EVOLUTION, BEHAVIOURAL ADAPTION AND LEARNING

Elizabeth Gaffan

6 September 2006

Part 1

So good morning everybody. This lecture is a lecture that I give to our first year Psychology students and I have only changed it a very little bit for you. The title, as you can see, is here. If you don't know the meaning of any of these terms I'll explain them as I go along. You have all a handout which shows you the slides, so you don't need to write down what is on the screen. I will say quite a lot of things that are not on the slides and that will help you to listen.

This is an outline of the lecture. I will be talking about the concepts of evolution and fitness. Many of you will be familiar with these already, some of you will not. I will talk about 'adaptation', that is how animals are adapted to their environment and how they are adapted by their structure, that is the way they are built, and also the way they behave. Then I'll be talking about a particular aspect of behaviour which is learning, and when that helps animals to adapt. I'll be talking about differences between species in what they learn. And I'll be talking about some kinds of learning that are only seen in species that are called 'precocial'. You won't know the meaning of that word now probably, but I will explain it later. Finally, after talking about learning that is specialized, that is seen in some species and not others, I will talk about two kinds of learning that are universal, that are seen in all species called 'habituation' and 'associative learning' and I'll try to discuss why it helps animals adapt to have these two simple kinds of learning. I gave Anne Pallant a bit of suggested reading in association with this lecture – here it is again if you want it.

So – evolution and fitness. First you need to know what a species is. *A species is a population or organisms that can interbreed successfully*, that is they can breed and have viable offspring – children. As you know species change over time. The way that the human species looks now, is different to how it looked 30,000 or 500,000 years ago. New species -because of this change new species evolve from earlier ones and the reason why species change is that they need to adapt to the environment in which they live. They need to develop characteristics that will make them successful, that will help them to produce successful offspring in that environment. So how do species adapt – and how do they change?

This slide is really just a lot of definitions, of critical terms, in evolutionary fitness. I won't talk about these in a lot of detail, but here are the definitions so you have them. The first thing is that individuals within a population, a group of animals living together, individuals within a population of a species, will always differ. For example, in this room there are different hair colours. I don't actually see anyone with pink hair. I think you all have your natural hair colour and it varies between individuals. Height varies, weight varies, other things vary, the clothes you wear varies. Some of these variations are inherited, for example your hair colour is usually inherited, unless you have artificially coloured it of course. You height is to some extent inherited, the language you speak is not. Inherited variations are ones that you will share with your offspring. When you have children and other relatives they are more likely to have the same inherited characteristics.

The next thing that's important is competition. Some individuals will be just better at succeeding, at gaining resources in the environment where they live. They will be better at getting access to mates, to food to space for living, or they're better at overcoming dangers such as predation, being attacked by other animals or sickness. The process of natural selection, which I am sure that many of you are familiar, with is that necessarily individuals who compete more successfully in a given environment will have more offspring. And also they'll have more surviving other relatives, because those other relatives will share the same characteristics. This is called 'inclusive fitness'. Inclusive fitness means how may offspring and other relatives you leave behind you.

And adaptation occurs because those individuals, who compete better, through natural selection, have more offspring and other relatives and therefore the next generation contains more individuals who have the same inherited characteristics. Thus the population of the species, slowly with each generation, gets slowly better adapted to its current environment.

Part 2

I am going to show you some examples of how adaptation can occur. Adaptation can occur, as I said, through structure, the way that animals are built or though their behaviour. I will talk about examples of both. Two examples of structure that I will talk about are cryptic colouring in insects, I will explain that in a moment, and something that many of you will have seen, the peacocks tail.

Cryptic colouring: this photo shows two moths. One there, and one there. You can't see this moth very well because it is on a light background, a light coloured tree and this moth's colouring makes it cryptic on that tree. Cryptic means it's hard to see. So this moth is very easy to see when it sits on that tree, this moth is hard to see. This moth has cryptic colouring. But of course if those two moths were on a black tree, it would be the other way round. You could see this moth very well on a black tree, you couldn't see this moth very well. So whether your colouring is cryptic or not depends what background you choose, or have available to sit on. Now these two moths are actually the same species, but within that species you get inherited variations so that some moths are black, some moths are white, just like some of you have brown hair, some of you have blonde hair. The same species but different colours.

Now what was discovered was that early in the 19th century most of the moths of this species looked like this, they were white. Whereas during the 19th century, and into the 20th century, the white moths, the proportion of white moths got smaller the proportion of black moths got higher. So these days most moths are black – so why was this? It was because of environmental change. During the 19th century in England a lot of factories were built, the Industrial Revolution, there was a lot of smoke and soot in the air. Trees which used to be white became black, walls which used to be light-coloured became black. So the white moths who were cryptic on the light-coloured trees were no longer cryptic on the black trees. The black moths who were very visible on white trees became cryptic on black trees. Why is this adaptive? Well obviously these moths are eaten by birds and it is much easier for a bird to catch a moth which is visible. So the explanation offered for this change in the species over time, is that those moths who were cryptic on the black trees survived better, they were less likely to be eaten by birds so they had more surviving offspring. So the proportion of black moths in the population got larger.

That is a structural adaptation, another structural adaptation is the peacock's tail. Here's a picture of a peacock, I'm sure you have all seen peacocks, spreading their tales to impress female peacocks, this is a male. Why is the peacock's tail adaptive? Well it's pretty obvious why the cryptic colouring of the moth increases fitness. A cryptic moth is less likely to be eaten so it will have more offspring. Why is the peacock's tail adaptive? For a different reason, it's because it's very attractive for female peacocks. A male peacock who has a very grand tail will attract more female peacocks so it will mate more successfully and have more offspring. And because the appearance of the tail is controlled by inherited variation, then peacocks with bigger tails will have more offspring, and the next generation will have more peacocks with bigger tales and so on. So these two structural adaptations increase fitness, but in different ways.

As well as structure to increase fitness you may need behaviour. The moths that I showed you on the previous slide need to keep still. Their cryptic colouring will only be successful if they stay very still. So the structure needs a behaviour that goes with it, they need to behave in an appropriate way. The peacock needs to behave in such a way as to display its tail. If the peacock never opens its tail the female will never see it. So most structural adaptations have behavioural adaptations that go with them.

Here is another one that I haven't talked about before. This is a gull, there are many species of gulls. This one is called the kittiwake. Kittiwakes are unusual in that they nest on cliffs. Most gull species nest on the ground, we'll hear more about the gulls later. Kittiwakes nest on these tiny little narrow ledges on the cliffs and what we find is that the chicks of the kittiwake – there they are in the nest, there is the adult, there are the chicks. The chicks of the Kittiwake don't walk around. All other gull chicks walk around, kittiwake chicks stay in the nest, they don't walk. It is not because they can't walk, they *can* walk, but they don't walk and again the adaptiveness of the behavioural difference is perfectly clear. If that kittiwake chick walked, it would fall out of the nest and it would not live to have offspring itself. Whereas other gull chicks, if they walk they won't necessarily come to any harm because they are on the ground. So the absence of walking, or the reluctance to walk of kittiwake, chicks is clearly adaptive.

Part 3

The behaviours that I have talked about so far are inherited. That is the young members of a species are born with a tendency to behave that way. They don't have to learn it, they inherit that behavioural tendency from their parents. You will see from what I have said before that inherited characteristics mean that each generation is adapted to the same environment that its parents grew up in. So inherited adaptations only work when the environment is stable, when it stays the same across generations. You have to - it will only work if your offspring are going to have to adapt to the same environment that you did. But many things change over time and learning is a special kind of behavioural adaptation which makes us able to adapt to things that change over time. Things that can't be predicted from what your parents experienced. Things that change within an individual's lifetime or things that change in your lifetime relative to your parents' lifetime.

And learning works by using experience. You experience certain things then learning enables you to adapt to that experience even if you don't have an inherited adaptation. So for the rest of this lecture I am going to be talking about learning. And I'm going to be talking about when learning is adaptive and when it is not. Because it is not always adaptive to learn. If you think about learning – a young animal that has to learn, let's say – think about the kittiwakes. The kittiwakes could inherit the tendency not to walk out of the nest, or they could learn not to walk out of the nest. The trouble is that learning is not a good way to achieve that result because it takes time, you need experience in order to learn. The kittiwake would have to walk out of its nest and fall over the cliff, in order to learn. That's not a wonderful idea, it's not going to survive very long. So, because learning takes time, the young are vulnerable during the time they have to learn. And also learning needs a more complex nervous system than a brain that doesn't learn. So animals don't always learn. If they can achieve the same result by an inherited characteristic that can actually be easier.

So learning has costs, as well as benefits, therefore not every species learns. There are some things that some species learn, and other species don't. Exactly the same behaviour, some species learn it and some don't. So you have to consider, why is it adaptive for one species to learn this thing, but not adaptive for another species to learn the same thing. And the example I am going to talk about is learning to recognise, parents learning to recognise their offspring, and offspring learning to recognise their parents. This is something that you may need experience to do because offspring look different, parents look different, sound different and the parent may need to spend a bit of time with its offspring in order to learn what it looks like, and in order to recognise how it differs from other offspring. Now, sometimes learning to recognize your own offspring increases your fitness, that is, it means you will be better adapted and you'll produce more offspring. Remember fitness means the number of offspring and other relatives that you produce. But sometimes learning doesn't increase fitness. Why not? Some learning is only seen in species that are precocial.

Remember, I mentioned that word at the beginning and said I would define it. The definition of a precocial species is one where *the young animals can move around very soon after birth.* So, some birds are precocial, gulls actually are precocial. Their young can walk around as soon as they are hatched. Sheep are precocial. Young lambs can move around as soon as they are born. The same is true of chickens, horses, and many other animals. But by contrast, there are species that called ultricial where the young are not mobile. When they are born or hatched they are helpless, they can't move. Now ultricial species have to keep their young in a nest because the young are not able to move so they have to be kept in the safe place where the parents can find them. And therefore with ultricial species, the parents don't need to learn what their young look like. They only need to learn where the nest is. And then they'll find their own offspring. They don't need to learn that my offspring look like this. Somebody else's offspring look like that. Because they never need to learn that, all they need to know is my offspring are in this place, in this nest. Here's a picture of a ultricial species. This is an adult bird, and these are three young birds sitting in the nest with their mouths wide open and the parent is feeding, their beaks wide open, sorry, if it's a bird it's got a beak not a mouth. These young as you can see, they all are the same, completely helpless. The only thing they know how to do is sitting in the nest and open their beaks. And they will survive fine that way. So, birds like this can raise their young quite safely, feed them, protect them until they are old enough to move around without recognizing the young at all.

Part 4

But in precocial species, obviously parents and offspring can get separated. If offspring are hatched, and then can immediately move around, then they may move some distance from the parent. The parent may see a whole lot of offspring. Some near some far, and they need to know which offspring are its own. Otherwise it can't protect its own offspring. And similarly, the offspring need to be able to recognize their parent. If a young gull, a gull chick wanders away from its parent, then it needs to know what its parent looks like, so it can follow its own parent, come back when it's lost and so on. And of course I've been talking about what offspring and parents look like. But animals have many other ways to identify themselves. The noises they make, the way they behave, and so on. So in other words, there is a selection pressure for precocial species to learn to recognize parents and offspring. The selection pressure is that parents who recognize their offspring will have more surviving offspring, and offspring who recognize parents will survive longer and be more successful in producing more offspring themselves.

So, what are they, what is this rapid learning, what's this learning to recognize parents and offspring, what do we know about it? In precocial species, we find that parents very rapidly learn the visual, auditory, or olfactory features of their young. That is what their young look like, what their young sound like, and what their young smell like. And as I've said before, gulls are precocial and it's been shown by experiment and observation that if you give an adult gull two chicks, one its own chick and a chick belong to another gull, it will prefer to feed and protect its own chick, and it will reject the chick of another gull.

There is an exception to this and it is the kittiwakes, that I have mentioned before. Here is the picture of the kittiwake again. Kittiwakes do not need to recognise their offspring, because their offspring always live in a nest, if they didn't stay in the nest they would die. So kittiwakes are unusual among gulls, they do not learn to recognise their own chicks. If you put in that nest a chick which looks completely different – you can put in a large black bird in that nest, and the kittiwake will still think it is its offspring and try and feed it. It doesn't recognise the difference between its own chicks and anything else, because all it needs to do, like the altricial species, is to learn where the nest is.

Now that's a behavioural adaptation – the fact that some gulls learn to recognise their offspring and others don't - and the behavioural adaptation is produced by learning. But very often behavioural adaptations and structural adaptations go together and we find in the case of gulls that there is a structural adaptation as well. You see this picture of the kittiwake chicks, they all look very similar to each other. They all have the same colour, the same size, they behave in the same way, make the same noises. Kittiwake chicks are very similar to each other, and all kittiwake chicks are similar. It doesn't matter because this parent doesn't have to see how its own chicks differ from other peoples' chicks, it doesn't need to know. But other gulls, I don't have a picture here, but you'll have to believe me, other gulls all their chicks look different. They have brown and white spots. All the gull chicks within other gull species they are all different from each other, so this is a structural adaptation. The fact that the chicks look different makes from each other makes it easier, makes it possible. for the parents to learn how their own chick differs from other chicks and some people have been sceptical about whether this adaptation in the kittiwake parents is really a behavioural adaptation maybe the reason they don't learn is because the chicks look so similar to each other and it's the structural adaptation which causes the difference not the behavioural adaptation. But I can't tell you which it is. I am just pointing out that when you have both a behavioural adaptation and a structural adaptation it's rather difficult to say which came first.

So what about the offspring? This is a goose which is a precocial species, and it's swimming along. You can see the little young geese, the goslings swimming along close behind.

Part 5

Just like precocial parents learn to recognize their offspring, precocial offspring learn to recognize their parents. So these young goslings will approach and follow their own mother and father, and will not approach and follow other mothers and fathers, other mother and father geese. Even though all the geese are living in the same area on the ground or same river, young geese very rapidly learn to recognize and follow their own parents. And this is called imprinting. This learning process that is seen in precocial young. In fact, sometimes, people use the same word, imprinting, for the learning by parents even they both parents had offspring show imprinting to each other. And this phenomenon is shown in nearly all precocial species, I've mentioned geese, domestic fowls that is chickens, ducklings, and sheep, all show the same effect. Imprinting is unusual in a number of ways. First of all, it happens very rapidly and at a very specific early stage in the life of the young. It has to happen rapidly because these young goslings or gulls are in a big, are born in a big mass of other birds, other families, they'll see lots of other young and adults. And they have to learn very quickly, the offspring have to learn what their parents look like and follow them. The parents have to learn what their offspring looks like and take care of them. So, it has a sensitive period. Animals are more likely to show this imprinting at a particular point early in life.

If you keep the young birds separate from their parents during the sensitive period then they will not later learn to recognize their parents so easily, it has to happen at a pre-determined period. The other thing that's unusual is that young birds will learn to follow the first large moving object they see, and it doesn't have to look like their parents. This learning process just latches on very rapidly to the first large moving object they see and if the first moving object they see is not their parent they wouldn't print to that and treated as if it was a parent like this. This gentleman here is called Conrad Lorentz. He was a very famous biologist, and he discovered imprinting. He lived on a farm in Austria. He had a lot of chicks and goslings, and he discovered that if he hatched young goslings out in an incubator, that is he put the eggs in warm place so they would hatch out without parents sitting on them. Then, he was the first thing, these young chick, these young birds saw when they hatched out. They learned to behave to him as if he was their parent. They followed him around, they nestled up to him. Fortunately, he was a kind man so he fed them and looked after them. But Lorentz discovered imprinting when he observed that young birds imprinted on him, and I think you all agree that Conrad Lorentz doesn't look very much like an adult goose. Now, up to now then, I've been talking about kinds of learning which differ between species, and I've discussed how the very same thing learning to recognize your offspring is achieved by learning in some species and without learning or at least without learning the characteristics of the offspring in other species. For the rest of lecture, I'm going to talk about some learning processes, which are different from imprinting because they are shown by all species, every species that have ever been looked at including you, shows habituation. Habituation and dishabituation are a very simple type of learning which is universal. They are seen in all vertebrates, that is animals like us with backbones. They are also seen in invertebrates such as insects. I'll show you an example in a minute of habituation in an invertebrate.

Now, what's habituation? OK. Habituation is essentially a change in the way that animals react to stimuli when they become familiar with them. They react one way when the stimulus is novel and unfamiliar and then they change the way they react to it when it's familiar. Now, another universal fact about animals, is that all animals react in some way to novel or unfamiliar stimuli. If I do something unexpected like aaah (loud scream), OK? You all reacted to that because it was highly unexpected stimulus and you reacted, some of you may have been a bit scared, and most of you reacted by investigation that is you went 'aaah' like that. You opened your eyes, you kept still. If you were a cat, you would have pricked up your ears. So, that's one way to react to novel stimuli, but other, some novel stimuli are reacted to defensively, we will see an example of that, or by attack. You give a spider a novel stimulus, it will probably to try and grab it or attack it.

Part 6

Now supposing I repeat that novel stimulus all over, again and again - I'm not going to do it as I will wear my throat out - but if I just screamed over and over again, you would stop reacting to it. That's habituation. Because that stimulus which was at first so novel and surprising, becomes more and more familiar, and unsurprising, the more times you hear it. So habituation is simply that process, that if a novel stimulus is repeated, i.e. it becomes familiar, whatever reaction was shown to the novel stimulus weakens and eventually disappears, may disappear. It can disappear slowly or quickly, depending on the kind of stimulus, I will show you an example in the next slide. Some stimuli, the response weakens very rapidly, others it weakens rather more slowly.

The other side of habituation, of course, is that if a stimulus becomes novel again, then the animal has to react to it again. Supposing I scream 10 times and you all got bored with it and forgot all about it, weren't interested any more, and then at the end of the lecture I scream again, that's going to be novel again so you will get surprised again. That's 'dishabituation'. If a habituated stimulus doesn't appear for a while, and then recurs, the reaction reappears. The other reason why you might get dishabituation is if the habituated stimulus changes. Supposing I screamed repeatedly and then all of a sudden I stood on my head. Then you would look surprised again, the stimulus changed, or if I screamed in a different way then it would be novel again. So the reaction reappears when the stimulus becomes novel again. Dishabituation happens when the stimulus is no longer the same old stimulus. They show that the organism can become familiar with the stimulus, that is learn what that stimulus is like and discriminate that stimulus from others. They become familiar with this particular stimulus and so they treat that stimulus different from other stimuli that are still novel.

So it's a very simple but very general learning process. Here's an example. This is an invertebrate it's called *nyreaus*, it's a marine worm that is, it's a little soft animal that lives under the sea. *Nyreaus* lives in the sea and it feeds on material that floats around in the sea, and when it's threatened by a novel stimulus it reacts defensively, that is it hides in a burrow in the sand at the bottom of the sea, it just burrows into the sand. So its reaction to novel stimuli is defensive. And in this experiment the novel stimulus that *nyraeus* was exposed to was a moving shadow, that is just something moving over the top of the tank.

When you present the same shadow repeatedly and you will see this in the graph in a moment the reaction habituates. That is as you present the same shadow repeatedly, the *nyreaus* become less and less likely to hide in the sand, in response to the shadow until finally they don't react to the shadow at all. So just look at this graph here first. The vertical axis is the percent of worms that react. This experiment was done on a large number of worms, and the experiment has simply measured what percentage of the worms reacted to that moving shadow. So up here we have the moving shadow experiment. This is the percentage of worms that reacted to it, and here 0-10 are the, 1 to 10 are the repeated presentation of the same shadow. And the first time the shadow was presented, about 25% of the worms reacted to it. Not all of them did because it wasn't a very intense stimulus or very frightening. So 25% of the worms reacted. But as it was presented more times, by the 10th time none of the worms were reacting. So that's habituation.

This graph also shows two types of dishabituation. The first one here, Group A is when, instead of the shadow, a new stimulus was presented. So-called mechanical shock which means just that the researchers tapped the side of the tank so it vibrated, just a vibration, different stimulus, and what you can see is when the researchers now presented a new stimulus, the mechanical shock, the *nyearus* now started hiding again, that's dishabituation. This time rather more of them, about 50% of them, 40% to 50% reacted and you can see that, here's repetitions of the shock stimulus up to 40 repetitions and again you see habituation but it happens rather more slowly. The worms habituate rather more gradually to this vibration, shock stimulus, then they did to the shadow as I said.

And finally when the shadow was presented again now the animals dishabituated because now the shadow is novel again. They haven't seen the shadow for the last 40 minutes. These trials happened once a minute so it's actually 40 minutes at this point since they'd seen the shadow before. The same thing happens if you just leave them for 40 minutes as in the case of Group B, without presenting any stimuli at all. Once again when the shadow is re-presented they respond to it again, as the shadow is re-presented 10 times they habituate. So this is a very simple illustration of the phenomenon of habituation in an invertebrate.

Part 7

Here are some more examples which you may find more interesting.

Another example of habituation and dishabituation is something called food *neophobia*. As you know many animals like us have a very wide diet. We eat a very wide range of things. Some other animals are like that for example rats, they eat a lot of different things. Now what you find with animals that have a broad diet, is that when they are first given a novel food, they are reluctant to eat it. They sort of sniff it and taste a little bit of it, but their reaction to a novel food by and large is to be very cautious. However once they've tasted it, if you give them the same food again then they will eat more of it. This too is just a very fast example of habituation. When the food is novel they are cautious and don't eat very much of it. But as soon as they have experienced the food once the food is now familiar, so they now treat it as familiar, they no longer avoid eating it, they are quite happy to eat it. So that's food neophobia, and the habituation of food neophobia leading to a disappearance of the defensive behaviour, this reluctance to eat novel food is another kind of defensive behaviour.

Why do rats behave this way? You might like to think about it. Maybe I will ask you at the end. Why it might be adaptive for rats to behave in this way. Here is another interesting example. This is to do with avoiding predators. As you know, a lot of young birds, especially those that nest on the ground, like the gulls I talked about, are in danger of being attacked by predators particularly hawks. Hawks are bird of prey. They fly over and swoop down and pick up young chicks and eggs and eat them. Now what you find, as shown here is that if you have a young bird that nests on the ground, if a hawk flies over - this is a picture of a hawk - the young bird hides. But if a bird of its own species flies over, this is a bird of the same species as the chick - I am afraid I can't remember what species it is, let's say it's a goose. If that adult flies over the young chick doesn't hide. Here the hawk flies over again and the chick hides. You can show it, this shows naturalistic stimuli but you can show this effect experimentally in a lab by flying different shapes over young birds.

Now why do young birds behave differently to hawks, and to adults of their own species? When this phenomenon was first discovered, it was thought to be unlearned because it is shown in very young chicks, very early in life. But, in fact, it's also possible that there is an element of habituation going on here. If you think about it, these young chicks live in an environment where there are lots of adults of their own species flying overhead all the time. So they will very rapidly become familiar with the sight of adults of their own species. Maybe the first time they saw an adult of their own species flying overhead it was novel, maybe then they would hide. But they get lots of repeated experience with adults of their own species flying overhead, and so they have the chance to habituate and as they habituate they stop hiding. So it's possible that this absence of hiding is the result of habituation.

But what about hawks? Hawks are rare, you don't often see a hawk flying overhead. Hawks have to be very selective about when they fly, so they only fly over when they have a good change of catching something. So hawks remain novel to young chicks for much longer and therefore perhaps the reason the young chicks hide in response to hawks is partly because they haven't habituated to hawks, whereas they have habituated to their own species. Now of course it's perfectly possible to study this experimentally and this was done by a German biologist called Schleight. He took some young birds, and one group of young birds he treated like what would happen in the wild. He gave them a lot of exposures to pictures of their own species flying overhead but very rare exposures to hawks, so hawks stayed novel.

With another group he did it the other way round. He gave them lots of exposures to hawks, so hawks became familiar but very few exposures to pictures of their own species and he found the expected difference. That is, the young who got a lot of exposure to hawks habituated to hawks, and became less likely to hide. Whereas they were still showing some signs of hiding to their own species. Now in fact what Schleight found was that this phenomenon is partly habituation and partly unlearned. The young birds habituated much more easily to their own species, than they did to hawks.
They habituated to hawks, but not so fast as they did to their own species. So there was also an unlearned tendency to be a bit more scared of hawks, a bit less willing to habituate to hawks. So basically this phenomenon is a mixture of unlearned and learned behaviour, which often happens in real life.

Part 8

So, why is... So why is habituation adaptive? It must be adaptive, and it must be adaptive to a very wide variety of species because we have seen that it happens in every species in which it has ever been looked for. The amount of habituation varies, and it may be different to different stimuli, but all animals show this phenomenon. So why is it adaptive? What I've suggested here is a reason why habituation may be adaptive. We've seen animals react to novel events and that's a highly adaptive behaviour because anything which is novel, by definition you don't know what it is. It could be something dangerous, it could be something nice like food, it could be a friend, it could be an enemy. It's a good idea to react to novel stimuli in some sort of way that helps you deal with them.

But once an event becomes familiar it's repeated over and over again and nothing else interesting happens, then you know that event is of no interest and you can get on doing other behaviours which are more important. Then think about the *narayis*, the marine worm in its tank. In order to survive it needs to feed, so it needs to come out of its hole to feed. But when a novel stimulus comes over, it needs to hide because that novel stimulus might be dangerous. So in order to survive some of the time *narayis* has to be out of its hole, some of the time it has to be in its hole.

If the shadow is repeated, and nothing happens, the shadow doesn't attack it, it's just a stimulus that goes overhead and nothing happens afterwards, then it would be very unadaptive for *narayis* to keep on hiding, because that would prevent it from doing other important things like feeding. So if it stops hiding when the stimulus has no interesting consequences, then it can get on with other important activities. And I think this applies to most examples of habituation that I have discussed. It doesn't explain the neophobia example, the rats being – avoiding new food. It doesn't explain that quite so well and I think that's an example where there is a special adaptive benefit to that behaviour. But this explanation will apply to most cases of habituation. But of course habituation is not the only kind of learning that animals show, because habituation, by definition, is when animals stop responding to an event which has no interesting consequences. It just repeats over and over again the same way. It isn't good to eat, it doesn't attack you, it isn't a potential mate, it isn't a potential enemy, it has no interesting consequences. So that's habituation.

But what happens when an event does have interesting consequences? What happens when that shadow flies overhead, and then it attacks you or attacks your friend? What happens if you eat a new food and then you get ill? Then the event has interesting consequences and it would be quite wrong to ignore it. So what happens when an event *does* have interesting consequences? I predict something else which may be important to you. This leads to another kind of learning, which I am not going to describe in detail because it takes me 4 or 5 lectures to talk about associative learning when I teach this course to the first year students, but I'm just going to tell you a little bit about it now.

Associative learning is exactly that. It's learning about the consequences of events. It's learning when one event predicts another or brings an important consequence. Here are some examples of the kind of things that animals can learn by associative learning. Suppose you see a place, and this place has food in it. Like you see a tree and the tree has fruit on it. Then you ought to keep reacting to that tree because it has important consequences. Supposing you eat food and then it makes you ill, you need to respond in a particular way to this food because if you eat it again it will have bad consequences. You can also get associative learning about the consequences of your own behaviour. I have been talking about the consequences of stimuli, like moving shadows and vibrations and food. I have been talking about whether stimuli have consequences. But of course behaviour has consequences as well. If a male animal behaves in a particular way to a female, the female will be attracted. If it behaves in a different way the female will be repelled. Behaving one way may cause you to be attacked by another animal, behaving another way may cause you to be left alone.

So the ability to learn associatively is obviously adaptive. I don't think I need to argue with you about why it's adaptive, it's obvious. And like habituation it's found throughout the animals kingdom including humans of course. There are lots of other kinds of associative learning. Learning language, that is learning what word to say when you see a particular object, that's associative learning. If I learn the name of a student, if I learn what name to attach to a student's face, that's associative learning. Basically associative learning is about associating one thing with another. So that's the end of the lecture. I have just put up the outline again here, this is the slide you saw at the beginning and this is to remind you of the topics that I have covered.