LIGHTWORKS

"NHS#5 ENGERGY HONEYBEES & HUMANS"

INTERVIEW WITH ROBERT PICKARD

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ROBERT PICKARD:

00:00:22;28 I like to cover a lot of ground in my talks, because I believe that if we want to overcome new problems, it's really important to have an understanding of the world that is holistic and covers a much broader reach than the subject that we're actually interested in at any one moment. When you suddenly bump into a lamp post walking down the street, it's almost like the end of the world. You can't really understand what's happened to you.

00:00:56;08 You feel so insulted, because your world has changed. And yet, in a few seconds, you get up. You look at the lamp post. You look around. You reorientate. And then you walk around the lamp post and everything's okay. Now the importance of that, of course, is understanding the context of the situation.

00:01:16;23 If someone has a problem to solve and they understand the context of the problem, they are in a much better position to solve the problem. So part of my approach to beekeeping and to human biology has always been to fit it in to the context of the whole universe, the physics, the chemistry, the sociology, and lastly, of course, there needs to be woven through a thread of all sciences, an understanding of the humanities.

00:01:49;02 Because at the end of the day, it's being human that we're good at. I have a grandson who's three. And I always say to him, "You're very good at it." (LAUGH) And-- it's almost a mistake to try to deny one’s humanity. At the end of the day, feelings and emotions and human values are what matter. I've always been quite outspoken with scientific colleagues by saying that I-- notwithstanding walking on the Moon and writing beautiful Shakespearean sonnets, I still believe that the greatest achievement of human beings is love.

00:02:35;09 Love is not limited by occupation, by gender, by race, by creed. It's available to everyone. And for me, it's a human birthright. To love and to be loved is a human birthright. And anyone who raises children will know that if those children feel loved, you give them a huge confidence. They will tackle anything. And that-- that's why it's so important in parenting never to say to a child, "If you don't do this, I won't love you."

00:03:10;29 You've always got to say, "If you don't do this, I'll be upset, but I'll still love you." And that's one of the really critical things. You do an awful lot of things if you love. I've loved honeybees all my life, since I was nine years of age. I collected bees and collected bumblebees, and kept bumblebee nests in my bedroom and connected to the outside world with pipes.

00:03:36;16 In fact, my mother didn't like to come into my bedroom when I was nine, because there were so many bumble bee colonies covered in mites. (LAUGH) It was a hazardous place to be. And the window cleaner never liked to clean the window, because I got all the entrances to the bumblebee nests in a piece of wood under the sash window. So what is at the end of all this, is really an investigation into what you can understand if you really love understanding things.

00:04:09;05 Our life is not something that we experience in true sequence. What we experience are really special moments. Births, deaths, marriages. And these we string together in a necklace of our life. And what goes on in between is not really important. It is just enjoying those special moments and recognizing them for what they are, when they come. And not just rushing helterskelter all the time.

00:04:42;11 I think that's a fundamental lesson. And we're gonna look at a few very special moments in this talk. Now it's always good to start talking about energy with a simple illustration.

00:05:15;05 The first law of thermodynamics is the most important law in science, because it says energy can neither be created nor destroyed. That means that we are all living in a state of infinity. I'm quite sure I've given this talk many times before. I'm quite sure that all our genomes will be constructed again and again into infinity. And we'll all live many lives in that process, if the first law of thermodynamics holds up.

00:05:49;21 That's because atoms cannot make whatever connections they want. Their connections are highly specified. It would be very, very difficult, indeed, to create a form of life with the intelligence that we have with different types of chemistry. It's almost as if the unfolding of the universe was like a determined clockwork process and every time we investigate situations, where we believe there is uncertainty or randomness or free will, the irony is that all those things are really expressions of our inability to see the future.

00:06:28;13 When we study them in great depth, we usually find there's only one way something could have gone at that moment in time. So that's really interesting. We seem to be living in a determined universe that's determined by physics even though we ourselves don't feel that we are determined at all. *Hamlet* is-- Shakespeare tells us in *Hamlet*-- a very nice line. "There is nothing either good or bad, but thinking makes it so."

00:06:58;20 In other words, an emphasis on the relativity of the humanities and human values. And it's quite interesting that-- perhaps one of our most famous scientists, Albert Einstein, came to the same conclusion in physics with the theories of general relativity and special relativity. That at the end of the day, you can't take anything for granted. You have to know the context. And if you know the context, you can establish the relativity.

00:07:29;10 So let's look at energy. I've already said it cannot be created or destroyed. So we are here forever. We've got no evidence for the continuity of consciousness between different people's lives. But I'm certain that every genome in this room will be constructed again many times in the future. And I'm quite certain that-- even in the size of the universe as it is at the moment, there are multiple copies of us out there-- struggling to survive our individual problems.

00:08:01;10 In the-- at the start of the universe 14 billion years ago, there was just energy. There was no solid matter. And in the Big Bang, the first ball of energy is converted-- partially into hydrogen. A little bit of helium where the hydrogens have been pushed together, because out of four hydrogen atoms, you can make one helium atom. Or you can do it a little bit more efficiently by using hydrogen isotopes.

00:08:33;07 But the Big Bang didn't produce any of the large atoms that you need to make honeybees and human beings. The Big Bang only made those really, really tiny atoms. Now I'm going to be begin by just showing you how that was done so that you can really appreciate how miraculous it is that we and the honeybees can survive together. Once some matter had been formed in the Big Bang, we then were able to see that energy can not only become matter, but energy can move matter to create change.

00:09:09;09 As soon as that happens, time begins. If we lived in an unchanging universe, time would cease. Time couldn't be measured. So time is a very interesting relative dimension. Let's just take you through the simple movements that occur and changes that occur when energy's involved in movement. So you've seen this so many times illustrated in little gizmos that you can put on your executive toy list for Christmas. But it is a little miracle.

00:09:48;00 So I'm now going to activate electrical energy by switching sodium and potassium ions in nerve cells in my motor cortex, this side. And it's going to activate my arm. Within a split second, the impulses have travelled. It is electrical energy. It's travelled down as pulses down my nerve cord into my brachial nerves. And it's now activating the muscles.

00:10:16;10 Soon as it hits the muscles, it releases calcium. So the energy in the electricity has been turned now from electrical energy to chemical energy. The chemical energy of the calcium energizes the calcium through the muscle, which sends off a very interesting enzymic process, which makes the filaments of actin and myosin in the muscle slide past one another. So my muscles shorten.

00:10:41;20 And as they do that, my hand moves. And it's reaching down now and picking up this ball. And it's lifting it. I've now given potential energy to this ball. And when I release it, something incredible is actually happening. What's happening is this ball is going to gain kinetic energy as a result of what I've done. And the kinetic energy in the impact will transfer to the other ball and make a perfectly stable ball move. That is an incredible event. It is so simple, but it is really a miraculous insight into the nature of energy.

00:11:26;20 No system remains stable unless the forces acting on it are equal in magnitude and opposite in direction. And what we saw here was I started off with a stable system. I released a ball which disrupted its stability. It then oscillated as the forces balanced about the equilibrium point. And it reached stability. The mathematics that describe that are exactly the same for a honeybee colony, for the health of a human being, for a national economy, for the maintenance of the planet, the maintenance of the galaxy, and the maintenance of the universe.

00:12:08;24 So if a system is to be remaining stable, the forces acting on it must be equal in magnitude and opposite in direction. And as a beekeeper, you spend all your time trying to do that, when it suits you, to achieve balance. The first lesson that we get from our study of the past is that it's not the strongest of the species that survive, nor the most intelligent. It's the ones that are most adaptive to change.

00:12:41;29 So 14 billion years ago, we could have stood at this point and looked out to the center of the universe. And we'd have seen nothing. Because there was an enormous ball of energy sitting there with a gravitational field that was so strong that neither light nor heat could escape from it. The biggest black hole that we have evidence of. Then suddenly it explodes and some of that energy particularizes into small entities that we call quarks.

00:13:12;11 I love the fairy tale language of nuclear physics. (LAUGH) And these little quarks can stick together like Velcro. And if you want to build a universe in your garage over the weekend, you need three forces. You need the mother force of the universe, gravity. You need the strong nuclear force which sticks quarks together to make atomic nuclei. And you need the electromagnetic force, which is creating the electrical polarization, magnetic fields and electromagnetic waves.

00:13:45;14 And it's also driving the connections between atoms that make molecules. Now there'll be some of you at the moment thinking, "This isn't gonna help my beekeeping." And there'll be others that are thinking, "This is not gonna help me to be a human being." But believe me, if you can stick with me for the next hour, at the end of it, you should leave this lecture theatre thinking, "Wow, I really do know now where I stand in the world and where I stand in relation to honeybees."

00:14:17;19 So here's the explosion occurring 14 billion years ago. And as soon as the gravitational field is weakened, light spreads out and the first atomic nuclei, largely hydrogen, spread out. How did that happen? The original energy balance was in a plasma. The gravity was pulling the plasma as tight as it could.

00:14:41;08 The centre was trying to occupy a greater volume, because it was running at millions of degrees centigrade, but the outer regions of the plasma were cooler. And they act like a straight jacket so that inevitably leads to an explosion. And out come the quarks. I don't have time to talk about all the different quarks. But we'll just talk about up and down quarks. The strong nuclear force immediately bound the quarks together, but only in small numbers, because of the force of the explosion.

00:15:14;11 That becomes very critical, because when we look at later where biological molecules come from and biological atoms, you have to appreciate that the force involved with an exploding star in our galaxy, for example, is so much weaker than the original Big Bang. So you only get quarks sticking together in very small numbers. And here you see you've got two up quarks and a down quark. And as soon as you've got that, the electromagnetic force will develop what we recognize or characterize as a positive electrical charge.

00:15:45;10 If you turn an up quark into a down quark then two down quarks and an up quark will make a neutron. And it will lose its positive charge. It's got less energy. The positive charge pulls in an electron around it. And we can see that the strong nuclear forces glue these little quarks together like Velcro. And we've created an atom of hydrogen.

00:16:08;24 Everything I'm going to say now, from now onwards, is all about the history of hydrogen. Our lives are all about the history of hydrogen. And I'll show that very graphically. So there's our proton, the single simplest atom in the universe, the most common atom, the most abundant, and the first atom, and the atom that makes possible everything else.

00:16:37;17 Without hydrogen, you don't get galaxies. You don't get stars. You cannot generate larger atoms. So we know that gravity asserted itself after the Big Bang and pulled the clouds of hydrogen into galaxies. And if we-- here on the planet Earth travel 2.5 million light years out into space and look back at the planet Earth, this is the sort of picture we would see. Our galaxy, the Milky Way. (SOUND EFFECTS) And we'll see our solar system, at that point, in the disk.

00:17:14;20 Now five billion years ago, a large star exploded at that point and did exactly what happened in the Big Bang. But because it was a lower temperature and lower pressure, the quarks stuck together in bigger numbers. So you got the bigger atoms, oxygen, carbon, phosphorous. So now you can build honeybees and human beings. (SLIDE NOISE) I've mentioned dynamic equilibrium again. And it drives all our lives. It's only because-- we only remain in existence in orbit around our remnant sun, because the forces that are pushing us away from the sun are exactly equal to the forces that are pulling us towards the sun.

00:17:59;06 And from second to second, traveling through space at 60,000 miles an hour, it's amazing to think that we can still manage to live out our lives on what is the cooling outer skin of a red hot rice pudding. This is what that rice pudding looks like from a distance. And we tend to think of it as true terra firma. But that is such a misjudgment. This is such a delicate little rice pudding. That skin is so thin.

00:18:32;05 And if you cut a slice through it, you see that most of the planet Earth is red hot molten rock and iron. It's a terror all right, but not terra firma. And of course, because it's full of molten iron that's moving, any time iron carries a charge-- an atomic charge, and whenever an electrical charge moves you will generate a magnetic field.

00:18:57;02 So according to the electromagnetic laws of force, here we get the magnetic field built around the Earth, which is part of our environment. So to put it in context, our environment is not just what happens in London (or Westminster politicians tend to think it is)-- it's not just what happens on the planet Earth. In our orbits around the sun, we pick up 20 tons of material. And we drop off 20 tons of material in every orbit.

00:19:28;03 Our total environment is the galaxy in its immediate application. And even as we sit here, tiny little particles and energy waves are traveling through us all the time. If I could see radio waves, I wouldn't be able to see you and you wouldn't be able to see me. You know would be completely obscured. Here's some bees that have been put in a box and left to build comb. And you see they've orientated their comb perfectly.

00:19:58;07 The comb in the middle is large. The two combs on the outside are parallel. But there's no bee walking up and down checking that the line is straight. Each group of bees is working on their particular part of the comb. And yet, miraculously, they pull out this highly ordered structure in parallel sheets. Now in this experiment, I've removed light from the scene. And I put a light trap on the entrance of every box.

00:20:27;24 And I was doing this experiment on the roof of the university in Cardiff. And I was trying to see if the bees were able to sense the Earth's magnetic field. It was a difficult experiment to do. One thing's for sure. In that box, they were all using a common reference point, whatever it was. But then I came one day and I found that the light trap had fallen off a particular box. And look what happened.

00:20:56;30 When a shaft of light entered the box, the first group of bees were building that large bit of brace comb. But then suddenly, the new group of bees that were exposed to the beam of light decided to use the beam of light as a reference value. And they started building their little adjacent comb out of synchrony with the other combs. In fact, almost at right angles.

00:21:22;30 So it does beg the question that it could be that the bees with no other cues than the Earth's magnetic field were using the Earth's magnetic field, but when a bright light came in, the other ones preferred to use the bright light. And so they switched their frame of reference. (SLIDE NOISE) Here we've got the surface of the planet as it was in the Cretaceous Period, 123 million years ago. And you can see-- the honeybee population there in Northeast Africa that is going to spread out around the world.

00:22:00;30 And 40 million years later, the human population is going to appear in exactly the same position. And then spread out following the migratory routes that were used by the bees. I mean, that's really quite amazing. You see, India's floating against the East Coast of Africa there. And it's going to float northwards. And we're going to get the Himalayas created when India bumps into Asia and pushes sea shells up to the top of Everest in the rocks.

00:22:32;16 And it's possible that some ancient bee stocks got onto India, at that point, and floated northwards. Because we've got totally different spectrum of species to the east of the uplands of the Himalayas and the uplands of Persia than we have to the west. So it's just an interesting curiosity that we've got the species being divided so precisely. And then the upland regions keeping them apart.

00:23:00;00 And then-- we can follow the migratory routes down south to apis mellifera capensis, the only modern honeybee in that African honey bee group-- that still has female parthenogenesis. So if you take the queen out of a capensis colony, the oldest worker assumes the role of the queen, produces pheromones that bring the workers around the-- that old worker. And she is then capable of laying an egg that will produce a female offspring, which can then be converted into a queen.

00:23:33;14 None of the other bees can do that. I think the reason that that wasn't selected for in evolution was that it tends to create inbreeding. And it tends to weaken the stock. And I think the reason that female parthenogenesis was dropped in the evolution of bees for most of the other races was that it then encourages outbreeding. So there you've got apis mellifera sahariensis moving across the green savannah (as it was at that time) into Spain.

00:24:09;04 Apis mellifera iberica, apis mellifera iberica, they're moving north to apis mellifera mellifera in France and the United Kingdom. In the Palestine region, you've got larmarckii from Egypt moving across, setting up caucasica in the Caucasian Mountains and then moving across-- towards Italy and carnica-- developing as a separate race here. And ligustica being isolated here on this chunk which is moving north and pushing into Europe to produce the Alps.

00:24:50;26 Along the top there, you've got the migration out of different races of bees into North America and down into South America. You've got the same thing happening in Indonesia. Wherever the sea limits a particular population by creating a population on an island, for example, then you will get rapid speciation. You get rapid development of something completely different to the ancestral stock, because of the controlled, limited breeding.

00:25:18;18 So we get apis koschevnikovi on an island there, that you won't see anywhere else in the world. And, of course, because humans followed the same route out, we've got some ancient hominids in the same place. And there's a hominid that lived--that was about this big, that was definitely human, but was very different to any of the hominids that we are used to.

00:25:42;01 Of course we don't have a very good history as a hominid, because there were many different human species. But we had ancestors that were the nastiest that you could imagine. We not only outcompeted our competitors, we actually ate them. And we've got lots and lots of fossil evidence to demonstrate that with human bite marks on the bones. Just to emphasize things, we've had glaciations, which push the honeybee populations and the human populations later into the three peninsula of Spain, Italy, and the Balkans. And that accentuates cultural difference and the differences in languages.

00:26:27;22 And that's why these different groups of bees in Europe have nuances in their language. Italian bees, for example, are much more expressive than than Welsh bees. (LAUGH) Italian bees have extra layers in their dances to communicate nuances of the forage. Extra levels and tiers like the sickle shape dance for communicating specific distances that the carnica bees and the mellifera mellifera bees don't communicate.

00:26:55;17 And it's quite interesting to see Welsh bees in the early spring sitting at the entrance to the colony with their legs in their pockets, watching the Italian bees go out. And you can see them almost saying to one another, "Tsk, tsk, tsk, tsk, tsk," because they know it's gonna get very cold. And the Italian bees are not gonna get back. And it's quite interesting when you put Italian bees and Welsh bees together, they don't understand one another, initially. And it takes quite awhile for the new brood to come through, to establish some better adaptation, which is extremely interesting to watch.

00:27:33;28 Well, of course, we did the same thing. And we racialized in the same way. We formed our different races by containment of populations of genes by mountains, by rivers and by seas in particular. And at the bee unit in Cardiff-- we gathered students from 50 different countries around the world, all fascinated by bees. And every year we would have courses from Brother Adam on queen rearing and mead making. And we had a terrific time.

00:28:02;10 Tusato Nakamura was one of my favorite students. You can see her here. She went on to become a marketing manager for a Japanese electronic company in Wales after she finished her work on bees. But she was extremely well-organized and tidy. And I remember John Free and I were walking down Museum Avenue in Cardiff and Tusato was walking just behind me between us. And I was getting a crick in my neck turning to her. So I planted my feet and she toddle alongside.

00:28:34;27 And I said, "Chisato, surely the girls in Tokyo today do not walk behind the men." And she turned to me and said, "Ah, but you are so old." (LAUGH) And John Free and I, we both said, "Okay, you can stay behind." (LAUGH) Here's a fossil bee from the Miocene Period 26 million years ago. There was no human footprint on the face of the Earth 26 million years ago, but bees were already fully socialized.

00:29:14;29 26 million years old, from the Miocene, perfectly preserved in amber. So this tells us a little bit about bees. Bees tell us what you need to be a society. You must regulate your population numbers. You must regulate your working structure. You must regulate your population so the numbers do not exceed the economic capability.

00:29:40;08 So when you take food from a beehive, the bees reduce the egg-laying rate of the queen. This is not just a collection of individuals, it's a supra organism. It's a whole level of development above the herd, above the grouping of the individuals. Human beings are really very innocent in the world. We've only been trying to form a society for a few thousand years.

00:30:10;04 And we're not really a social animal. We're a herding animal aspiring to become social. So we've got a lot of things to learn from the bees. Our ancestors were nasty pieces of work. Because in herding animals, reproductive success is determined by the size of the territory you can hold. So the psychopath in the biggest cave was the one that got the most females and therefore generated the more copies of himself.

00:30:40;00 So we've inherited psychopathic maleness. And we still see it dotted around the world in places like Russia and Iraq and, of course, there are individuals that meet that criterion even in our own country, at the moment. If you were born as a really nice gentle, easy-going cooperative male in Neanderthal times or caveman times, you didn't get a chance to get any genes through into the next generation that were behind your gentleness and your cooperative nature.

00:31:14;27 Because, of course, the psychopath in the cave next door would steal all your wives. He would eat all your children. And if times were hard, he would eat you. So we've inherited all the characteristics of a herding animal, but we aspire to become social. (SLIDE NOISE) It would be wrong to think that the fossil record only tells us about bones. I've always been interested in the archeological history of organized graves.

00:31:50;15 And it's interesting that up to 130,000 years ago, people are left where they drop. They're eaten. The bones are thrown away. And they're just-- the fact that they've died seems to be of no significance to anyone. But then suddenly at 130,000 years ago, you start to see bones collected together. And little mementos are left with the bones.

00:32:13;06 So something happened around 130,000 years ago, which is very, very recent in evolutionary time. Something happened to the brain, where it started to be able to conceive all sorts of things that it hadn't done before. And it attributed significance to death and showed respect for people that had died. And you get less and less cannibalism as you move through that period. And you only get cannibalism today in groups of people that are still practicing lifestyles that were very close to those that we saw in cavemen.

00:32:52;02 Our first beekeepers in a really organized way are illustrated in Egypt. And here I'm working halfway down the Nile with four generations of beekeepers in one family. And you see he has a basket on his head to protect him. He manipulates the combs with what I can only describe as long fire irons. His hives are made completely of mud. And his house is made completely of mud. So it never rains at this part-- of the desert-- near Minia.

00:33:24;30 And you can see here at the back of the apiary. He's manipulating the combs in a very advanced way. He disturbs you occasionally, when he refers to the queen as the sheikh. (LAUGH) In fact, I said to one Arab beekeeper once, "Why do you occasionally call the queen the sheikh?" And he said to me, "Oh, we like to show respect (LAUGH) by making the queen an honorary man."

00:33:54;00 And I just thought that was so funny, at the time, because Ingrid Williams went to Oman. And she told me one of the things she really disliked was before she was given free contact with the scientists there that were all male she was told that she could rest assured that she had been made an honorary man for the purpose of her visit. And that really did upset Ingrid, I think-- or annoy her a little bit.

00:34:19;26 This is really advanced beekeeping. You see the beekeepers are using displacement techniques. They're opening the apiary at the back. So the older stinging bees fly over the top of the stack to the front, so the individual doesn't get stung half as bad as he does if he's a British beekeeper standing over the hive and lifting bits and pieces off the top. Displacement is a really fundamental technique in beekeeping. And we can use it for lots of different things.

00:34:48;14 I remember some nuns in Warwick coming to me once after a talk. And they told me-- quite seriously that their mother superior had declared that they were now going to be entitled to one hour of compulsory joy every week. (LAUGH) And they'd chosen to spend their hour of compulsory joy keeping bees. But they didn't want to get stung. So would I help them in advising them in how to set up the apiary?

00:35:16;27 So we set up the bee hives on wheels. And we put colored screens in front of the wheels. And you can see how well this system works, because you have your hives here. You're ready to investigate one. So you put some empty boxes behind the colored screen. And then you wheel the hive over here. You then start opening it without smoke. And the all the nasty bees come up and (MAKES NOISE) over there. And they pile up on the outside of the colored screen.

00:35:48;11 So now you've only got the baby bees. So you can sort through. You're not going to get stung. You can see everything. The queen is where she should be, because she's not panicking, because of the smoke. She's usually in the center of the brood nest. And you can find her very easily. Do all your manipulations. And then you can wheel this hive back behind the screen and all the old bees will go in. And it's all nicely united.

00:36:12;13 Now that's a displacement technique. We use it for separating old bees from young bees, because-- if you're setting up a queen rearing stock, you want young bees. Because the hypopharyngeal glands are producing royal jelly. In the old bees, the hypopharyngeal glands are producing invertase to convert sucrose into glucose and fructose.

00:36:33;08 So you don't want old bees in colonies that you're specifically designing for queen rearing. And you don't want very young bees in colonies that you're designing for honey raising during the honey production, during the honey flow. So, for example, if you want to produce a lot of honey and you're not just sort of interested in the biology as I am, you might put three hives together, put the same colored screen in front of three, give them the same flight entrance, and then just before the honey flow starts, you take away the two on the side. And their adult aged population of foragers will immediately come back to the center hive. And they'll storm in.

00:37:19;09 You now have one hive that has three times the forager population relative to the brood. So it will produce an enormous amount of honey. More than the three hives would if you'd left them all separate. These two hives now in the honey flow will be reducing their size, because they've lost their worker forager population. But this hive has got maximum invertase production for inverting the nectar into honey.

00:37:46;25 This hive has got enough foragers to generate the heat that's necessary for producing honey. And it's got enough foragers to build up the air flow which has to be driven through the colony to drive off the water. So just by displacement, you can separate the bees out into old and young for totally different purposes.
(SLIDE NOISE) Now, I said we were a herding animal aspiring to become social. And you're really seeing that now.

00:38:23;07 It took the honey bees 30 million years to evolve chemical control of one another's bodies through pheromones. We haven't got time to do that. So we're evolving a phenomenon of using microelectronics, computers, televisions, mobile phones to deliver information simultaneously to every human being in the world to try to influence every human being in the world towards the same set of values.

00:38:54;26 We are trying to create a supraorganism, even as we speak. But we're doing it very, very rapidly. And the question is, "Can we adapt in time?" Now the default condition for a human embryo, of course, is to be female. And as you know--females have two X chromosomes and males have an X and a Y chromosome. So if I show you how many genes there are on an X chromosome, there's an X chromosome, stuffed with genes for survival as a human being.

00:39:37;25 So what's the Y chromosome look like? That's the Y chromosome. (LAUGH) The Y chromosome doesn't contain any genes that you need for surviving. The Y chromosome is there specifically to convert a female embryo into a male. That's why, of course, females don't need a Y chromosome to live a very long and happy life. And that's why females are stronger in genetic principle compared with males, because you've got two X chromosomes, so you've got two chances to get a good gene for each action on the X chromosome. The males don't. They've only got one chance.

00:40:16;02 So if they've got a recessive gene, they'll show it, like hemophilia. So why is this interesting? If you have a husband who doesn't believe that he is an under-developed woman, it's very important (LAUGH) to stand him in front of a mirror, take his shirt off, point to the nipples on his chest, and say, "Just exactly what are you intending to do with these?" (LAUGH)

00:40:44;09 Now this is all extremely relevant. Because nowadays, it's not just the alpha male and the alpha female that gets their genes through to the next generation. Every individual now has a chance to get their genes through. The really happy males, who are nice and gentle and don't like fighting. The really assertive females who'd be wiped out by an aggressive alpha male in caveman times. She can get her genes through.

00:41:11;16 The trouble is when they reproduce, you get a little band in the middle, which I call the intermorphs, which are non-reproducing. There are 17 different sexes now in the human population. Alpha males, alpha females, and then a whole range. And where they cross in the middle, you've got individuals that don't have the reproductive organs that they need to reproduce. You've got individuals that don't have the psychology of wanting to reproduce.

00:41:37;28 And what you're really evolving is a worker population. A non-reproducing group of humans who will spend their lives effectively maintaining the economies that serve the needs of the offspring of the reproductives. And I think what'll happen over the next few hundred years is that middle group will get larger and larger. And one of the really interesting things we have to ask is, "Will the females inherit the control of the human supraorganism or not?"

00:42:08;13 Because in every other walk of animal life, wherever there's been a move from the herding animal to the social animal, it's been achieved with female domination. So females that have the behavior pattern for the care of the young more easily translate that into the care of the larger society. So during this talk, I want you to keep asking yourself the question, "Are the females going to take over now that we're moving from a herding animal to a social animal?"

00:42:42;01 So now you can see that studying bees is extremely relevant if you want to understand why you have relatives that don't want to reproduce--at all, under any circumstances. This is the view that we have of our environment when we look at it. It always puts in my mind Wordsworth's point, when Wordsworth was the great sort of poet who believed that if you looked at nature long enough, it would educate you. It would instill in you a moral and ethical appreciation of the world around us.

00:43:16;30 And he had this nice line. "Enough of science and of art. Close up those barren leaves. Come forth and bring with you a heart that watches and receives." Now that's a really totally different view to the view of a scientist. Here's the scientific view of a natural environment. (LAUGH) I've already told you that everyone in this room, including the honey bees outside, are all made from stardust.

00:43:51;12 And that stardust was produced only once in the last five billion years, when the star exploded that produced our solar system. And gravity pulled the heavy atoms together to form the planets orbiting the sun. So each of these cycles represents carbon, nitrogen, sulphur, oxygen. They all have to be recycled. One of the reasons biological systems die when they don't need to die is that the elements need to be recycled if the population is going to remain adaptable to future change.

00:44:26;30 If the Earth didn't change, if the environment didn't change, people wouldn't need to die. And so you'd see a change in the evolutionary pressure for dying. Every species has a species specific life expectancy. We are the only creature that's done a dramatic job in extending our life expectancy from a Roman of about 20 years to a child born today that could, with really careful nurturing, get up to 120 or 130 years.

00:44:56;25 In fact, we've increased life expectancy every year for the last 200 years in the United Kingdom, which is spectacular. Now if you ask a physicist what a species is like a honeybee or a human, he'll tell you, "Oh, that's simple. The species is there to recycle atoms." So each of those dots is a species. And the waste of one species and the body of one species becomes the food for another species.

00:45:24;08 And it's a beautiful chain of recycling elements. And we can connect these up together with lines and talk about living webs. And ultimately, we talk about the whole biological sphere, the whole biosphere, all the species connected together to form some holistic whole for the recycling of elements. It's only because all these species are recycling these elements that we and honeybees exist today.

00:45:53;11 We would have run out of the nutrients that we require to build ourselves long ago if these creatures had not been building their associations and living and dying in the process. There is no reason for a biological system to die in a controlled way over a short period. A biological system can last a very, very long time, if it's designed to do so. But evolution has worked against that.

00:46:18;18 As we get to know more about the human genome, and here you've got a complete plan for building a human being in your garage over the weekend, with a box that's no bigger than that, to synthesize the DNA code. And here you've got all the instructions. So it is quite amazing that as we learn the occupations of the genes and not just the addresses, we will be able to change in a huge way all sorts of aspects of our lives.

00:46:52;01 We will, if we wish, be able to change genes that limit our life by limiting our ability to repair ourselves and replace them with genes that can repair ourselves. So there is a very open ended future awaiting us at the end of the study of the genome. All diseases will be treated through the genome, rather than applying drugs that work against the genome. But a word of warning, the human body's only designed to get you to 26 years of age and reproduce.

00:47:26;29 After that, a lot of genes in your body are closing you down, and getting you ready to donate your elements to the next generation. Incidentally, we change, in ten years, every atom in our bodies. So there's nobody in this room that is older than ten years of age. (LAUGH) What is older than ten years of age is our design. And I've already said that that design will come again and again as the chemistry that was established right at the beginning unfolds time and time again.

00:48:05;25 Here's our little honeybee, sitting in the center of this web producing survival potential or encouraging survival in so many species. The honey in my garden in Cardiff has species of plant represented in the pollen analysis - 243 different plants are being helped by the honeybees just in my garden.

But look at humans. Man has always been his own worst enemy. We're the only species now that produces waste that is so toxic. 300,000 years of toxicity in spent nuclear fuel.

00:48:44;24 So we're the only species that is now producing industrial waste on a vast scale. And we can only do that, because we're using energy. And energy is cheap. Whatever you think about your gas bill and your electricity bill, it is really, really cheap. And we don't have to do anything for it. And if you have no regulation of that energy, the way in which other social creatures do, if you use it just for industrial processes, you generate huge amounts of pollutants. And we know now that we're polluting the world at an astonishing rate. Not just atmospherically, but in the oceans of the world.

00:49:35;21 We used to recommend two portions of oily fish per week for a healthy adult diet, human diet. Now we only recommend one, because of the pollution in the sea. Methylmercury building up in tuna to the level where we can't even recommend a healthy diet to people. And no no individual under the age of 16 should really eat swordfish, because it lives long enough to accumulate a huge number of poisons.

00:50:06;20 And no woman carrying a baby should eat swordfish. And I wouldn't recommend any woman carrying a baby to eat any of the long-lived fish. And she wants omega three, to eat sardines. 'Cause they don't live long enough to accumulate all the poisons. So we're reminded that despite the beautiful programmes that we see with David Attenborough on television that we're not part of an orchestra that has a lifelong permission to exist and play beautiful music in harmony.

00:50:36;21 Nature is not benign. We're given a fiddle a birth. And we're thrown into the orchestra. And we're told, "Play in tune or you're out." And if we don't play in tune fast enough, we're out. We lose the battle for survival. We're in an intensive, intensely competitive situation. Charles Darwin's granddad embodied all this sort of discussion in his poem, *The Temple of Nature*.

00:51:02;29 "From hunger's arm, the shafts of death are hurled. And one great slaughterhouse the warring world." That was the reality for Erasmus. And here for our bees, we see this played out continuously. Here's the crab spider that sits on flowers, mimics the colors of the flowers. You see this in the United Kingdom. The bee lands to suck the nectar and the crab spider bites at exactly the most vulnerable point on the soft part of the neck, just behind the head.

00:51:34;26 And when we forget that we're in a competition, when we forget that the universe is a hostile universe and become complacent about our survival and complacent about our food supply, we will be in serious danger. But there are points of optimism. I've said that the universe doesn't owe us a living. I've said that the universe is neutral. It does not recognize love or social conscience or natural justice.

00:52:09;13 But for me, it's amazing that we do. And we still can add and create value with those human aspirations. We can if we only choose to make it so. Of course, we make big mistakes when we discover nuclear fission. We thought that was a great way for our-- producing energy. And we used it in war, which is one of our big mistakes. We're always developing science for good purposes and using it for bad purposes.

00:52:44;21 When I was in Hiroshima once, I went down to the atomic bomb museum. And this is a photograph that was taken by the reconnaissance plane that flew behind the plane dropping the bomb over Hiroshima. And next to it, they have a copy of the instructions given to the bomber pilot. And the instructions say, "Fly towards Hiroshima. If the sky is clear, drop the bomb. If the sky is cloudy, fly on to the next target."

00:53:14;16 And that was entirely so that the reconnaissance plane could get a clear picture of the bomb is it was dropped. And I stood there for about 15 minutes thinking, "You're telling me that the people of Hiroshima moved into history and had an atomic bomb dropped on them, because that day they woke up to a sunny morning." Here is our sun, a furnace of nuclear fusion and nuclear fission. If you superimpose the Earth on that disk, it would be a tiny, tiny black dot.

00:53:49;04 The sun is of an enormous size. And here you've got fusion occurring all the time. Hydrogen is being fused together to produce helium. There are atomic explosions that send energy waves far out into space that are pulled back by the electromagnetic field and the gravity. And yet, this is still the source of all energy for life on Earth. There's just another source that we never talk about, but only the bacteria can exploit it.

00:54:20;17 And that is some of the rock we have has materials in it that contain energy that bacteria can extract, like some of the sulphur bacteria. They can live in complete darkness and still extract energy for life from the rock. So we live in a bacterial world, as I'll demonstrate now. None of us, either honeybees or humans or any complicated plants or animals can live without incorporating bacteria into our bodies and into our cells.

00:54:51;30 So chloroplasts that are responsible for catching light energy in green plants and building it into the molecular structure of glucose are all bacteria. Right at the beginning of the evolutionary process, single-celled organisms engulfed these bacteria, cyanobacteria, engulfed them and kept them prisoner for the rest of their evolutionary history. They have a symbiotic relationship with us. And as you can see here with the red dots, they've still got their own DNA. And they still divide like bacteria inside our cells like sausages dividing in half.

00:55:32;16 So when a human being says, "I've got a nucleus in each of my cells and it contains all of the instructions for making copies of me," they forget that they've also got bacteria inside their cells, living with them symbiotically, that have their own DNA and are functioning in a completely separate way. Now once chloroplasts have trapped light energy and put it into the glucose molecule in the junctions between the atoms, you've then got to get the energy out again.

00:56:02;29 So you have to grab another bacteria which are now the mitochondria. And this bacterium can take the broken fragments from the glucose and release the energy to turn it into a chemical energy store. And I'll bet even today, with all our modern education, if you gave children a quiz going into A level about mitochondria and chloroplasts, they would think that they are just some part of the cell.

00:56:31;04 They wouldn't realize that they are a symbiotic friend that we need and have needed for millions of years to be able to use light energy at all. So our total source of light energy coming into the entire biosphere is being controlled by bacteria. And if we didn't have those bacteria in our cells, we couldn't survive. So that is a huge bit of insight. Here's the light, the water, and the carbon dioxide are being combined together to set up glucose.

00:57:05;02 Here we can see the chloroplasts in a green plant, capturing the light. And we can look at them at high magnification. And when we magnify them up on the electron microscope, we can see all the different filaments that are used to assemble the molecules that will handle the chemical transduction process of capturing the energy and building it into the bonds between the atoms.

00:57:34;09 Then, of course, we've got to get the energy back out again. So the green plants have to have mitochondria. So do the fungi and so do the animals. And first of all, we drive off the carbon dioxide by breaking up the ring. We then have coenzymes that collect up all the hydrogen atoms or protons. So here again now we see that hydrogen is determining our survival. Because the coenzymes are collecting all the hydrogens from the glucose molecule and taking them to the mitochondria.

00:58:05;23 And there's a mitochondria from a human cell. It would look exactly the same in the brain cell of a honeybee. And you can see all the membranes lined up. And it's on those membranes that the hydrogens will be brought in. And the hydrogens will be coupled to the oxygen that we breathe and the honeybees breathe to make water. And in that little process, we'll generate some chemical energy that we can store.

00:58:29;01 It's really quite salutary to be reminded that we, the great human species, are really totally and utterly bacterially dependent. All our batteries are bacteria. It's also fascinating for beekeepers to realize that because honey is largely glucose and fructose, fructose is just a different molecular arrangement of glucose, that when you hold a frame of glucose like that, a frame of honey, you are holding the fundamental store of energy that is used by all living things.

00:59:05;22 Our brain can only use glucose for energy. If you're going into an exam, suck a sweet that's got some glucose in it. Because the brain will rip the glucose out of the blood at a fantastic rate if you're really concentrating. This is what's keeping me nice and slim all the time.

(LAUGH) The brain can't store glucose. So usually at normal room temperature, after three minutes with an absence of glucose and oxygen, the brain cells start to die.

00:59:38;08 Here we're in the Philippines and we're collecting huge amounts of honey. Every time I look at a frame of honey now, I don't think, "Oh, that's lovely and sweet and nice." I think, "Wow, this is-- the bees are actually storing the one molecule that is essential to provide energy for every major complex living organism on the face of the planet."

01:00:03;02 Of course, plants store this as starch by connecting the glucose molecules together. That's why it's very important if you want to lose weight that you cut the potatoes in half and just eat one. Because the glycaemic index of potato is almost identical to cane sugar. Then of course, now we have this information, we can get the genes that make a chloroplast, and we can embed it into the skin of a cow.

01:00:27;17 We can get the genes that produce root nodules on a leguminous vegetable and build it into the legs. So now the cow doesn't need to eat grass, does it? We can just plant it in the field. And it will photosynthesize with its chloroplast, and it will fix nitrogen for amino acids with its feet. And if we take the fluorescent genes from jelly fish, we can find it in the dark. (LAUGH)

01:00:53;10 My plea here is a simple one. Yes, we can manipulate genes. But let's not do it to produce blue bananas. You know, let's do it only when there is a really really good reason for doing it like growing plants on toxic ground in a starving country. That might be a good reason. Let's look at every application of genetic modification and study each application in isolation. But let's not waste it. Because that is really the history of mankind, a history of wastage.

01:01:26;24 But we've got people to defend us. (LAUGH) And here you can see George looking through his binoculars. He hasn't taken the covers off the binoculars. But he knows that what matters is the image that he's presenting. And he doesn't bother to admit that he can't see anything. He keeps talking as if he could see things. And the press keep noting down the appropriate comments.

01:01:55;13 Now unfortunately, it's a real shame that we have politicians guiding us who don't devise policy based on evidence. Scientists base their policy and conclusions on evidence. And if the evidence changes, the scientific view changes. But politicians don't. They have a mantra, an ideology. And you would not believe the number of times I've given advice to government departments. And if they don't like it, they will say to me, "Well, that's all very well, but actually, we want to achieve this. Which bits of your evidence will support this?"

01:02:34;14 And that's exactly what Tony Blair did over the Iraq crisis. He decided that he had an ideology that he was going to go in for-- for personal reasons that he agreed with George Bush. And then he looked for evidence. And it was appallingly scrappy, rubbishy evidence that he used to defend his case. So we need more scientists in politics. And I would urge you at the next election to check out the scientific credentials of every candidate that you have (SLIDE NOISE) to choose between.

01:03:06;10 I couldn't give this talk without ending on the nervous system and the brain. So I very quickly want to look at how energy is used in honeybee brain and human brain to draw the analogies. Honeybees have wonderful sense organs. Here you can see the little hairs on a honeybee's shoulder that measure the weight of the head. When a honeybee wants to fly, she needs to know the direction in which gravity is pulling. She needs to orientate with respect to gravity.

01:03:37;22 So she comes out to the entrance. And you can see her do this. If you get your nose on the ground next to the entrance, you'll see the bee comes out. And she's like a World War I pilot. She's got a little checklist. So she measures the ambient temperature. And she wants about 10°C. Tick. She measures the turbulence in the wind. And she can just check around. If it's too turbulent, she'll go back.

01:03:58;30 She looks up to see a patch of blue, so she can detect the position of the sun for navigational purposes. And if there's a patch of blue, polarized light will come through it, indicating the true direction of the sun, even if it's hidden by the cloud. And then just before she activates the flight motor, she waves her head on her shoulders. And the weight of the head presses on these hairs, which only bend in one direction. And the nerve cells, there are three nerve cells in each of these little hair capsules, that then send the signals back to the brain. And she knows where gravity is. Then she starts the flight motor and takes off.

01:04:34;07 And you can imagine I was eating my corn flakes one morning in Cardiff. The phone went. I was in my pajamas. Picked up the phone. And someone said, "Is that the bee man in Cardiff?" Always the bee man, never the A man. (LAUGH) And I said, "Well, I could be. Who are you?" And they said, "You are now live on Radio New Hampshire." (LAUGH) So in the middle of my corn flakes, I'm being asked questions about bees going into space, on a radio programme that's being broadcast along the eastern coast of the USA.

01:05:14;03 And they said to me, "Will the bees fly?" And I thought to myself, "I bet NASA don't know about these hairs." And I said, "No, I don't think the bees will fly in zero gravity." So you can imagine, when I put the phone done, all my pals like Roger Morse, would be laughing at me if I got this wrong, at Cornell University. So I was very interested to see the footage.

01:05:34;17 And the astronauts came on in the space vehicle, in zero gravity. And they had the bees inside a Perspex cylinder. And the bees were clinging to the inside of the Perspex cylinder refusing to let go. So the astronaut got frustrated and shook it. And the bees floated off into space like this. (LAUGH) So if they’d just rung us before they actually designed the experiment, we could have told them to put a bit of paint on those hairs and fasten them down or a little bit of sticky tape. And that would have then comforted the bee. And she'd have been willing to switch on her flight motor. (SLIDE NOISE)

01:06:18;14 So in 1996-'97, we made, with the medical physics department in Cardiff run by Huw Griffiths at the time, an experimental platform that would allow us to take M.R.I. images of the honey bee brain. And we put the little bees intact into a miniature M.R.I. sensor. And we were able to create 50 different slices through the intact honeybee brain.

01:06:49;09 Here you can see in the last slice there's a hole in the middle of the brain where the esophagus is passing through the brain. Something you would never design, because if you get anything lumpy in the esophagus, it's going to nudge the nerve cells and make them fire. You'd never design that. It's just because in an evolutionary process, the ganglia of the brain was set up around the esophagus in worms.

01:07:16;03 And then later on, when those worms evolved into insects, they still had to go through the same genetic process of putting them in blobs around the esophagus, before they could then add genes or evolve genes to push them together to form full brains. And even in a human embryo, you can still see those very ancient genes setting up the ancient wormy structure that was the basis for both honeybees and humans.

01:07:43;09 Here is the honeybee brain. And we can do experiments with it. And we did for 25 years. You can identify a group of cells in the brain- the Kenyon cells, which make all the big decisions in a bee's life. The honeybee is the only creature, apart from human beings, that can give symbolic navigational instructions. So if a dog or a dolphin finds something, they have to lead other individuals to it. They can't say, "Go in this direction two miles and you'll find it."

01:08:18;07 Honeybees can do that for new accommodation, for forage and for water. So it is a truly unique capability in terms of intelligence to give navigational instructions symbolically. These are the cells that do it. And I could cut a slice through the human brain in the cerebral frontal cortex here. And I could show you a structure that you'd find difficult to separate and distinguish from this structure.

01:08:48;14 If you've put electrodes in the brain here, you can record all the sensory information coming in, like the equilibrium hairs and gravity hairs that we just looked at. The light, the sound, all the information feeding in here. These cells integrate it. And they make a decision. They then send a wave of pulses down here to the nerve cord, which commands either flight or walking or stinging, whatever is the appropriate behavior.

01:09:14;10 So the electrical energy is being driven down here. And what effectively is a thought becomes--a thinking process here is the integration of electrical energy. And the electrical energy is then dissipated down these axons as frequency of pulses. (MAKES NOISE) That's what you hear when you plug into this command system. If you put an electrode in here and actually add your own electricity, the bee will try to walk, fly, and sting simultaneously. Because you've switched on all the behavioral commands, simultaneously.

01:09:56;04 Now just to remind you that journalists have a very poor understanding of nutrition, they think that if one gram of something does you good, ten grams will do you ten times as good. And they have this graph. But it's not true, of course. This is the graph that applies in both honeybee nutrition and in human nutrition. It's not good for honeybees to get all their food from one source. It's very important for them to have a diversity of food sources.

01:10:28;05 Honeybees can produce a lot of honey from oilseed rape. But they still need other pollen grains with other contents to come in to maximize their immunological system, for example, and make sure that it's got all the nutrients that it needs. So although honeybees will produce a lot of honey on single types of crop like oilseed rape, it's very important to make sure they have access to other forage, as well.

01:10:54;05 So here you see what happens is-- and if we take that human case, a little bit of something-- a vitamin or a mineral gives you maximum health benefit. Every time you then take the same quantity, you get less benefit. Then eventually, it gives you no benefit, and then it starts to kill you. This graph is exactly the same, even for oxygen, and even for water.

01:11:17;28 So if you want to be healthy, you eat a little bit of everything and not too much of any one thing. And you keep moving. So we've got an obesity problem, at the moment, because people are consuming more energy than they are using in their activity. So all these products on the left will give you a hundred calories of energy. And all the activities on the right will dissipate a hundred calories of energy in your muscles.

01:11:48;04 So if you have two teaspoonfuls of fat, you can then walk for 25 minutes, mountain bike for 13 minutes, or sleep for 91 minutes. I've always preferred the last option. (LAUGH) But you don't get enough time to sleep it all away. So obesity results when input of energy is greater than output. It's a simple equation. And I'll try and explain why it's so difficult to balance ones weight, particularly as one gets older.

01:12:20;03 Part of it is really due to the fact that we don't use our bodies for the purpose they were intended. This is a New York subway. No one is using the steps. Everyone is using the escalator. So we need a government that will redesign our town spaces and working environments so that we have to take opportunistic activity. 12th century monks used to eat 6,000 calories a day. Today, if you eat 2,000 calories a day, you'll find it very difficult to keep your weight down.

01:12:52;15 The key, of course, is you have to keep your activity up. You'll have all seen on the television on the Michael Mosley programmes that if you're have a tendency towards obesity, you'll also have an increased risk of type II diabetes. But if you increase your activity levels, even though you are obese, if you increase your activity levels to the correct level recommended by a dietician, your risk of type II diabetes will revert back to normal.

01:13:22;12 So what's happening is that when we become obese, we don't move. We particularly don't move at nighttime. It's really important at nighttime to keep moving. The muscles have to be kept moving. They squeeze the veins to drive the blood back to the heart, giving a respite to the heart during sleep. All the time-- you know, something should be twitching. So if you've got a partner in bed who's always twitching, they're really healthy. (LAUGH) And if they're laid still not moving, you should jab them every five minutes. (LAUGH)

01:13:58;00 Here you see the experimental evidence of this. Drivers and conductors, 31,000 London transport workers, they eat the same food in this study.

They were eating the same food, living the same lives, supporting the same football teams. The only difference between them was that the drivers weren't moving much, but the conductors were. And because the drivers weren't moving much, their risk of their incidence of coronary occlusion and early mortality was more than double. And in some cases, triple.

01:14:30;27 So you do have to keep moving.

So just to look at that communication of the honeybee, here's Axel Michelson's robot. As you know, Axel Michelson in Odense University made a robot bee and controlled it by computer. So he could send the bees out to different compass vectors for different distances.

01:14:50;24 And you'll remember the way in which the dance language works, as it was fully described by Karl von Frisch when he won his Nobel Prize. Here the robot is going to wiggle its abdomen. And it's going to move a centimeter, then turn back, and wiggle its abdomen again. The wiggling of the abdomen is inversely proportional to distance.

01:15:15;23 So if the food is very close, the abdomen will waggle slowly. Sorry, the abdomen will waggle quickly. If the food is a long way away, the abdomen will waggle slowly. If it waggles slowly, it recruits fewer bees. If it waggles rapidly and excitedly, it recruits more bees. So it recruits more bees to the closest object. Very clever. We call this "the figure of eight dance." The orientation of the dance, of course, indicates the vector with respect to the sun.

01:15:46;05 So here's the sun, which is vertical in honey bee dance language on a vertical bomb. So this robot is going to tell these recruit bees to go to the hive entrance, take off, adopt a 90° angle to the right of the sun. And then fly for a specific distance. Which is what they will do. And then they fall down. And they look for the smell that they've been given.

01:16:12;14 So when Axel first made this robot, he didn't have a reward system in it. And the bees paid attention, looked at the dance. And when they didn't get a reward, they started stinging the robot. (LAUGH) The reward is really important, because it contains the fragrance of the flower. So when the bee drops down from its navigation, it needs to search for the fragrance. And when people ask me, "What is the most important thing that honeybees have given to mankind?" I always say, "Flowers, the diversity of flowers."

01:16:47;04 Because in the Cretaceous Period, the flowers were all pollinated by the wind and the water. So they were green and yellow and just dangled about. They had no shapes, no special shapes, no special colors, no special smells. It's only because bees can memorize the differences between the flowers. And they've built this contract of association over millions of years that the flowers have competed for the favor of the pollinator.

01:17:13;04 Because a crocus wants pollen from another crocus, not from a totally different plant. So it's in the plant's interest to make its flower, its smell, and its shape, and its time of opening very, very specific so that the bee can memorize that and bring pollen from another crocus flower to it. So that's why the honeybees are such outstanding pollinators. Because they have evolved a brain that can do that. So let's watch the dance in action.

01:17:51;01 (VIDEO NOT TRANSCRIBED)

ROBERT PICKARD:

01:18:32;20 So this is a wonderful experiment, because if you put a number on each bee, you can send numbers one to 20 due north, numbers 21 to 31 due south. And you can have students in all compass bearings around the university at different distances with feeding platforms containing the smell (I used to use lavender oil) containing the smell that you've trained the bees to come to.

01:18:57;02 And then you can show that the numbers go to where the robot sends them. It's a super experiment. Well, you remember I asked you to keep an eye on whether or not the females were going to inherit the Earth. Here's a group of males and a group of females, human beings, given a language problem. The red area shows which part of the brain they used to solve the problem.

01:19:25;02 One group only used the left side. The other group used both sides. Which is the male group? Is it one-- is the group on the left male or is it female? (SLIDE NOISE) When our ancestors were swinging through the trees and didn't have language at the level that we have now, these two parts of the brain were used to analyze three dimensional space. And you need a lot of cells to do that if you're going to survive.

01:19:57;08 When we came down out of the trees, we had cells in high population numbers that were no longer needed for that function. But there was a tremendous merit in being able to communicate, to build your beginnings of a society. And it's really interesting to see that the males sacrificed one half of their spatial-visual capability for language, but the females are cheating. They're using both sides.

01:20:23;23 This does also explain why females that are very good linguistically often have to rotate maps when you give them it and ask for directions. And it's why my wife will constantly say when we're driving, "Turn right. Turn left." (LAUGH) She is a linguist in French and Spanish.

So here's a brain, just to show you why it's so difficult for us to control our weight. This is a brain I know very well, because it's my own brain.

01:20:56;14 I've never understand people who own a car and never want to look under the bonnet. (LAUGH) Here you can see the pituitary gland that controls all our hormonal system, which we can mark out. And just above it is the hypothalamus, which is controlling the pituitary. And at the anterior end of the hypothalamus here is the pleasure centre. Whenever a human being professes to be happy, whether it's Wales beating England in the rugby match or some beautiful damsel saved from distress, the impulses appear here in the pleasure centre.

01:21:40;13 But right next door to it is the satiety control centre, the centre that determines whether you feel full or not. And it's really interesting, because to begin with, as a child, you get a few wires between here so that when you are full and the stomach is distended, impulses go to the pleasure centre and that makes you feel contented. And you stop eating.

01:22:07;11 But if you've got no other source of pleasure, what tends to happen is that active nerve cells recruit other cells that are not active. So what started as a little country lane of communication becomes a four lane motor highway. And I'm going to show you how that sets up an obsession in a brain as my last topic. Here's a synaptic field in human cerebral cortex. And the decision that's being offered to this individual is, "Do you want an apple or an orange?" Now the person believes that they have free will. And they can choose whatever they like. My contention as a neurophysiologist is that they only think they've got free will, because they can't predict the outcome:

01:22:55;10 A) because it's fast. B) because it's complex. And C) because it will change from moment to moment, depending upon the circumstances that the brain is recording. So in come the signals to the sensory cortex. Smell, shape, and color, for example. The electrical energy is then relayed through the neuronal network. And you will see the pathways light up as the nerve impulses are conducted to the perceptual area, which has been trained in childhood to identify apple, when impulses arrive in that sequence with those particular frequencies.

01:23:40;01 Let's look at the choice for orange and compare them. You'll see the projections in the perceptual cortex cortical area there are different for orange and apple, as you would expect. But look on the input side, the shape of an apple and orange is the same. So they'll activate the same energy flow in that area. But the colors and the smells are different.

01:24:02;25 So how do we then build an obsession? We build an obsession if one of those pathways is rewarded for its activity in whatever way. It could be you enjoy eating apples. It could be someone slipping a fiver under the apple. Whatever the reason, more nerve cells get recruited to that pathway. So what was a country lane becomes a motor highway. And this is the nature of obsession.

And humans do this naturally.

01:24:32;27 If they've got nerve cells that are not busy, they'll be recruited for the nearest obsessional pathway. And that's just one of the strange things that explains the nature of football supporters. (LAUGH) And you'll see that hundreds and thousands of cells will be recruited and alternative pathways will be recruited. So when the person is next offered a choice between an apple and an orange, they still don't know which they're going to choose. But their subconscious does. And it's already predetermined at the subconscious level.

Well, here I am, sitting on the hillside, looking over the Bay of Naples. And I'm looking at the Isle of Capri. And I'm thinking to myself, "What a wonderful world." Thank you. (APPLAUSE)

01:24:30;10

AUDIENCE QUESTION:

Should we be testing politicians using your machinery, before we actually allow them to take power?

ROBERT PICKARD:

01:24:33;20 Yes, we should be testing politicians. And we should be testing would-be parents. We should definitely have a very big form that parents can fill in for their own purposes to just see if they're ready for parenthood. Because it's quite interesting. Look at what a honeybee has to do to achieve a contribution to the next generation.

The queen, the virgin queen is driven out of the hive by the workers, because she's not fertilized, and forced to fly on her own past predators for several miles to a congregation area in the sky, where there will be hundreds of drones competing to copulate with her, who have also had to negotiate all the dangers. And they've had to have the strength to fly and to make it.

This is an examination of fitness to reproduce.

The queen will copulate with up to 17 different drones to get a mixture of semen and genetic mixture to put with her own genes. She'll fly all the way back and gets into the colony. And if the bees are satisfied that she's properly mated, they'll never let her out on her own again. And if she walks towards the entrance, they'll bite at her legs and drive her back.

Now there you see a really good system for deciding whether or not someone should contribute genes to the next generation. Now I don't want to raise old spectres, but I do think that when people are thinking about raising children and having children, they certainly need to think about it a lot and get a lot of information and not regard it as a simple, straightforward process. Because we have created a world that is totally inappropriate for raising little cavemen.

01:28:12;08 Little cavemen want to break things, because they test their strength. They test the environment.

When my grandchildren come to my home, I spend hours whizzing around, (LAUGH) moving things out of the way, because it's not designed for them. And our whole society, at the moment, is not designed for raising little cavemen. And it requires a very special aptitude to do it in this unnatural world that we've created.

AUDIENCE QUESTION:

01:26:53;19 You were very keen on the idea of adaptation and-responsiveness to change. But the honey bee has obviously, from your image of the 23 million year old amber, has not changed for a very long time, even though you talked about it having evolved from a worm-like type. But do you think the honeybee is in a slow process of change and adaptation now still?

ROBERT PICKARD:

01:27:17;01 It is still, but it is an optimized formula one vehicle. 26 million years ago, it had already been evolving for best part of 30 million years. So it was already super tuned and highly optimal. And you'll find as a beekeeper that if you use a breeding programme to change one particular aspect that you'll probably suffer in the bee's lifestyle in some aspect. Because it is so highly tuned.

01:27:48;04 However, of course, if you create a situation where the bees are inbreeding, then you'll need to do some outbreeding to ensure that you keep the stock with hybrid vigor. But I doubt if there's anything that you can tweak on a modern honeybee that wouldn't, if you changed it, for example, lengthening its tongue or increasing its resistance to a particular disease, there will be a compromise and you will lose some other aspect. I think--

AUDIENCE QUESTION:

01:30:07;27 It's quite unique in that-- it can't be quite unique. Do you think it's unique in that--

01:30:11;22 (OVERTALK)

ROBERT PICKARD:

01:30:12;03 It's unique in the sense of many terrestrial animals. Deep sea fish that live in an unchanging environment tend themselves not to change once they've optimized. Like the coelacanth off the coast of South Africa. But our honeybees have reached such a level of perfection, in terms of the balance of the requirements in their life, that it's very, very difficult to see how they could improve without sacrificing something. But-- you spotted that very well. That was top of the class. (LAUGH)

AUDIENCE QUESTION:

01:28:57;16 You mentioned the neurological pathways with regard to soccer supporters. Does the same thing apply to rugby supporters? (LAUGH)

ROBERT PICKARD:

01:29:08;16 It does. But rugby supporters sing at the same time, (LAUGH) demonstrating an exposure to the humanities that is sometimes lost in the soccer world. (LAUGH)

AUDIENCE QUESTION:

01:29:23;00 When you talk about female domination, (LAUGH) honeybees are female, and they're social. There's no one dominant, so I don't think that you know, women will take over and dominate.

ROBERT PICKARD:

01:29:45;11 It's collective feminism, isn't it?

AUDIENCE QUESTION:

01:29 :48;06 Well, yes, I don't think it's feminism at all, actually.

ROBERT PICKARD:

01:29:50;26 Oh right.

AUDIENCE QUESTION:

01:29:51;04 I don't think honeybees are feminist. Because, for one thing, they do housework. And-- (LAUGH) and feminists believe-- you know, housework is sheer drudgery. And-- they're also-- not victims, you know, of male oppression or anything else. So--

ROBERT PICKARD:

01:30:14;08 If-- you're absolutely true in the sense that women have been misled by men for a very, very long time. (LAUGH) And what's coming out of science now is a very clear indication that you can get now in modern human beings the complete range of characters. And when I talk about female domination, I could be more accurate and say what I think will dominate will be what we tend to associate with female behavior patterns.

01:30:46;13 And I think we'll have to educate young males to be more cooperative, more genuinely team working. If you have a team of male football players one becomes the striker, one becomes the goalie. If you've got a team of female football players, it's amazing how they can interchange their roles in an amazingly plastic way. Because when you're raising children, you cannot just focus on one thing. You have to focus on many different dangers simultaneously. And that's where that multitasking capability comes from in women.

AUDIENCE QUESTION:

01:31:20;25 You were saying that the honey bee fossil-- the fossil honey bee hasn't changed in 26 million years. Do you think the human species will change in that amount of time?

ROBERT PICKARD:

01:31:39;14 Yes, it will be lucky if-- at the current rate of use of energy, it will be lucky to last a few hundred years. The dinosaurs reigned for 20 million years. I don't-- you know, it's gonna be really tough. I don't believe that we should harness the nuclear fusion reaction until we've developed an international humanitarian code that dictates how we use that energy.

01:32:06;19 Because if we're going to use that energy to do stupid things, we will pollute ourselves out of existence very, very rapidly. So if we get cheap, enormous amounts of fusion, nuclear fusion energy, we will need to have policies in place to control how it's used. Because if we just have a laissez faire attitude, the consequences will be truly disastrous. So I think humans will change dramatically.

01:32:35;24 Julian Huxley used to believe that as computation capability increased, people wouldn't want to expose themselves to nasty diseases. So they wouldn't go out of their boxes at all. They'd all stay in their boxes and interconnect through computers. And then, of course, you've got a situation where legs and arms of the sort that we have at the moment become inappropriate.

01:32:56;19 So I think none of us here would want to live in the humanity of the future if it continues to evolve into a supra-organism where all human beings are united, because we all love our individual freedom. And to become truly social, you have to sacrifice your individual freedom as part of a contract with your government. The contract is, "If you will protect me, I will relinquish my individual freedom." And as soon as that contract is broken, then your society disintegrates.

ROBERT PICKARD:

01:33:35;03 Thanks very much. Thank you. (APPLAUSE) Can-- can I leave you-- can I leave you with just one really simple thing? And that's a little bit of Chinese philosophy, which is, "Sleep well, tomorrow is coming. And it's all yours."

(LAUGH)

01:33:56;18 (MUSIC)

* * *END OF TRANSCRIPT* * *