million hectares a year it will happen somewhere.

> Generalisation without supporting evidence.

> Evidence for evolutionary impact (gene flow) of herbicide tolerant crops.

Plants that can kill their insect pests also have great potential for being more environmentally friendly than their natural counterparts. The most common gene for this type of crop is Bt and comes from a bacterium. Organic farmers brush their crops with the Bt bacterium which then produces the toxin. However, this method has problems, as all insects around the plant are affected. GE crops for insect resistance could remove this problem and could drastically reduce insecticide use. The gene would be in the plant cells and so would the toxin, so only insects that ate the plant would be affected. However, studies have shown that Monarch butterflies are affected by Bt GE crops and who knows what else is that we don't know about. The chance that these crops could affect aspects of the environment is high, but perhaps it is one that is worth it if insecticides can be removed from use.

> Why? Statement is not explained in rest of paragraph.

> Weak evidence for ecological impact of insect resistant crops, not completely correct.

Insect resistant crops again raise the spectre of a genetic arms race.

> Attempt to provide evidence for evolutionary impact of insect resistant crops.

Only insects able to cope with the toxin could survive in a field of GE crops (this is excluding innocent insects) and so very soon a population of Bt resistant insects will be established. Scientists will have to keep producing more and more toxic plants to counter this. This is a very real evolutionary concern, and must be addressed as these insects, resistant as they are to Bt, could cause major ecological problems. We could find ourselves infested with insects we cannot kill by any normal means and the insects could devastate our ecosystem. The chance of such an extreme occurance is low but the chance of smaller problems is very high.

GE crops for insect and herbicide resistance raise different problems, but they are along the same line. Both crops could cause an ever escalating evolutionary arms race and could produce 'super bugs' (or weeds). However, the possibility of overuse of herbicides is an added ecological hazard concerned with herbicide resistant crops while insect resistant crops really show promise of being ecologically friendly. With 70 million acres already planted in 2003, GE crops are here to stay. The challenge in the next few years will be to decide how to use them in a sustainable manner. These concerns must be addressed or 50 years down the track we will be blamed for biological negligence.

Inappropriate terminology, "innocent insects".

Generalisation without supporting evidence and not correct.

General Comments

The answer attempts to address the question but lacks detail and supporting evidence.

Insufficient evidence for ecological impact, minimal evidence for evolutionary impact.

QUESTION TWO

(a) Using Figure 1, compare and contrast the activity patterns of the ptarmigan at the two latitudes of the study.

Sample of assessed candidate work – Performance Descriptor 3

For both activity patterns light appears to be the zeitgeber resetting the biological clock of the ptarmigans. This can be seen as both show predominant activity during the continuous polar day during February through to October and sporadic activity during the winter nights. This is more evident in the actogram from 70°N as at the latitude the distinct transitions from polar day to polar night are blurred by photoperiod storms more resemblance to a normal day-night pattern during the day of the months of October to February. Thus while activity at 79 °N starts with the start of twilight through to just before the end of twilight (shows evidence of an internal biological clock as the birds are able to anticipate the onset of light) showing no activity between and activity increases as the light period increases 70 °N is less structured.

> Evidence for feeding activity more intense in summer than in winter.

In both most activity concentrated in areas between start of twilight and sunrise and then later in the day sunset and end of twilight. Although 70 °N also shows a concentration of activity in middle of day in months April-May.

> Weak evidence for crepuscular feeding.

General Comments

The answer is difficult to follow and has just described two seasonal patterns only.

QUESTION TWO

(c) Comment on the extent to which the results support the following hypothesis: That the control of food-searching activity is more strongly entrained by access to food than by light-dark cycles.

Sample of assessed candidate work – Performance Descriptor 2

This is clearly shown by the study. There is a clear shift from a crepuscular rythm to being in time with food at day 31. Before this food was always available. Then again on day 64 the timing of activity moved with the food although the light regime remained constant. When the light regime was changed on day 98, the activity rythm changed a little bit, but stayed mostly in time with the food. By day 120 activity was almost completely around the time food was present. Because the activity rythm moved most for food once can see that food is the stronger zeitgeber. The control of food-searching activity is more strongly entrained by access to food than by light-dark cycles.

Recognition comment.

General Comments

The answer provides evidence that recognises that food searching activity is more strongly controlled by access to food, but no supporting evidence is provided.

QUESTION TWO

(d) Considering both studies, discuss the significance of the responses shown by the ptarmigan to its survival in its natural habitat.

Sample of assessed candidate work – Performance Descriptor 2

The ptarmigan is adapted to a territory where the photoperiod changes in length. During summer it can afford to forage when the sun is up, but during winter the sun doesn't appear for months on end. The ptarmigan must continue to forage during this time and must do so when food is available, as food is scarce in winter. Thus the biological clock for food availability is more important than that of the light-dark cycle.

Recognises that light cannot be a zertgeber because of continuous polar night.

Birds in the rest of the world (apart from Antarctica) can rely on a fairly constant photoperiod. If the food availability is highest or the predator threat lowest at dusk or dawn they can have a single biological clock in time with the light cycle which can tell them when the best foraging time is (dusk/dawn). However, the ptarmigan does not have this luxury as its photoperiod changes right from full light to full darkness. Thus it is more dependant on a biological clock that 'remembers' when the food was last available. This works in summer and winter. In summer, this enables the ptarmigan to forage continuously all day as seen on figure 1. In autumn and spring, the best foraging times must be in the twilight as it is most active then. This is probably due to both clocks 'agreeing' on the best time. In winter, as in summer, the day/night clock is useless, but the food availability clock will still work. In winter is seems as if this best time is around midday as there is greatest activity then.

Further reference to light evidence.

General Comments

The answer provides explanations for the presence of two zertgebers, but lacks detail and elaboration.

QUESTION THREE
The three examples shown represent just some of the diversity found in bony fish. Use the diversity of the fish and/or any other named group(s) to discuss the following statement: 'Diversity is the end product of evolution.'

Sample of assessed candidate work – Performance Descriptor 2

Throughout the process of evolution, diversity is both increasing and decreasing. For example, mutations, crossing over, independent segregation increase diversity but natural selection reduce diversity.

However through the ages, there has been from a simple one celled organism arisen billions and billions of species, some of which survived and some of which have become extinct, but as of the present we live, in a very diverse planet.

This would have come about by the process of evolution – the availability of niches on this planet is huge, and because is any population of a species, the natality rate is higher than mortality rate when there is unlimited resources, it eventually reaches a point where resources are limited and must be competed for, so that the mortality rate must increase (decrease in diversity), or another way would be for speciation to occur where the individuals with the suitable genes diversifies to occupy a new niche. And where there are new niches to occupy, it eventually does become filled, so in the billion of niches available on this planet, each is filled by a species especially adapted for it. At times, changes in environmental may cause new niches to become available and old niches to disappear, with the extinction of some species and formation of new species. Especially at times when environmental changes are sudden and extreme, then adaptive radiation occurs to produce many many new species and diversifying the planet.

> This paragraph continues a good description of evolutionary theory.

For example, the ancestor of all fish would have been perhaps an intermediate form of the three fish shown, or perhaps more alike to one of them than another. However the availability of many niches is the ocean, and the increase in population of the ancestral fish to the point these resources have run out may have caused sympatric speciation to occur, where the fish with the genes more suitable for the new niche (e.g one fish may have, through mutation, evolved the gene for a prehensile tail) become adapted to being in seaweed where it reproduces offspring like itself with prehensile tails, then eventually natural selection act on its other features, like internal swim ladder would have been advantageous for buoyancy, and been acted upon, so that some one with this gene would have produced the most offsprings while the other alleles died out, and eventually, this population will evolve into what today is known as the seahorse.

> This paragraph links the theory in the previous paragraph to a named example.

Or the speciation may have been allopatric where a geographical isolation (e.g land) separates two populations. Different selection pressures then select them for different extremes, until finally, when geographic barriers disappears and the two population mix there is pre or post zygotic barriers interacting to prevent them from hybridising into one species, therefore one species has diversified into two as a result of evolution, e.g flatfish may have been geographically isolated from other fish by the presence of an island. Being forced in shallow water all the time, it would have evolved the unique colouration through natural selection, and its left eye migrating to the other side as it would be no use underneath (since its left is facing floor) and would have been a waste of energy to have it growing there, where on the right, it could be beneficial to it by making it more visually aware of predators.

Theory linked to example.

In the case of the anglerfish, diversity has occurred hugely even within the species, with sexual dimorphism, where the males are smaller than the females. This evolution has come about because of the benefits that the male would have, being small and parasiting on females, it is able to seek shelter and food, and the female would be defending it against predators. It also has instant access to the female and can mate with it whenever it wants, passing on its genes to the females offspring, which is the ultimate goal of this organism, to ensure the survival of its genes.

Therefore, evolution is all about survival of the fittest, and each organism is pushed to adapt to a certain niche and evolve to survive in the way that it can do best. So because of evolution, there is speciation which causes diversity. However by thinking about evolution as natural selection acting on an organism, where those with weak genes are eliminated, evolution in this aspect also decreases diversity, and when we consider the world around us today, evolution is still continuing, so we cannot say that we have reached the end product, but already, the presence of humans has had an effect on the environment where we have dominated the planet and are in the process of destroying habitats of other species and eliminating all the other species, causing them to go extinct and decreasing diversity. However if humans leave the plane alone, this diversity may again find a way to increase, as mass extinctions have happened before. So diversity has come about as a result of evolution, but other factors out there act to limit diversity.

Good summary, which shows evidence of thinking beyond the immediate questions.

General Comments

The answer shows a tendency to describe evolution from a Lamarkian perspective – very common, and possibly unintentional.

The answer has integrated theory and examples, but only discusses a very narrow part of the evolutionary process – natural selection and allopatric speciation.

There is no evidence of ability to see interaction between environment / ecology and genetics / evolution.

QUESTION THREE continued

Sample of assessed candidate work – Performance Descriptor 3

Diversity is the end product of evolution. Gauses Principle is implicit in such a statement. Gauses Principle effectively states that not two populations (species) with identical ecological niches can survive in the same area for very long. This means that two competing populations, often of the same species will have a mutual detrimental effect on each other due to competition, but eventually one group with gain ascendancy and drive the other group out of the ecological niche, or our of the area.

> Evolutionary theory. Not a good understanding of Gause's Principle

Another key concept to understanding the above statement is the principle of natural selection. The reasoning is as follows: populations tend to overproduce; overproduction leads to competition for resources which are limited; in any generation, some individuals with have a specific combination of genes which makes them more fit to survive in the environment they are in; these animals are more likely to reproduce and pass on their genetic material, hence the frequency of specific alleles that confer a survival advantage to the individual increase in frequency.

> Evolutionary theory.

If one imagines a scenario where a particular animal (say but it could equally be a plant or a bacteria) species is introduced to a new environment, whether this be through migration, geological events or otherwise. Such a population will be less well adapted to survive in this particular environment than existing populations. Hence, in order to survive (by gauses Principle) this animal must change its ecological niche. However some individuals of this population will have, by chance, specific aspects of their phenotype which make them more able to survive in a particular niche, which may be different to the adaptation's other individuals have. Hence, individuals with a partial ability to survive in a particular niche will begin spending more time with similar individuals whom they will breed with. Eventually such groups will cease to come into regular contact with each other and cease to interbreed. From this point selection pressures between each of these populations will be quite different, and natural selection dictates that such groups become more and more different. The end result is what is known as adaptive radiation: the evolution of a diverse range of species from a common ancestor in an attempt to exploit specific, unfilled ecological niches.

> Lamarkian.

> Not a good illustration of natural selection as it contains errors and misunderstandings.

Such a scenario is well documented. In the example of Osteichthyes, a common ancestor has given rise to a diverse range of species that are very different. For example, Seahorses look very unlike a 'typical' bony fish. They have evolved to best survive in their particular ecological niche. Flatfish have evolved very specialised camoflage defences which confer upon them an advantage to survive in an environment at the

> Description of diversity with attempts to link to evolutionary theory but hasn't used the example to illustrate how evolution results in diversity.

bottom of shallow beaches – a rich source of food, but a dangerous area with respect to predators. Angler fish are highly specialized, the dark conditions of the depth of the sea require a ability to find prey without seeing it from long distances and angler fish have evolved as one solution; attract prey rather than chasing it. The sexual dimorphism seen in these Angler fish is an example of an attempt to ensue the survival of the species, since the male parasitism of the female means that the two sexes are always together, increasing chance of breeding as valuable time does not need to be spent finding a mate.

Another example of such diversification is that of early hominids. The evolutionary pattern that eventually lead to Homo sapiens can be seen as a series of adaptive radiations where newly evolved homonids have differentiated to exploit a range of niches. The genus Paranthropus is a prime example. Paranthropus species (Robustus boisei/ had specially adapted skulls and jaws in order to best exploit their diet of hard seeds and nuts. The evolution of Paranthropus is seen as resulting from large competition of food such as meat sources (scavenged) and fruit, leading to the nead to exploit other, lower quality food in the form of hard nuts and seed. Hence the need to have a jawbone that is much larger than their contemporary Australopithecines as well as large molars. Complicit in this is a requirement of large muscles to work the jaw, and a large attachment area for these muscles; the saggital crest (not seen in humans who have small jaw muscles). Such features also include heavy brow ridges to resist the stresses of chewing hard food. These were indeed "nutcracker men".

> Mainly a description with weak link to evolutionary theory (competition).

The finches on Galopogos Island, studied by Darwin also show the typical pattern of diversity arising from evolution. There are several species of these finches that have specific adaptations for their respective ecological niches. For example some of the birds have thin, needle-like beaks which aid them in reaching in to tight areas, such as logs, in order to extract insects. Others have more heavy, blunter beaks that can efficiently exploit fruit bearing trees.

> Description of diversity by describing adaptations.

Other adaptive radiations may not be as immediately recognisable. In an example of the New Zealand bush several species of birds that look quite similar manage to survive together by either feeding at different times of the day (a nocturnal/diurnal differentiation) or in slightly different parts of the same tree. Fantails hunt insects by catching them in mid-flight, while a closely situated rifleman may search for the same insects in the bark of trees. Other similar sized birds catch insects by searching through the leaf litter.

> Description of diversity.

Diversity is indeed the end product of evolution. Evolution tends to encourage niche differentiation; often through adaptive radiation. Such an encouragemet inexorably leads to a range of organisms with a common ancestor and some common features, but crucial morphological and behavioral differences that allow them to survive in a wide range of ecological niches.

General Comments

The answer presents some evolutionary theory, but is not always correct.

It focusses on describing diversity but has not discussed how evolutionary processes have resulted in diversity described.