

THE RICHARD DIMBLEBY LECTURE

by

Professor Susan Greenfield

THE FUTURE COULD BE TOO MUCH FUN

The final month is about to tick away of what has been declared to be,- with happy disregard for too much accuracy,- the final year of the old millennium. And here we all are, two-faced, like the Roman God Janus, looking backwards and forwards. Simultaneously nostalgic, and yet at the same time, raring to start afresh with that clean row of the three big zeros. The inevitability of the 21st century can thrill as, like Miranda in the Tempest, we marvel at the prospect of a Brave New World,- and at the same time shudder, as in the Huxley novel of the same name, at being merely a stereotype, living out a sanitised existence freed from the intellectual and social messiness of being an individual. Perhaps, more than ever before, this coming century will throw into sharp focus that age-old question: 'What am I doing with my life?'

Inevitably, the spotlight is on us scientists, -we dysfunctional nerds who are bent on draining the world of its warm sepia glow, but at the same time who seem to hold the power to eradicate pain and hunger, and to offer longer and even more interesting lives. Tonight, as we look to the past and future, I want to re-visit

'human nature'. After all, until now, our 'natural' virtues and vices have been impervious to inventions, however whizzy. Traditionally, science has had little truck with subjective inner feelings and outpourings of emotion,- facts of life traditionally ring-fenced by The Arts. But I want to suggest that for the first time in some 50 millennia science, -more specifically neuroscience, - could be ready to challenge this status quo. In the process, as we discover more about the brain, we might, for the first time, have to face up to some difficult questions, re-defining personal responsibility, and even personal identity.

This issue of what, if not who we are, might seem obvious. We are bounded by our physical bodies. Your personal territory stops at the outer surface of your skin. Yet just the other night I attended a fascinating lecture that challenged even that assumption. The lecturer, a cybernetics expert, Kevin Warwick, intends to have a silicon chip implanted in his arm. This chip would be able to send signals through his nervous system to simulate the kind of messages that go between the brain and the heart when one is excited, experiencing a strong emotion.

So what happens when the chip, controlled by an external computer, sends its own signals to the brain? In theory, the feeling of excitement associated with a thumping heart and dry mouth would then be triggered instead from outside the body. Who would be in control, the person, or the computer? And where would the actual boundary lie, between the biological

entity, and the silicon impostor? We have known for a long time that emotions are much more than feedback from the organs below the neck,- but the silicon high-jacking of the signals going to Kevin Warwick's brain will still have a dramatic impact directly on his emotional state.

How far can we go? What about implanting a silicon chip, not in the arm, but directly in the brain itself? This technique has been piloted as a highly novel approach to Parkinson's disease, - a condition where the patient has severe difficulty generating movement. The implant can take over from the dwindling clump of essential brain cells, restoring in part the necessary electrical signals, so the patient can once again move around freely.

But the question for the future, is not so much one of using a chip as a mere servo-mechanism, as in this instance to translate a thought into a movement, -but rather as to whether the silicon implant could actually merge seamlessly with thought processes themselves. Imagine, for example, having an implant of all you needed to know for an exam, grafted into your brain within a few hours in one relatively brief surgical operation. In this way you could circumvent all that tiresome, time consuming and imperfect business of assimilating knowledge, -the learning process. Leaving aside the technical difficulties, which is a bit like ignoring the fact that Mt Everest isn't flat, my own view is that even if memory implants were technically possible they would actually be pretty pointless. All you would be loading in would be simple facts,

which surely can be accessed with increasing ease from a conventional CD. And we can go even further. What about dispensing with tenancy of one's flesh altogether, and effectively becoming entirely silicon? There are some that already cherish the dream that one day they will be immortalised by having their personality and entire memory banks down-loaded onto the future equivalent of a CD. The idea would be that every single memory you had ever had, the portfolio of 'you' therefore, would be on a disk, -and therefore the essence of 'you' would be there too.

The immediate problem here is, of course, a disk doesn't actually feel very much. It wouldn't be actually reliving those memories first hand, so it wouldn't actually be you. But it might, arguably, be an accurate testament to you. And yet, perhaps not. There is after all, much more to a memory than its factual content.

Let's take a really straightforward, uncontroversial fact, -one that I have remembered, and which is thus part of me. 'The French for table is table'. For this well known fact to be truly indicative of me personally, it would have to be downloaded with something more particular, for example how I hated French as school, or was frightened of one of the French teachers. And it would, to be completely accurate, have to touch on specific events in my particular life, -such as the time my mother first told me that words in French were male or female, and table happened to be a girl. I remember that instance quite vividly because at the time, I thought she'd gone crazy.

Even these facts I suppose could be downloaded too, but how far would we have to go for the very word 'table' to trigger all the many ramifications, the associations, -that very element that makes me me, or you you. To down-load a highly personalised memory that related to you, and indeed was part of your character, one would have to down-load all the other one-off scenarios, the prejudices and values, thoughts and ideas as well: but not just that - all your emotional responses - fear of a teacher, hatred of a subject - would have to come too, to the recall of that memory each time it rose up. And, each time it rose up it would need updating and revising in the light of all the subsequent experiences that you had had. So a twenty year old you, would be very different from a forty year old you. This raises the incidental but somewhat tricky problem of having to decide at exactly what age you would want to be immortalised!

In the end, then, in my view, there's no substitute for the flesh and blood version of you. Because no real memory is just a stand-alone fact. Indeed, when facts do stand alone, they are of little value. Hence the denigration among sophisticates, of pub quizzes. It's what you do with the fact that counts, -how it relates to other facts that convey some sense of 'significance' for the person, event or process in question. This is perhaps what is so chillingly missing in Gradgrind's exultation over facts in Dickens's *Hard Times*:

'Facts alone are wanted in life. Plant nothing else and root out nothing else. You can only form the minds of reasoning animals upon Facts: nothing else will be of service to them.'

So why is this not enough? What are the benefits of having a brain? What does a brain do, other than act as a bank for facts? Surely, it allows us, in addition, to have understanding. Understanding is when we can appreciate a fact in the light of what we have learned previously. So the facts that people have at their disposal might be the same, but their understanding would be different. Any one person's understanding would be distinct from another's, because each of us has our own portfolio of facts, - of a lifetime of different experiences. Moreover there is a potential in each human being to go beyond the facts, to have our own ideas, - novel pairings of otherwise disparate facts. So we need an education system, and a general culture that encourages us to assemble facts into our own scheme of things. Charles Dickens was already aware of the danger, when he introduced, again in *Hard Times*, the teacher Mr M'Choakumchild:

'He knew all about all the water sheds of all the world, and all the histories of all the peoples, and all the names of all the rivers and mountains, and all the productions, manners and customs of all the countries, and all their boundaries and bearings on the two and thirty points of the compass. Ah rather overdone, Mr M'Choakumchild. If only he had learnt a little less, how infinitely better he might have taught much more.'

Whilst the Dickensian approach to education is clearly out of fashion, an alternative, more beguiling source of facts has appeared, in the form of the ubiquitous computer. Indeed, while the Internet offers more information than anyone can possibly deal with, it does not necessarily bring us automatic knowledge and understanding. It is the placing of facts into a personalised framework that lifts us from the Gradgrind mentality, and indeed lifts us from being a small child, -a cerebral sponge for facts,- into a being that has 'developed its own mind'.

At least still for the moment, your mind will grow, -develop, - as you do, giving you a unique view of the world and at the same time allowing you to escape from it. But what actually is going on in your head when this happens? What is this human mind?

Normally it is regarded as some murky and mystical alternative to the physical brain. So is 'mind' after all something that science can really deal with? I would argue that it is, and if so, then perhaps the more penetrating futurology question, is not so much what technological gadgets we will have, but who we will actually be. How might our minds have changed?

Here, until now we have been on safe ground, - after all we can look with confidence back to the Greek tragedies, let alone to Chaucer or Shakespeare, and identify the same ambitions, the same needs, weaknesses, virtues and anxieties that have characterised what we can confidently and comfortingly call

'human nature' for thousands of years. However technocratic our weapons and tools, we still go to war, still fall in love, still are reduced to intellectual rubble by our emotions, - just as we have been ever since human thought and human emotion has been recordable in picture and word.

It is because we fancy ourselves so different from our ancestors, that it is so remarkable that our own physical brains have, it seems, changed not a jot for some 50,000 years. Since that time, we appear to be unique as a species in that we have been able to see one thing in terms of something else quite different, -to incorporate an event, process or object into an astonishingly wide framework. For example, the archaeologist Steven Mithen has pointed out that we, but never our chimpanzee cousins, can see an old tooth, not just as a tooth, but as part of a necklace, -an object that would in turn have an additional 'meaning', the knowledge that the wearer was of high status.

In parallel with the explosion of cave art, of artefacts, of tools, came language. With language we have been able to pass on the fruits of our experiences to the next generation. So they haven't had to start from scratch: hence our meteoric over-taking of all other animals. We have been able, in a technological sense, to progress from one generation to the next. Human beings have been able to pass on information, but each of us, as we go through life, still need to develop our own brand of understanding.

At the level of our brains and, indeed, our bodies, we are of course, still prehistoric. The all too familiar executive stress simply is a harkening back to our original roots, when it was important to have a system in the body that could switch to a 'fight-or-flight' scenario. Similarly, and perhaps more controversially, the fact that we women can multi-task and communicate so much more effectively, compared to our male counterparts, - those obsessively fixated, goal orientated, fiercely competitive and violent, - not to mention status-conscious, - creatures, - could again be traced back to the different life-styles and agendas unfolding within the stone walls of our predecessors' homes. (Perhaps we'd better not open up that particular can of worms tonight.)

Standing here on the brink of the year 2000, I don't want to look backwards into the mists of prehistory. If our physical brains, and the mentality that goes with them, has until now been so seemingly impervious to any change whatsoever, why might now be the very time for a dramatic intellectual makeover?

Perhaps it is arrogant to assume that now really is so special, - perhaps every generation thinks that it is at the perfect cusp of the perfect time, - to be more extraordinary, more innovative, than any of our predecessors. That mood was certainly in the air way back in the London of the early 1960s. I was there as a schoolgirl, swept up in the thrill of revolution in music, dress and social mores that seemed to be over-turning completely all our preconceived notions about what one might expect from life,

and indeed what was expected of you. Little did I know that at the time, in Cambridge, the roots were being laid for a far more dramatic upheaval by Crick and Watson as they prepared the ground for the massive scientific explosion engendered by molecular biology, the manipulation of organisms at the level of the gene.

Molecular biologists have already discovered the rogue gene for certain diseases, such as cystic fibrosis and for the disorder of movement, Huntingdon's Chorea. However, these remarkable advances can beguile some into thinking that there is a single gene 'for' almost anything, however complex or abstracted. Indeed some might even see it as only a matter of time before the gene 'for' shyness, the gene 'for' good cooking, or good motherhood need only be tweaked a fraction one way or another to produce the perfect person, freed from all anti-social tendencies and bad habits. Therefore we might be caught up in a new determinism, -just as in the old Greek mythologies, where mere mortals were at the mercy of The Fates, spinning out each of our destinies. So, thanks to our genes, the individual need again no longer be accountable for anything. Such a case was, I believe, actually made in the American law courts for a particularly violent defendant: it wasn't him, said his lawyer, but his genes that were to blame. But just as the swapping between chips and bits of brain I was describing earlier,- silicon-carbon interchanges,- cannot account for an individual mind, so I would argue that genes, on their own, cannot either.

Now, don't get me wrong, eventually those suffering from cystic fibrosis, or Huntingdon's Chorea, will benefit enormously from identification of the related gene, followed by appropriate modification in cases where it is aberrant: 'gene therapy'. The problem is that if, as may well happen in the future, people try to tweak their genes to make them better people, then they will not be selectively targeting a particular behaviour or trait.

Not only will we benefit from treating single gene disorders, but also we'll have to face up to the more ethically dubious aspirations of genetic screening, where insurance companies could increase your premium if your genetic read-out was less than ideal. Then there is the terrible prospect of eugenics, -of the 'virtual child' assembled out of a ranges of different gene options as well the more immediate prospect of a 'designer child', where the genes that are already about to swing into action are swapped or suppressed to give the desired physical and mental end product.

Already, only recently, have we heard about the option for high-risk parents to decide whether or not to terminate a pregnancy on the results of a genetic screen for single gene disorders. This issue in itself seems humane, but already we are entering shaky ground. In the case of the single gene disorder, Huntingdon's chorea, for example, the movement impairments do not usually set in until middle age. So is there not the risk of

starting to prescribe only perfect individuals, destined to live a long and perfect life? I for one can see no obvious way of distinguishing between an acceptable disease and an unacceptable one, no Rubicon between a physical or mental trait which is merely undesirable, and one that threatens physical or mental well-being, and therefore potentially justifies something drastic - like gene therapy - being done about it.

When it comes to complex personality traits, not only are futuristic scenarios of cherry-picking genes chilling, they actually rest, as far as the brain is concerned, on the mistaken premise that a gene, a strand of DNA can somehow have a complex behaviour or character trait locked into it. So our brains may be under threat by dissection of genes and targeting of genes for certain improved traits.

When it comes to the brain, there is very little one to one mapping of gene to final function or dysfunction. Most disorders are not attributable to a single gene, -for Alzheimer's disease for example, already at least 6 genes or so have been implicated. Conversely, any one gene would not in itself express the final product, an illness, but rather a chemical that in turn, could indirectly, affect that illness. The point I wish to make is that the gene is only one factor in brain function. The substances, the proteins that they cause to be made, will in turn play their part in a nested hierarchy of increasing complexity from parts of brain cell, to the whole cell, to circuits of cells, to brain region, to diverse

operations that in turn eventually play a part in some aspect of a clear function, like memory. In ways that neuroscientists still do not really understand, the working of the whole brain is somehow more than the sum of these different parts.

Another important reason to be cautious here, is that you only have at most a million genes. In contrast, the brain consists of a hundred billion brain cells, - as many trees as there is in the Amazon rain forest. Even more mind-boggling still are the connections that enable these cells to network with each other- an estimated hundred trillion. The configuration of these connections, and their respective efficacy, will be unique to each individual. Even if every single gene in your body was responsible for the configuration of a brain connection, there would still not be enough genes, - by a factor of some 100 million. What controls the formation then, of the connections in our brain?

No less than our own experiences.

If you were a goldfish, it could easily be your genes which give a clear genetic blueprint to the brain, so that a normal interaction with the environment would lead to a fairly predictable fishy lifestyle. But then again, one goldfish does not have an enormously developed personality: imagine your child had a pet goldfish and the goldfish were to die, a swift substitution at the pet shop while the child slept, might well fool them into thinking that the now demised Goldie still lived. No such swap could of course

be made with cat or a dog, and would be inconceivable with one of their siblings,- as much as they might relish the prospect. And that is because we are so much the products of our own experiences. Even clones, identical twins, have their own minds.

So it all boils down to the configuration of connections between our brain cells: what makes these connections unique and freed up from the tyranny of our genes? In humans, many of the connections between our brain cells grow after we are born, influenced by experience. It is this shift in emphasis from Nature to Nurture that makes us so individual,- because we all have unique experiences. The human brain is par excellence a system that adapts, that learns from experience rather than obeying a genetic imperative,- instinct. That is why we occupy more ecological niches than any other species on the planet.

And that is why our human brains have not changed for 50,000 years. They haven't needed to. They are so good at adapting. Just as we are different people from those born in other climates or cultures today, so we are indeed very different people to our ancestors who stalked and staggered on the savannah. And even when we've learnt a particular lifestyle, learnt to live in a certain way in a certain place, our brain connections still continue to change.

True, by the time we are grown up, we like to think we are clear-cut as individuals, with what we call a 'mind of our own'. But

nothing could be further from the truth. Certainly in my case in the early 1970s someone would have told me I would end up a scientist, I would have laughed in their face.

And I bet you would have a similar, though different story. Look back and ask yourself whether you're the same person as ten years ago, or five years ago, or six months ago. None of us is. Remember it was an issue whether the 20 year old or 40 year old you would be downloaded on to a CD. There is some kind of consistent theme to 'you', but you are evolving all the time. Think of a room, bare at the beginning of a tenancy: it could be the same as other rooms, identical. Within a short time however, a style is imposed. At the start this choice of style is most conspicuous,- but the room will still evolve with time, as fashions or accidents change or as the occupant modifies their activities, as the demands shift of their way of life. So although our brains, more precisely our brain connections, are most dramatically influenced by early experience,- they are always slowly developing, constantly shifting and adapting in the light of what happens.

Let me tell you a personal story. In 1991, my own father suffered a stroke. For a few days he was confused and disorientated; when we, his immediate family visited him in hospital, the prospect of him ever being able to come back home seemed remote. A few weeks later however, he was indeed home and has now had his driving licence back for several years. As a present for his 82nd birthday, he went on a helicopter trip and only

a few weeks ago, he is now 84,- he was saying how much he would like to try bungee jumping. In short, my father is back to normal: groups of brain cells that survived the stroke have taken over from those that did not.

Our brain connections are in a constant, restless state, reflecting our individual experiences. It's a jungle in there: your brain operates on a ruthless 'use it or lose it' principle, and this is very precisely mirrored throughout your life in the growth of connections between brain cells.

It is this growth of connections that I call a 'mind'. A mind therefore would be the personalisation of the brain, not some airy-fairy alternative to the physical sludgy brain; not something beamed-in from some outer planet or different dimension: but quite simply the physical process by which the world is uniquely interpreted for you. Your mind is the best definition of you.

So what would happen to the unique 'you', if from an early age you had had exactly the same experiences as a lot of other people? Imagine a world where we hired a Virtual Reality cassette, a day of life from the local store. If the same days of life were available to everyone, thereby for the first time giving them the same experiences, -might we end up more standardised, with less of a 'mind of our own'? Just like Huxley envisaged in Brave New World, where each person belonged to a clear social

categories of society, each with their own level of abilities and therefore standardised way of thought.

Even today, the plasticity of the brain and the concept of the individual, can lead to some interesting complications. For example and most topically, the case of the Jamie Bulger killers, Robert Thompson and Jon Venables, now both 17: there is currently a controversy as to whether they should continue to be punished. Some might argue that they were very different people six years ago, at the time of the crime, and that they will suffer from their custodial environment in the future. It's an interesting idea as to what extent one should stay accountable and remain the 'same person', -despite what we know about the constantly shifting neuron connections in the brain. There is, I think, a useful debate to be had between lawyers and neuroscientists about personal identity and responsibility.

And we could go further still. Just think about other potentially criminal scenarios,- for example the crime passionnelle in France or, indeed, nearer to home, the outbreak of road rage and, indeed, air rage. Here the issue is not just that you have 'changed your mind' but that you have temporarily at least 'lost your mind'. You are back to being a small child again, at the mercy of the moment.

My own view is this: above and beyond the brain cells and the so-called 'hard-wired' connections of brain cell circuits that

gradually evolve as we grow and interact with the environment, there is also a further, distinct property of the brain, - a property that is changing all the time, from one moment to the next. This property is your consciousness. The subjective feel of the experience you are having at this very moment. I would like to suggest that this consciousness comes in degrees. After all, let's face it, we can have different states, - we can be highly reflective and meditative, locked away in our own minds, looking back to the past, or the future, where there are many associations predicated on others.

In contrast, the modest degree of consciousness of an infant, would be associated with relatively few connections operational. However as our minds grow, then more and more connections would be pressed in to service, -and we would have a deeper consciousness, -eventually even self consciousness.

A mind stops us taking the world at face value. If you go along with the 'scientific' idea of a mind I have suggested tonight, then it is easy to see how we might gradually develop a two-way dialogue between brain and the outside world. We can gradually see a meaning in things and people around us, beyond the mere physical properties that have always stimulated our senses. The more we use our minds, the less we are at the mercy of the thrills and spills of the outside world.

But when we've 'lost' or 'blown' our minds, the outside world dominates once again: we are no longer accessing our individualised configurations of connections, but have become the passive recipients once more of our abstract sensations, -blurs, colours, sounds and smells bombarding us. We are once more, in the heat of the moment, purely feeling entities, not thinking ones.

It seems to me that we might be getting nearer than in identifying how different states in the physical brain match up with, - correlate, - with different types of consciousness. But exactly how one causes the other, -how the brain generates consciousness, is one of the big challenges to neuroscience in the next century.

Nonetheless, a more immediate, and still intriguing issue here, is that our adult state can be abandoned for while. Think of an example when you might expect to 'lose your mind', 'blow your mind', or be 'out of your mind' with joy or sorrow. You might enter into such states through chemical manipulation, - with drugs both prescribed or proscribed; or you could put yourself into a very fast changing environment such as that of white-water rafting or downhill skiing and, yes Dad, bungee jumping.

It is in these mindless moments of strong sensory stimulation that are sometimes pleasurable, - sometimes not, - but which are certainly always emotional. At these times we no longer access the past or imagine the future: we feel 'at one' with other people. Now we are completely passive and in the present moment.

Indeed whether chemically aided or otherwise, one is in ecstasy - literally standing outside of oneself. I'm suggesting that the more we are experiencing a strong sensual sensational moment, the more we are likely describe that experience as an 'emotion' and the more we relinquish, just for the moment, our individuality: we are no longer accessing our minds.

One way that this might happen in the future, might be with an increasingly powerful IT. Think about the strong stimulation of our eyes and ears as we stare at the rapidly changing images on the screen, conjured up by the mere press of a button. Might we lose the skill of abandoning the throb of the outside world, to retreat into our own world, our own imagination? Might we become such sensationalist junkies that children of the future will no longer be able to turn an old box into a car or castle, or listen to the mere words of a fairy story?

It is this scenario, where with, more thrilling multi-media, more promiscuous use and availability of drugs, and hence more dramatic stimulation of our senses that might be awaiting us in the coming century. Hence the title of this lecture: the future could be just too much fun. If facts on their own, however thick and furious they tumble from the silicon, are literally meaning-less without the ability to use imagination, and translate them into a body of knowledge, - and if our abilities to develop and use our own minds have declined, -then the only recourse might be to stay on the sensual kicks of the moment.

We might be indeed set on a course where eventually we will be purely hedonistic, following in the wake of the jaded celebrities and weary wealthy who die in an attempt,- either on purpose or through circumstance,- to pursue a life of out and out emotion: -a life of unadulterated fun. But surely I'm being a crabby old Calvinist - why for most of us, is living for the moment so bad? Surely a world of drugs and sex and rock and roll, wine women and song, is what human beings have always craved.

But that is the point, 'human nature' seems to need something more. Look at the mega rich who could spend their days sipping cocktails on a yacht, but are still chasing power and recognition with all the hard work and vicissitudes that entails. Throughout civilisation, human beings have always wanted to be more than just comfortable and excited. They have wanted, it seems to become individuals, to have a sense of self, and self-worth.

I am not saying that we should never abandon ourselves to a passive, sensual experience; of course it is marvellous to let yourself go, literally: but there must be a self there in the first place in order for this 'letting go' occasionally to not become a bewildering and boring experience. We face a future that might standardise the individual, not just genetically with nature, but also perhaps with nurture, -the standardised day of VR living distributed to all.

I would call for the importance to be recognised of occasional reading of low-tech books in an education increasingly dominated by multi-media,- whereby by virtue of the non-sensational written word alone, one can escape into the medieval bazaar or the Victorian drawing room: it is a fascinating feat of neurophysiology yet one that we all take for granted, redolent of listening, for example, to the radio, where your imagination can fill in so much more than literal pictures can - hence the inevitable complaint that the book is always better than the film.

I would like to see more education on the actions of drugs, of what genes really are and how they relate to brain function. Indeed, call me biased, but it would be wonderful if the A level syllabus, instead of shying away from the brain as a difficult subject, included some of the most basic facts in the syllabus. I would call for more funds and encouragement for truly innovative research into the really big questions, such as the physical basis of consciousness.

Already we are allegedly spending more money on leisure pursuits than anything else, even food. We are facing a time when there will certainly be an increase in the ageing population: one in three of us will be over the age of 60 by the year 2025. Surely this means that most of us at some stage of our lives at least, we will be squaring up to great chunks of free time, whether willingly or not. So, we come back to the old question, the one I raised at the

start of this talk, and one that I predict will be asked increasingly in the future: 'What am I doing with my life?'

I would love to have a few days to try out the mindless life, where the extent of my working brain connections was reduced to the sensual thrill of eating and shopping, of lounging in a leisurely bubble bath, and of spending the rest of the time dosing in the sun. But then what?

Imagine a perpetual existence in a bubble bath. What if there was really no choice, no alternative at all? The idea of *carpe diem* of 'grabbing the day', 'living for the moment' as the ideal is, of course, not a new one. But the problem with the future might well be that it is realised, -that we end up being lured permanently into a perpetual present where, if what I have suggested is true, we abrogate our individuality.

I hope that, as a scientist, I have convinced you this evening that, we may well be a breed that wears white coats, and spends our lives on specialised - not to say incomprehensible - technical matters. But we also care as much or more as anyone else about the implications of what we are doing. It always angers me when people I meet react dismissively: 'that's far too complicated for me to understand,' together with a hint of disapproval, that we are somehow responsible for all the ills of the modern world. Scientists alone cannot carry the conscience of the world.

As an intellectual enterprise, science, is neutral. It has never before given each of us the chance to understand so much about the physical basis of our own mind, and yet at the same time, such a diverse and powerful range of means, be they carbon or silicon, to blow it. The choice is up to all of us.