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The Human Genome Project: Tool of Atheistic Reductionism or Embodiment of the Christian Mandate to Heal?[1]

Let me begin by saying a brief word about my own spiritual path. I did not come from a strongly Christian home. I was raised in a home where faith was not considered particularly relevant, sent to church to learn music, but instructed that it would be best to avoid the theology. I followed those instructions well and went off to college with only the dimmest idea of what saving faith in Jesus Christ was all about. What little glimmers of faith I might have possessed were quickly destroyed by the penetrating questions of my freshmen dorm colleagues who, as one will do at that phase in life, took great delight in destroying any remnants of superstition, which is what they considered faith to be. I went on to study chemistry and physics, and then to do a Ph.D. in chemical physics, and became quite an obnoxious atheist with whom you would not have enjoyed having lunch, because I too felt it was part of my mission to point out that all that really mattered could be discerned by science and everything else was irrelevant. And then, somewhat troubled by my own discovery that chemical physics didn't suit me as well as I thought, I went off to medical school to try to learn some other skills and to keep my options open, being in somewhat of a disarray about how I wanted to spend my life. Only several years after that, as a medical resident, watching people with terrible illnesses struggle with those challenges, I began to wonder how it was that some of the people I encountered seemed to derive such strength from something which I viewed as nothing more than superstition. I realised that though I had spent much of my life trying to discern truth, using the tools of science, I'd never really considered the evidence for the truth of faith. Fortunately through the guidance of some very patient people, who tolerated a lot of insolent questions, I was led to read C.S. Lewis and then the Bible, and so was led to understand many of the concepts that had completely eluded me before, and gave my life to Christ 20 years ago.

That, I think, was an interesting bit of timing, because by then I had already made a decision that the field that I wanted to pursue was genetics. I often wonder, had I been a committed Christian before that decision of a sub-specialty

1 This article is an edited version of a lecture given on 3 August 1998 at Churchill College, Cambridge, at the conference 'Science & Christianity: Into the New Millennium' jointly organised by the *American Scientific Affiliation* and *Christians in Science*. Since this research area is moving very rapidly, information has been up-dated only to June 1999.

choice, would I have chosen differently, given that genetics presents us with so many challenges in terms of the appropriate application of discoveries. But I do believe that God has put me in this position for some reason.

So that's my background. I came to the National Institutes of Health (NIH) 5 years ago, after James Watson, who of course, a rather famous person in Cambridge, resigned as the head of the Human Genome Project in the United States after a big row with the head of the NIH over patenting of DNA. I, least of all people, expected to be chosen to take on that task and to step into his shoes. But there I was. It has been a remarkable experience to stand at the helm of the U.S. Human Genome Project and to watch it grow and move forward in a way that has outstripped even the most ambitious expectations. I take no particular personal credit for that, but it is a wonderful experience to work with such a committed, dedicated group of scientists who are involved in this effort around the world.

So in this address I would like to cover three areas. First of all, what are the goals of the Human Genome Project and where are we now? Secondly, where are we going in the near, and the perhaps not so near future? And thirdly, what are the major consequences for humanity of this project and what can we, as scientist-Christians do about it?

The Current Status of the Human Genome Project

Of course, we are here in Cambridge. Watson and Crick's Nature paper on the double-helix, published in 1953, could be said to have started the notion of a Genome Project. It was perhaps a natural step to contemplate determining the sequence of that DNA for an organism, even humans, and in fact, that's what we are now engaged in. There are 3 billion base pairs in the Human Genome, and of course, they are a rather simple 4-letter code which makes up that instruction book. Those 3 billion base pairs include an estimated 60-80,000 genes, each one of which carries out a particular instruction, although increasingly we are learning that many genes have more than one function. This is actually a remarkably economical system, isn't it? The notion that you could carry out all the biological properties of a human being from a mere 60-80,000 genes is rather astounding to me, even now. If I had had to predict that, I would have guessed a much larger number, and I suspect you would too. Again, an occasion to appreciate the elegance of creation.

The Genome Project began in 1990 and is international in scope, involving many efforts around the world, and particularly right down the road here in Hinxton Hall, the Sanger Centre. There are also significant contributions from Germany, Japan, France, Canada, and a few other countries. But about two-thirds of the effort is currently contributed by the United States, guided by a series of goals aimed at trying to understand medicine. None of us can claim genetic perfection – we are all walking around with glitches in various genes, that place us at risk for something. A few of those are almost certain to come to pass; most of them, however, are not. They are relative risks and they may only come to pass if they interact with some other genetic predisposition, or the environment,

or importantly, we make a choice of our own free will to do something which causes these genetic predispositions to come back to haunt us. By the way, I worry a lot when we make statements about disease risk. We talk about the hereditary component and the environmental component as if that is all there is. Let us not forget free will. Some scientists seem to be embarked upon the notion of getting rid of that. We as Christians should resist that with our last breath.

The goals of the Genome Project for human DNA are rather simple. As planned by scientists in about 1988/9, the goals of the project were to obtain genetic maps and physical maps and the DNA sequence of human beings, with sequence data from several model organisms being derived at the same time to try to better interpret the results obtained from humans. Without going into the details of how you build these maps, perhaps the best way to explain them is to tell you how they are currently used. Already the products of the Human Genome Project have greatly accelerated the efforts to discover genes that cause human disease. Let me give you an example which will illustrate how genetic maps and physical maps, and ultimately the sequence, can be used in understanding a human disease.

When I was a resident in medicine, I was already interested in genetics and I asked one of my learned professors, 'Can you tell me of a disease that doesn't have a hereditary component?' And his immediate answer was 'Parkinson's Disease – everybody knows that that's a disease which comes about sporadically, doesn't cluster in families, and has no hereditary contribution'. Well, he had not heard of a large family in Italy and the U.S., where Parkinson's Disease is being inherited in what appears to be a dominant fashion, passed from generation to generation, with a 50/50 risk to the offspring of the affected individual. This is something a geneticist would have little doubt, must be caused by a single mutant gene. So is this in fact Parkinson's Disease? Well, from every appearance, it seems to be. It has the same clinical features, it has the same response to drug therapy, namely L-Dopa; importantly, at autopsy it has the same inclusion bodies in the neurons of the *substantia nigra* called Lewy bodies, which are the hallmark of the disease. There are two unusual aspects about this family. One is, that there are so many affected individuals, and the other is that their age of onset is quite young, in their 40s and 50s as opposed to the usual 60s-80s onset of this disease. But to a geneticist this ought to be a way to obtain insight into a disease which has been completely obscure as far as causation. We know a little bit about the 'what' of Parkinson's Disease; we know very little about the 'why.' So DNA samples were collected from this family and using a genetic map produced by the Genome Project with about 10-fold greater detail than the map previously available, it took a mere 9 days for investigators at the NIH to map the gene in that family to chromosome 4, simply by using a collection of markers which vary from individual to individual and allow you to track inheritance in a family. They were able to show that markers in this part of chromosome 4 actually predicted in this family who got Parkinson's Disease and who did not. This can only happen if the markers are close to the gene. And this took 9 days.

By way of comparison, I had the good fortune in the 1980's to lead one of the groups that worked together to find the Cystic Fibrosis gene. It took us 5 years to

progress from having a family's collected DNA samples to locating the gene on chromosome 7. The recent telescoping of the time table is truly gratifying, because it's not particularly amusing to spend year after year going through this process. It's far more rewarding to just get that step over with, and move into the area of interest.

Now, of course, this doesn't end the story. You know the gene is somewhere there on chromosome 4, but you'd like to have the actual gene. For this purpose, the physical maps come into play. You want to be able to study that piece of DNA where you know the gene is and, ideally, you would like to know the location of all the genes in that stretch of DNA, their sequence, and some idea of their function, so that you can assess the candidate list of genes and ask: 'Is there one here that, if mutated, might cause this disease?' Well, we are coming very close to that goal. We do now have physical maps, collections of overlapping cloned fragments of DNA for 99% of the human genome. So the physical maps are essentially complete and can be accessed through the NIH home page [http://www.nhgri.nih.gov]. And on this map, roughly half of the human genes have been placed in their proper location. And so you could go to chromosome 4, click on this region of the chromosome and see what genes have been mapped there, and then assess whether one is a possible candidate for the disease. In fact the Parkinson's Disease investigators carried out exactly this process and found that a gene called a-synuclein harboured a very subtle change – an 'A' instead of a 'G' in the coding region of this gene, which appeared in all the affected individuals with Parkinson's Disease, but never in DNA taken from healthy individuals. Further work has established that this mutant gene is clearly the cause of Parkinson's Disease in the large family. As many times as I look at it, I am always astonished that a single base in a vulnerable position, out of 3 billion bases, is capable of creating such havoc and human misery. So, somehow changing that alanine to a threonine, which is the coding consequence for the protein product, produces a protein which is unstable, leading to deposits in the Lewy bodies, causing neurons to die and ending up resulting in the progressive neurodegenerative disease we call Parkinson's disease.

Interestingly, while this is a rare cause of Parkinson's disease, we now know that this same protein, synuclein, deposits in the brains of virtually everybody with Parkinson's, presumably from some other cause that makes it unstable, which is not due to a mutation in the gene encoding the protein. So, we have found our way through the genetic approach into a common pathway for this dreadful disease. And that, it seems to me, is very good news because it provides many new ideas about preventive therapies that would not have occurred to us if we did not have this molecular insight.

So, all this was facilitated by the genetic and physical maps. It would have been even quicker if we had finished the human genome sequence by now, obtaining the position of every single A, C and G and T in the DNA. That would have saved a good deal of time, and we are on that path, but of course the sequence is the hardest part and the part that had to wait until the maps were done, and the part where the technology was not really up to the task eight

years ago when this project began. We have therefore been 'practising' on a series of genomes of model organisms which are of enormous benefit to the research community, since so much is already known about their biochemistry and physiology. Therefore the DNA sequences of the bacterium *E. Coli*, of yeast, and of the nematode worm *C. elegans* are now completed. The DNA sequence of the *Drosophila* fruit-fly will be completed soon. In contrast the mouse has a genome as big as the human's, and will not therefore be completed until 2005, or sooner if possible.

Now how are we doing on completing the human DNA sequence? As of now we have reached about 600 million base pairs of total sequencing output which represents about 20% of the total. Recently we have projected finishing a 'working draft' of the human genome by the Spring of 2000, and the finished sequence by 2002 or 2003.

Various standards have been established for the quality control of these sequence data. First, it needs to be accurate. You don't want to have to go back and correct all the mistakes later, so the error rate is supposed to be 10^{-4} or better. The sequences also need to be assembled in the correct order, you don't want pieces of DNA that are homeless islands. Like sentences in a book, they will only make sense if placed in their correct context. Also sequencing must be affordable. The sequence cannot be afforded at a cost over 50 cents a base and it would be a lot better if it was 20 cents or 10 cents. Right now the cost is about 35 cents per base. Finally the sequence needs to be accessible – it is of no value if people cannot use it, and many of us feel rather passionately it needs to be accessible without any strings attached, that this is the kind of information to which every scientist should have free access.

So in summary, the genetic maps are done, the physical maps are done, DNA sequencing should be 100% complete by 2003. All of these rapid advances should be welcomed.

Where Are We Going?

Occasionally I have students come to me saying, 'You know I'm still in training, you guys are going to have the Genome Project done before I've really finished my post-doc, will there be anything interesting left to do?' Well, yes, actually, that's when the fun begins! Because even though the Genome Project, in my view, is perhaps the most significant scientific undertaking of an organised sort that we have mounted as human beings, providing, as it does, an ability to read our own instruction book – it is still necessary to put this in context. Basically what we are doing is building the periodic table of the elements for biology. The periodic table for human biology has 60–80,000 entries, the human genes. Each of those have isotopes, the variants in those genes, some of which play a role in health and disease. Variants are all around us – 0.1% of my DNA is different from your's, and a small part of that 0.1% accounts for the fact that we are different people, and an even smaller part of that accounts for the fact that I am at risk for some diseases and you are at risk for others. But the variable part is

obviously very interesting. The isotopes need to be understood and we are only just beginning. I think this analogy helps a lot in putting the Genome Project in context. Did chemistry end with Mendeleyev? No – you could say it began. But that organising principle allowed then the full flowering of the understanding of how the elements can combine together to do interesting things, and the same will be true of the 60–80,000 (we do not yet know the actual number) human genes that must interact together in some remarkable way to account for human development, all of the normal, remarkable homeostatic mechanisms of the human body, the development of the brain, etc. To understand those things will occupy us for decades, in fact I would say centuries.

So what are the consequences of the Human Genome Project for medicine? The futuristic vision is actually already here in part, and that is the application of these gene discoveries in making predictions about risk factors for human diseases. In some instances that information is deeply needed and anxiously sought after by individuals in certain families. Figure 1 illustrates this point. It shows a family tree. You can see this family has been haunted by cancer, particularly breast cancer [BrCa], at an early age [individuals with cancer are shadowed, followed by age of onset]. Recently a woman from this family came into the clinic seeking advice. She had just learned of her sister's diagnosis with breast cancer at age 37 [BrCa 37] and was also aware of her aunt's diagnosis of cancer, although her aunt was long since dead, and of her mother's diagnosis of ovarian cancer [OvCa 46], which took her life in her 40's. She wanted to know, 'What does this mean for me? And what does it mean for my daughter?' Ten years ago we would have had relatively little to say in this circumstance other than the fact that this did look like something that might be hereditary. All that has changed. This is a family which would now be recognised by medical geneticists as being highly likely to fall into the 10% of breast cancer patients in which a mutation in the genes called BRCA1 or BRCA2 is the most likely explanation. But how to be sure? If you really want to offer additional information to this family, you might consider offering them a molecular diagnostic test, to look at BRCA1 and BRCA2 and find if there is in fact a mutation in one of these genes. That's not trivial. In fact, such a test is now commercially available, but it costs $2,500 in the United States and many third parties won't pay for it, and so little of this is being done.

But now all that is changing. The technology for doing DNA testing is advancing with lightning speed. In a recent project carried out by a post-doc in my lab, DNA chips were used to test that woman with breast cancer aged 37, to see whether her BRCA1 gene is normal or not. A DNA chip is a piece of silicon onto which single-stranded molecules of DNA have been synthesised, using light-mediated photo chemistry. You can put any DNA sequence you want on this chip, and you can put an enormous density of such molecules, up to a quarter of a million of them, on a chip the size of a postage stamp. The chip can then be used as a detector to screen any DNA-containing biological sample you want, to determine what sequences are present by using the remarkable attributes of molecular hybridisation. Using the chip, we found she has a 'T' instead of a 'C' in position 2457 in the nucleotide sequence. That is a serious mutation because it

creates a 'stop' signal in the translation code and basically inactivates the BRCA1 gene. This point mutation explains why this family has such a high incidence of breast and ovarian cancer. This DNA chip test, once it is brought out into the clinic, after some more tuning of the effort, will probably cost in the neighbourhood of $100 or maybe less, and it can be done over the course of a few hours, as opposed to the current test which takes several weeks. A comparable test can be applied to virtually any gene.

So the technical barriers to offering people large amounts of information about their personal DNA sequence are coming down, and coming down rapidly. So it's appropriate to ask the question: are we ready for that or not?

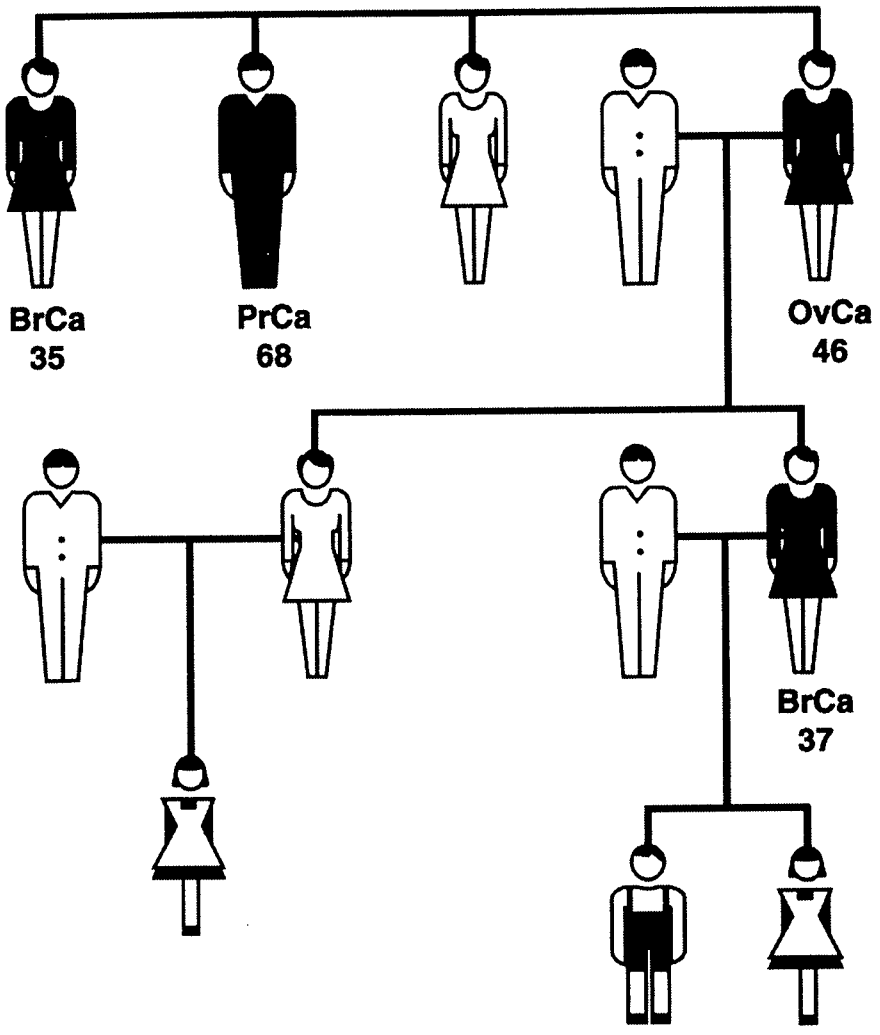

Figure 1

The unaffected woman in the family with cancer already knew from her family history that her chance of carrying a gene predisposing her to cancer was high. But using this new test we can now tell her for sure whether she is carrying the deleterious mutation in the BRCA1 gene or not. She wrestled quite long and hard with whether she really wanted the information or not, for fear that it might be used against her (a point which I will address later). But she eventually decided, particularly because of her concern about her daughter, that she needed to know this information. She was tested and happily found not to have the mutation her sister carried in the BRCA1 gene [Fig. 1]. In one stroke the years of anxiety that she had lived with, thinking that this cloud was over her head, as it had been over her sister's, were taken away. Genetic testing does not always give you bad news. Now, could she still get breast cancer? Of course. Just like all women can. And it is very important that we do not provide assurances based on genetic tests of this sort that in fact they cannot provide. Genetic counsellors have to be very careful in how the results of such tests are conveyed.

We are now moving in the research arena from the search for the cause of single gene disorders, which we are getting pretty good at understanding, towards polygenic conditions, where disease arises from the interactions of multiple genes, but the risk conveyed by any one of them is fairly low. These multigenic disorders include diabetes, hypertension, coronary artery disease, the common cancers and schizophrenia. All of these are now being tackled using these same tools of molecular genetics. We will, over the course of the next 5 or 10 years, uncover the major genetic predispositions to virtually all common illnesses, further increasing the likelihood that we will be able to offer individual tests to assess risk factors. Would you want such a test? You probably can look at your own family history and make some guesses about what your risks might be, but your guesses would be incomplete. Do you want to know that information?

We will soon have access to such information, in large part because the Genome Project has now embarked on a brand new goal. This has not been particularly publicised, but I believe it will be every bit as important, perhaps more so, than the determination of the basic DNA sequence. That goal is to catalogue human variation. We all have a sequence difference about once every 1,000 base pairs, comparing one person to the next; many of those sequence differences are common in the population. It appears likely that predisposition to various illnesses usually arises from such common variants. If we could develop a catalogue of the roughly 10 million common variants in the human genome, we would have a powerful tool to dissect out predispositions. We will discover, probably in the next 3 years, upwards of 400,000 of these common variants in the human genome, focusing particularly on those that are in coding regions and are therefore most likely to have functional significance. Some of these will turn out to be very valuable for predicting not only who's going to get what illness, but if you get the illness, what drug you should be given.

In fact, the diagram of molecular medicine illustrated in Figure 2 helps to integrate the various points considered so far. If you want to understand a disease,

you map the responsible gene and then you clone it. Then you can use that information diagnostically. In some instances, where interventions are available for the person at-risk, this is already a major achievement, because you can warn them of their risk and allow them to take advantage of preventive medicine strategies. Colon cancer is a prime example. Vigilant surveillance in this case may be sufficient to prevent that person's premature death from cancer. But of course, for many diseases, that's not very effective. You can offer people diagnostic information, but you don't have interventions to offer them to solve the problem. There our hope has to be that future research will elucidate how the gene works so that a therapy can be introduced to solve the particular problem. Unfortunately there is going to be a gap between our ability to carry out diagnostic work and our ability to intervene therapeutically for a large number of diseases, at least for the next few years. Living in that gap is going to be an uncomfortable experience for all of us, in which our ability to collect information exceeds our ability to do something about it. I don't know any solution to that. That is a consequence of the way this diagram works, the way that molecular medicine flows from top to bottom.

This, of course, raises the question of how much information people want to know. Interesting words from the Psalmist David here: 'Show me, O Lord, my life's end and the number of my days. Let me know how fleeting is my life.' [Ps.39:4]. Is that something which most of us want to know? I think many people are mixed in their feelings. The closer you get to offering them real information, the more uneasy people become about whether they want the information or not. Clearly, in most instances, the information that's most appealing is the kind that allows some intervention, whether it's a change in lifestyle or medical surveillance, or diet, or something else which allows the risk to be reduced. If no such interventions are available, many people are less

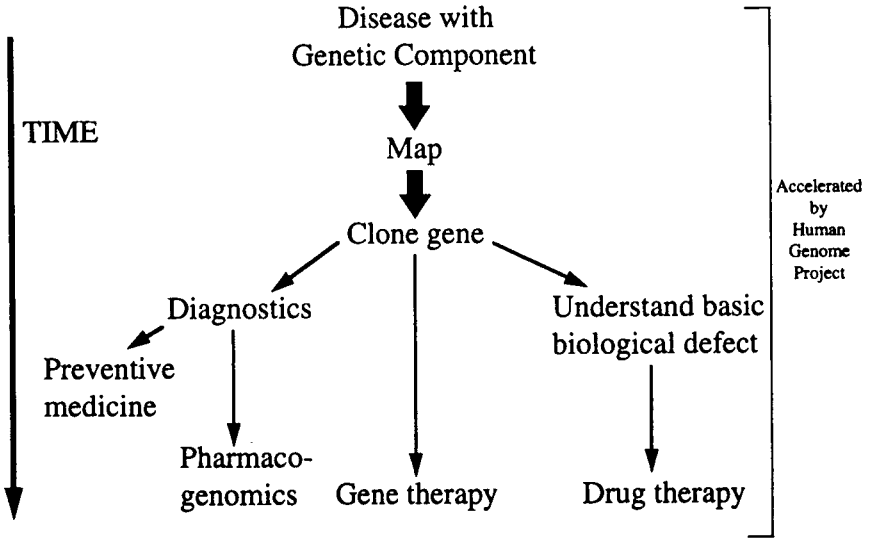

Figure 2

interested. You can imagine a time in about ten years where the average young adult going in to see their physician for a check-up, may be offered the opportunity to undergo 30 or 40 different tests that can indicate their predisposition to particular illnesses. This is not science fiction. This is something which is potentially possible. But what does it mean to say your relative risk is 4 times the average or that you have a 20 percent lifetime risk? Health care providers are not particularly good at conveying this quantitative information. And patients are not particularly good at absorbing it. We have a real challenge to work out how to properly use this information in a clinical setting.

Consequences of the Human Genome Project

Let me conclude now with a final question – What are the major consequences for humanity of the Human Genome Project? The consequences extend beyond medicine to many other aspects of humanity. What can we, as scientist-Christians, do to try to improve the likelihood of a happy outcome? I'll ask you five questions, though I'm not sure I know the answers to any of these.

First, will we successfully shepherd new genetic tests from research into clinical practice? Many tests are being developed by private companies who have a desire to make money, so will we see these tests introduced too soon before we know what they mean? And will the results in the process do damage to unwitting and unsuspecting individuals because, in America at least, laboratory diagnostics have become big business and at the moment there is no effective mechanism for overseeing the introduction of new tests? Knowledge is power. Knowledge heals. But knowledge can also be toxic in some instances. If you're given information about yourself or your child that is profoundly troubling and that turns out to be wrong, that is certainly not a desirable outcome. We need to have better oversight of this system.

Second, will we solve the problems of genetic discrimination? As I said at the beginning, we all have glitches in our DNA, but some of us will be finding out sooner than others what our glitches are. Health insurance companies in the United States are delighted to get access to that information so that they can exclude from coverage those that they presume to have a higher risk. I think that is morally offensive. We do not have the alternative of choosing our DNA sequences. They are something we are born with, and to have that information used against a currently healthy person to deny them access to health care seems both illogical and immoral. This principle applies also to employment, and to a variety of other situations. In fact legislative efforts are underway to take care of such problems, but in the U.S. they have not yet succeeded, and we need to make sure that they do succeed.

Third, a further major problem for the Genome Project is to determine how to educate the public and providers to be adequate consumers of this new brand of medicine. We are a long way from that goal. Many physicians are poorly trained in genetics, and yet they're going to be asked to be sophisticated genetic counsellors of the future. The public is in no better shape.

The final questions are the toughest of all. Will we arrive at a consensus about the limits of genetic technology for trait enhancement? I think all of us, as scientists and Christians, take seriously the mandate to be healers. Jesus Christ, who lived such a short time on this earth, spent much of it healing the sick. I don't believe that was an accident. I believe He intended to model for us what one of our roles must be as Christians, and that is to reach out to the suffering and attempt to alleviate that suffering. In that regard it seems to me that not to pursue genetic research would be the most unethical position of all, because in so doing we would doom many individuals, including perhaps ourselves, to the absence of an intervention that's needed to alleviate the suffering that lies ahead.

Yet there is no sharp line between what we call a disease and what we call a trait. It's easy with a severe disease to know what you're talking about. But what about obesity? What about hyperactivity in children? What about some of the personality disorders, which are increasingly subjected to a reductionist view, but which make human beings more diverse, more interesting. What about manic-depressive illness? Should we wipe that disease out if we know how? In the process we might wipe out a significant number of creative individuals who have contributed to art, music and literature over the course of the last several centuries. Where is the line here? This is, I think, the most difficult debate, a debate that we have not effectively faced so far. It's a debate which can only proceed if you are grounded in some principles. We as Christians are fortunate to be so grounded. Many others are finding themselves without an anchor, and we have a real role to play here as the debate intensifies.

The final question is whether our remarkable sense of accomplishment at being able to read our own instruction book will lead people to conclude that that's all there is? If you don't think that's happening, you must not be reading the things on the newsstand. Recently the cover of 'Life' magazine proclaimed 'Were you born that way? Personality, temperament, even life choices—new studies show it's mostly in your genes.' False. The data do not really support that, and yet the public thinks that because the story makes the cover of 'Life' magazine it must be true. How about the headline in 'USA Today' stating that your genetic constitution determines your 'Real Key to Happiness'. No, it's not a relationship with Jesus Christ, it's not reconciliation with your family, it's not seeking a goal in life and reaching it, but simply whether you inherited those happy genes or not. The data to support this, by the way, are completely non-existent, but it made a nice story in 'USA Today.'

A serious article in a Christian journal recently asked the question, 'Is it Possible that Some of Us Have Inherited a Predisposition Toward Spirituality?' And that's why we're in church on Sunday morning and some of our friends are not? Again, I find this deeply disturbing. There are quite possibly genetic predispositions to certain aspects of human behaviour – we know that from identical twin studies. But that is a small fraction of the total picture. Much of our behaviour, in fact, is shaped by other factors and particularly by our own free will. I was moved by last night's sermon in the service we went to, which reminded us that

even Christ, faced with His own crucifixion, struggled with His free will to decide the proper course of action. We also have that free will. We choose to use it in certain ways, often in ways that we later regret, biology will not take that away. But all too often, it seems, our society and the popular press are willing to write it off.

Well, what then should we as Christians say about the study of the human genome? First, we can and should experience astonishment at the elegance and beauty of the genome. Second, we must study the genome if we believe in the mandate to heal. Third, we can study it without ascribing divine powers to it. It is possible to do that. And we must be certain that we of all people are making that point. More specifically what can scientist-Christians do to facilitate the proper traversal of this very important time in our history?

First and always, we can pray earnestly for a resurgence of faith in the scientific and medical communities, without which it is difficult for me to see how we're going to negotiate these troubled waters. I'm happy to see that such a resurgence of interest in spirituality is occurring in the medical community, but much less is apparent in the basic science community. And that needs to be a fervent topic of our prayer.

Second, as 1 Peter 3:15 exhorts, we must ourselves be prepared and willing to make a reasoned presentation of our faith, especially to young scientists, who have all too often concluded that a serious faith in a personal God and objective pursuit of scientific truth are incompatible. We know that not to be true, and yet most young scientists have never heard those arguments.

Third, through our actions and writings and scientific work, we must be unassailable in our scientific rigour, and our objectivity. The cause of Christian faith is not served by sloppiness or mediocrity in our scientific work. In fact, I would venture to say, and it breaks my heart to say so, that more damage has been done to the image of Christian faith amongst our non-believer colleagues by the extreme views of the young earth creationist movement than by any other group, despite their sincerity. Those who encounter those views, and assume that to be a Christian you must accept them, find it very easy to walk away.

And fourth, we must be willing to spend time ourselves on the social consequences of genetic science, based on our expertise, both in faith and in science. We have a lot to offer, in our academic environments, in our communities, and the political process, and we should not, and must not, shy away from that responsibility.

So, am I fearful about the future? No, actually, I'm not. Since we're here in Churchill College, I'll quote Churchill for you. He wasn't talking about DNA, because he didn't know so much about that, he was talking about another frightening aspect of science in his day—that of understanding the nucleus and the atom. 'Science,' he says, 'which now offers us a golden age with one hand, offers at the same time with the other the doom of all that we have built up inch

by inch since the Stone Age and the dawn of any human annals.' One could say that about genetic engineering, I suppose. But Churchill responds, 'My faith is in the high progressive destiny of man. I do not believe we are to be flung back into abysmal darkness by those fearsome discoveries, which human genius has made. Let us make sure that they are servants, but not our masters.'

My final quote for you, which is from another scientist, and which could well be the motto of the *American Scientific Affiliation* and *Christians in Science*, is a wonderful quote from a scientist, namely Copernicus, arguing for the value of knowledge. 'To know the mighty works of God, to comprehend His wisdom and majesty and power, to appreciate in degree the wonderful working of His laws, surely all this must be a pleasing and acceptable mode of worship to the Most High, to whom ignorance cannot be more grateful than knowledge.'

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Science and Christianity: into the new millennium

(CiS/ASA conference held during 2-5 August 1998)

Audio tapes of most of the talks are available.

tape	talk(s)
S5/1	Oliver Barclay: God and nature Sam Berry: The fall
M1/1	Francis Collins: The human genome project
M1/2	discussion after talk by Francis Collins Gareth Jones: The human embryo
M1/3	Donald Bruce: Ewe, me and God
M2/1	Pattle Pun: Towards an ethic of the human genome project Nancy Hopkins: Science and the Urban African-American Church Dormer and Kinoti: Science and development in developing countries
M3/1	Michael Poole: Explaining or explaining away? Richard Bell: The subject-object relationship in theology and physics Cook and Bestman: Neo-Lamarckian thought ... (start of talk)
M3/2	Cook and Bestman: Neo-Lamarckian thought ... (talk continued) Denis Lamoureux: The Phillip E Johnson phenomenon
M5/1	Colin Humphreys: The number of people in the exodus from Egypt Richard Ruble: Mr Oddity and science Donald Kobe: Copernicus and Martin Luther (start of talk)
M5/2	Donald Kobe: Copernicus and Martin Luther (talk continued) Michael Corey: Supernatural agency and modern scientific method
T1/1	Charles Harper: The portraits of human nature project Warren Brown: Introduction to this symposium Elving Anderson: A genetic view of human nature Malcolm Jeeves: Brain, mind and behaviour (start of talk)
T1/2	Malcolm Jeeves: Brain, mind and behaviour (talk continued) Warren Brown: Cognitive contributions to soul
T2/1	Nancey Murphy: Non-reductive physicalism Joel Green: Monism and the nature of humans in Scripture
T4/1	Stephen Post: A moral case for non-reductive physicalism Newton Malony: Counselling body/soul persons
T4/2	Fraser Watts: Comments on the symposium panel discussion chaired by Malcolm Jeeves
T5/1	Colin Russell: Faraday and the Sandemanians Paul Marston: Sedgwick and the Scriptural Geologists
T5/2	David Livingstone: Darwinism and Calvinism Michael Roberts: Design up to scratch?
W1/1	John Houghton: Caring for the Earth
W1/2	John Sale: Biodiversity loss in the developing world Brian Heap: Towards sustainable consumption
W2/1	William Monsma: Wilderness and garden Rod Benson: Creation declares the glory of God Joseph Spradley: Christological contributions to science (start of talk)
W2/2	Joseph Spradley: Christological contributions to science (continued) Don Munro: thanks & Jack Haas: summing up

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