Professor Steve Jones

Did Adam meet Eve? The view from the Genes

Genetics is all about differences, and I'd like to start by showing you a few. Please stick your tongue out. Who can roll their tongue up at the side into a tube? Now who cannot? We all know about Different sexes, different hair and skin colour, different blood groups and so on, but they are just a tip of a giant iceberg in biological diversity. While I'm in the business of being silly I'll try another test. Clasp your hands together without thinking. Have you got the left thumb on top and or the right thumb on top? You might just try it the other way but I think you'll agree you find that it is a bit uncomfortable. Now the genetics of hand clasping and tongue rolling isn't straightforward but it is certainly a statement that we are all very different from each other. All that diversity of course, is coded in the magical molecule that is known as DNA.

And it's pretty remarkable stuff.. If any one of you were to rush out into the busy streets of Birmingham and be squashed flat by a speeding bus, the DNA in your body would stretch to the moon and back 8,000 times. So there is a lot of DNA about and everybody has got their own unique flavour. Where do all those differences come from? Well the answer is, basically, from sex.

The reason we are all so unique is that every generation we mix together a DNA recipe of different people to make the recipe that is me or you or anyone else. That is a very familiar notion but we tend to forget how powerful the process is. There is so much variation in DNA - something like 3 million individual places in your DNA differ from everybody else's. So everyone is very distinct from everybody else in the world but they are also distinct from every human being who ever lived or ever will live. All this comes from the very familiar and banal pastime known as sexual reproduction.

Every one of us only ever has one sexual experience in our lives and that is when sperm meets egg. From then on all the billions of cells in a human body are made without benefit of sexual reproduction. They happen by cloning. We tend to forget we are all clones. There is nothing to be frightened about, cloning is a perfectly natural process and many creatures reproduce that way. Potatoes, for example, are all clones of each other and there is even a famous sheep. Perhaps the most famous clone of all is Eve. If you look back at the old testament, or the book which is common to many faiths in the western world, you will remember that in the Garden of Eden first we had Adam, who appeared by some mechanism that isn't made completely clear. Then somehow Adam's rib was taken out and from that came Eve. It also isn't explained why Eve is female and Adam is male - but I guess we can live with that. But clearly the metaphor is that they were actually asexual, that they didn't have any sexual reproduction. So Adam and Eve were clones.

But they were certainly not the only clones in human history. Identical twins, of course, are nothing more than clones themselves. But when did they appear? If you take the

literal date set out in the Old Testament you will find, if you do the sum very carefully, that the Garden of Eden appeared with Adam and Eve on October 23 4004 BC at 11am. It was worked out by a chap called Archbishop Ussher and was believed quite literally for hundreds of years. If you look at the Bible that belongs to the founder of the theory of evolution, Charles Darwin, you can actually see that in the margins the dates are written. Genesis, "In the beginning was the word" is marked October 23 4004 BC, and then the various dates are listed throughout the whole narrative until the book of Revelations.

I can certainly see it is a very powerful metaphor, it is a very beautiful legend in many ways, but I can't imagine that many biologists can believe in the literal truth of the biblical narrative However, it is easy to forget that worldwide the majority of people probably do. They do believe in the story of Adam and Eve. Even in the United States a supposedly highly educated country, something like 100 million people believe that Adam and Eve appeared on earth 6,000 years ago and that they lived at the same time as the dinosaurs. I've written a couple of books on evolution which have done rather well in this country I'm glad to say - and much worse in the States. I did point out to my publishers that I didn't mind if these 100 million creationists burnt my book as long as they bought it first!

All of us as biologists are so used to thinking in evolutionary terms, that we forget how new the notion is.. In 1859 Charles Darwin came up with the "Origin of Species" in which he scarcely dared to talk about human evolution. But in 1871 he came up with a book called "The Descent of Man", in which he proves that humans evolved as much as anything else. What Darwin didn't realize was how much time evolution had available. There is a rather nice metaphor of how old we are as human beings - of how long ago Adam and Eve in their general biological sense actually lived. It is generally accepted that modern humans, |*Homo sapiens*, the species to which many of us claim to belong, appeared on earth 150,000 years ago. That seems like a long time ago - that's even before New Labour. But actually in evolutionary terms, which has 4,000 million years to play with, it is almost nothing. If you stretch your arms wide, and imagine the origin of life at the tip of your left hand and today on the tip of your right hand. If you take a nail file and scrapethe nail on your right forefinger, the little tiny bit that comes off that's the relative age of our species, Homo sapiens,. So we are young indeed. But in that time quite a number of interesting things have happened and we canto read the story of our own evolution because it is written in DNA. In particular we can read the narrative of Adam and Eve and we can ask the question which I set at the title of this talk, Did Adam meet Eve?

Well, Adam and Eve went in for perhaps the least original of all sins - sexual reproduction, boy meets girl, Adam meets Eve; and with all the sordid details we learn about at A level, children are born. That's a very familiar idea, everybody is an expert on sex in some way. But what does it mean? Everybody in the arts faculty does nothing but talk about sex. Think about any novel, most paintings, all operas, nearly all plays - they are really involved in this question of what sex actually is. But biologists or scientists in general have got a unique ability to make the fascinating boring and that is what I propose to do in this talk and make sex into a deeply tedious subject.

So what is sex to biologists and what does the asexual reproduction of Adam and Eve mean when we compare this to the sexual reproduction we see all about us? Well, there are many ways you can study sex. If you turn on the television most of the time it is about sex. The natural history programmes on television are full of wonderful images of sexual behaviour. In some of the recent David Attenborough Blue Planet, series there is amazing behaviour going on from coral reefs to giant whales who are indulging in sexual behaviour. And that's fine, it's very interesting and a lot of it is very good science, but actually to a biologist it is rather trivial. It's merely the tip of the sexual iceberg. I'll give you an illustration. People don't often think of plants as having sexual behaviour but in fact they do. What a plant needs to do is to get its pollen, its male germ cells, to another plant. As is often said from a flower's point of view a bee is just a flying penis. What they actually have to do is to attract this insect, to pick up the pollen and move it somewhere else.

There are other ways we can talk about sex, for example there is the mechanics of how it is actually determined. Men and women are different because men have a chromosome which women don't have - it's called the Y chromosome and women have two X chromosomes instead. And so you might think that this is what sex really means, what maleness really means, Adam had a Y chromosome and Eve did not. But that's not a universal explanation either because there are plenty of creatures that determine their sex without chromosomes or even genes at all.

My favourite without question is a kind of fish, a Blue Finned Wrasse. This fish lives in a school, or swarm of fish with 30 or 40 other fish. If there are 30 fish, 29 of them are female and there is a big butch male that swaggers around looking important, doing the mating and keeping the other males off. If you take that male away then the females are understandably are pretty distraught for a while and swim around not certain what to do. Then one of them begins to look a bit shifty and turns into a male. That is sex determination by social pressure. The individual who is at the top of the social tree is male and all the subordinates are female. It has got nothing to do with genes at all.

So even the Y chromosome is not fundamental to the nature of sex. All the biologists or the geneticists know that sex actually is a process. It is a process whereby one child has got two parents. Now you might think that is obvious one child has got two parents. But it is worth sitting back for a moment and realizing what a strange system that is. We know that in evolution if you are a female and have offspring at a rate perhaps of 1/10 of one per cent better than the female next door then your genes will spread at her expense. So, how come we have a system that a female is only making less than half of many copies of her own genes as she might because she is having sons as well as daughters and is taking on board the freeloader, the parasite or male and copying his genes at her expense? Males in most species generally do very little once they have impregnated the female. They just go away and start the job somewhere else and the female does all this work. One of the most fundamental questions of biology is why do women let men get away with it?

I am not sure that we have got the answer, but when they do it completely changes the nature of the species they belong to. Sex is a process whereby every individual has got two parents rather than (as in asexual creatures) just one. As a result , the population as a whole becomes a shared pool of genes. Any variations that arise by accident, by mutation in one individual spread by virtue of sex through a large group really quite quickly. So all that males do really is to transfer genes between females. Without males every individual would be a clone.

Now that is what sex actually is. But what are males and females? There is only really one good definition of who was Adam was and who was Eve. Males are the sex with small sex cells; sperm (or pollen in plants). Females are the sex with large sex cells; eggs. That is universally true and is the only general definition of what maleness and femaleness are. The reason behind the difference is that only one sex transmits one particular kind of structure that is known as the mitochondria.

Cells have got various structures within them, including hundreds and hundreds of little tiny objects which power the cell called mitochondria. They were once bacteria and have got different genes – and different interests - from other parts of our body. They are only passed down through females. Males cannot pass on mitochondria but they do pass on something different, a structure of their own which is the Y chromosome.

In other words, even humans have some asexual reproduction. We have females who pass on mitochondria and males who pass on Y chromosomes. If we want to search out who Adam and Eve actually were, either in the metaphorical sense of the Adam who gave rise to the population of Birmingham let's say, or in the wider sense of the original Adam at the basis of the human race, we can use the Y chromosome to search him out. Conversely we can use mitochondria to search out the history of females, to search out Eve.

As I said, sexual reproduction is a process that links female lines together. Here we have the longest of all human pedigrees, tracing back to a chap called William Brown who was born in Canada in about 1750. William Brown had a rather unusual genetic problem. Firstly he was profoundly deaf and secondly he could not open or close his hands or feet - they were frozen. The condition appeared suddenly in his family, probably because of some new genetic accident and it has been carefully tracked ever since. Interestingly, the gene has spread all over the world because of sexual reproduction. This pedigree is only a tiny part of the entire William Brown family tree but it has got some interesting aspects. Here is our friend Mr Brown at the top. One group is actually still in Canada but another group have moved back to Britain and most of them live in Norfolk. Another are actually West Indians living in Jamaica and have got black skins. So what has happened? This gene by virtue of this wonderful process of sexual reproduction has managed to mix itself with other genes with which it did not find itself when it first arose. What has happened is that sexual reproduction has led to a kind of democratization, to an averaging out of and a spreading of the genes of William Brown, and they have ended up in some rather unexpected places.

Sexual reproduction mixes your genes with those of other people. And it means that we all share ancestors. Obviously in Britain in the last 50 years we have had a lot of population mixing going on. But certainly if you look at Birmingham in the 1950's, before we had a lot of movement in and out from different parts of the world, the average pattern of relatedness among the people of Birmingham was surprisingly close. If two people walking in the street were to look at their family trees they would find on average that they were fifth or sixth cousins, in other words that they share a great great great grandparent in common (although they almost certainly would not know who that was). We really all are quite related to each other by virtue of this mixing up and scrambling of genes during sexual reproduction. Obviously these days those figures have changed a bit because we have much more global movement. But we all still are, because of sexual reproduction, surprisingly close relatives. Sexual reproduction is inclusive and means that the genes of different people very quickly mix together.

But what about asexual reproduction of the Adam and Eve type, of the mitochondria and the Y chromosome? Well that is completely exclusive. Women get their mitochondria from their mothers, their mothers got it from their mothers and so on back into history. And women who have children will pass on mitochondria on to their daughters and sons, but only daughters will pass it on to further generations. The men's story is exactly the same for the Y chromosome. Men get their Y chromosome from their father, who got it from his father and so on and it will only go forward through the male line. We can use these things to trace particular lineages really quite accurately because they never mix up. Asexual reproduction is a dictatorship of particular lineages rather than a genetical democracy in which everything gets blurred every generation.

You can trace the history of men and women, of Adams and Eves in different ways. Sometimes you can actually use the records to search them out. The pedigree of Canadian women - in other words of Canada's mitochondria – tells the story. The history of Canada is like many recently colonized parts of the world - it involves various waves of migrants. Much of Canada initially was French. Some came as early as the 16th century to Canada and then later waves were forced to settle in rather less hospitable places One group came to a part of Quebec called Saguenay. They were (and still are) French speaking and they arrived in large numbers in the 18th century and sat and stayed in that remote valley. They kept extremely good family records. In 1780 there were something under ten thousand women who lived in Saguenay, nearly all of whom had come recently from France. So we can guess that there were something like that number of different mitochondrial types there. The records are so good that we can actually trace their asexual fate by asking the simple question. How many women living there today have got a direct link through women alone to the population who lived there in the 18th century? It has got to be a direct link. Many people can trace themselves back to their mother, their grandmother and so on but then they have to go through the great grandfather and that breaks the link. Is has to be a link that goes from woman to woman to woman to woman. Of the 9,000 or so mitochondrial types, the different genetic variances of mitochondria that was there, only something like 700 are left. So you can see that in 200 short years, almost nothing in evoluationary terms, asexual reproduction has lead to a great loss of diversity, and to the beginning of a takeover, of one particular

genetic type. And indeed one type is carried by a substantial proportion of all women now living in that place. And if we were to come back in 2 or 300 years then it is quite likely that all the women of Saguenay would carry that type - in which case they would all trace themselves back to a single female who lived there in 1780 or so and she would be the Eve of their population. She would have had no idea that that was her fate, indeed she was no different from anybody else but, just by chance, hers were the mitochondria that survived.

We can do that quite well with Eve and we can do the same with Adam. Unfortunately it is much more difficult to trace the ancestry of men through the records than it is the ancestry of women for reasons that are too sordid to go into in detail. It is much easier to associate a baby with a mother than it is with a father. There are a number of accidents that take place where the supposed father is not the real father, so you cannot really use just written records to work out the history of the male lineage. However you can use the Y chromosome.

The Y chromosome used to be thought to be completely empty of information. Now, there are all kinds of rumours about what types of genes might be stored on it. There are some very strange candidates. One is a gene that was shown for many years in most textbooks ; a gene for hairy ears. In parts of India there are supposed to be families where these hairy earlobes are sometimes waxed by their proud owners and the gene is passed down the male line and there are pedigrees to show that. But it is not always just men. Once I saw a chap, an African from Botswana and I went up to him and said "Excuse me, I hope you don't mind me asking but you have got magnificent hairy ears, does anybody else in your family have them?" And he said "Oh yes, Sir, my mother does". So it was not on the Y chromosome.

Another famous example was the so-called porcupine man. The porcupine man was in Birmingham in the 18th Century and he showed himself as a sort of circus freak. He had skin that was covered in thick scales. We now know that he had a particular genetic mutation that is quite well understood. It was thought for a while that it only travelled down the male line. But then, unfortunately, a porcupine daughter was born so this was not dependable. It is not on the Y chromosome at all.

However, one very important gene of course is on the Y chromosome and that is the crucial gene that makes people male. It is remarkably simple; a tiny gene with only 55 amino acids, 55 building blocks, but it is very important at least to half of the population.

We searched for Eve using the mitochondria, let's now search for Adam. The Y chromosome tells me some pretty interesting things on the way. First of all it tells me a lot about the mating patterns of men in the past. Y chromosomes are inherited a bit like surnames. They pass from father to son. Daughters get surnames too but then they change their names on marriage, or they used to, so they do not count. A geneticist called Sykes had a good idea just last year of thinking "Well Sykes -that is an unusual name. Why don't I write to lots of people called Sykes and look at their Y chromosomes." He found 80 or 90 people and gave them kits to sample their DNA. He looked at the Y

chromosomes and he found that about half of them were identical. So the family Sykes really did descend from Mr Sykes, somewhere in the north of England perhaps as early as the 13th century. Or at least half of them did. The other half descended from men, we know not who they were. Men who had crept into the Sykes double bed at one time or another over the last 700 years and had donated their Y chromosomes without donating their surname as well. So there is quite a lot of illegitimacy. If you do a sum actually there was not that much, it was only about 1% a generation, it just builds up over the years.

On the US census you have to fill in a little box with your race. Many people will have objections in doing that but the US insist that you do. People can define themselves as being black or white or American Indian or whatever. If you take people who are Black Americans – what proportion of their genes come from West Africa? There are certain genes there that are found in a different form to those in Europe. So any versions of those different genes must have come in by mating over the past several hundred years since the days of slavery. On average, black Americans have about one third of all their genes that come from Europeans. So it is a reasonably mixed population. Interestingly enough though - if you look at the Y Chromosomes of black Americans, the ones that come from men, something like 85 or 90%, of those chromosomes come from Europeans. That, of course, tells us something perhaps rather unpleasant about the nature of the social relationship between blacks and whites and between men and women during the days of slavery.

If you go to Africa itself, again you get some rather startling results about the Y chromosome. I spent some time working in various parts of Africa, and I spent a while in Botswana which is to the north of South Africa. Now Botswana and also Zimbabwe has a group of African tribes. One group is called the Lemba. And the Lemba has always had a legend that seems very odd, that they are descendants of one of the lost tribes of Israel. Many people all over the world have claimed to be the lost tribes of Israel. But the Lemba are strong believers in the legend and they believe that they are Jewish. Most people of the Jewish faith do not accept this; these people are Africans, they do not speak Hebrew, they do not follow the Torah rules in general.

But the Lemba strongly believe that they are Jewish and if you look at the Lemba chromosomes, amazingly enough it turns out that they do have middle eastern chromosomes, not Y chromosomes like those found in the rest of Africa. Not only do their Y chromosomes, from male lineages, come from the middle east, they are the same Y chromosomes as are carried by a particular sub-group of Jewish people and are called the Cohanim. The Cohanim believe themselves, with some accuracy, to be the descendants of the priests of Solomon's temple. As Solomon's temple was cast down several hundred years BC the priests disappeared, but they continued this male heritage father to son. The Cohnaim have got a set of Y chromosomes of their own and amazingly those Y chromosomes are also in this African people the Lemba. We are not clear how they got there but most probably by trade and mating between middle easterners coming down the east coast of Africa and the chromosomes spreading in land. It gives a startling

insight as to what the male ancestry of that particular group is. So Y chromosomes can actually tell us some quite interesting things about particular peoples.

But what about the big picture? What about Adam and Eve? What about Y chromosomes in the world? We have been mapping Y chromosomes quite a lot. I have been to Syria, just last year where I was persuading lots of Syrian men to spit into tubes. We looked at their Y chromosomes What immediately emerges is the startling differences in the geography of men and women across the world, the genetic geography, the biology of the Adams and the Eves. Women it turns out, all of us men knew this anyway, are the boring sex, they are pretty much the same everywhere. Men are much more diverse. If you go west from Birmingham until you get to Aberystwyth where I myself was born, and you look at Y chromosomes - it turns out that there is a sudden shift in identity at the Welsh border. In fact Welsh men have Y chromosomes on average which are quite different from those of most English and European men. They are rather like Irish men. And that probably reflects the fact that when the Anglo Saxons arrived Britain, the Welsh men stayed put and the women moved. The mitochondria of the invaders, the females of the invaders moved in to Wales, rolled over the local male population, as it were, who mated with them. But the males stayed put. So if we look at the geography of maleness and femaleness we find males are much more diverse from place to place. And we see that all over Europe. It probably has something to do with economics, with property. What actually happens, well at least in farming communities all over the world, the son inherits the family farm and he gets a wife from somewhere else.

What that means is that the mitochondrial genes, the female genes, move more than the male genes. We can draw a map of the genetics of the world's women in context of chimps, gorillas and orangutangs. (I am sorry about the Chimps, gorillas and orangutangs but they help us to see the story.) Female chimps are tremendously different from place to place. Humans on the other hand are extraordinarily similar. The world's women are really almost identical to each other. There are less differences between the women living in Iceland and Australian aboriginal women than there are between two female chimpanzees living 50 miles apart in Africa. So women, because they have moved so much, are actually really quite homogeneous from place to place. Men though, as I said, are quite different. Men actually are quite strongly structured in their genes from place to place. Some of those effects are actually fairly dramatic.

If you go to New Zealand and you look at Maoris it turns out that nearly all Maori men have the same Y chromosomes so they all descend from a single male. Indeed there is a legend of a single certain important chief who came to New Zealand when it was founded about 1000 years ago. Thousands of Native Americans all over North and South America descend from perhaps four different men who made the journey across from Asia something like 15,000 year ago. And if you look at the globe as a whole it turns out that the lineages of males or the Adams of the world have a very definite split between a very diverse group in Africa and a much less diverse group outside Africa. You can do some sums and it looks as if all of the men outside of Africa descend from a group of less than 50 "Adams" who actually escaped perhaps 150,000 years ago. So men, and Y

chromosomes, really are a pretty inbred and exclusive set of genes, much more so than the mitochondria which are passed on down the female line.

We have learnt quite a bit about the genetics of Adam and Eve and they are really quite different. However, let me finish by asking the question, Did Adam meet Eve? The answer almost certainly is no, because the answer turns on the difference of the mating habits of men and women. Obviously everyone has one father and one mother, but in all kinds of animals ourselves included, there is much more success of different males than there is of females. To put it crudely and I'm not applying this to humans but in animal behaviour, there is a good general rule that every female however unattractive, unfit in one way or another, - ill, maybe, or badly fed – will always find a male desperate enough to mate with her, but among males only the best will win.

If you look at pictures of sea elephants on the beach as we saw in David Attenborough's Blue Planet, you can see male sea elephants fighting and in fact only about one in twenty of those ever passes on his genes. The females are sitting there with pretty smiles on their faces and they are waiting until after the bloodshed, after the poor old males have been torn to pieces, and so they all get a mate. They all pass on their genes. So there is much more variation in the mating success of males than among females. A few males pass on very many copies of their genes on their Y chromosomes, while some pass on none. However, nearly all females pass on their mitochondria. That has important implications to patterns of relatedness – and to the search for Adam and Eve.

The most sexually successful male human that I have ever read about is a chap with the rather startling name of Mulai Ismael the Cruel of Morocco. He lived in the 16th Century and he clearly wasn't a very nice man, although he was a very great emperor. He killed 30,000 people with his own hands or so he claimed. He also had enough time to have 888 children. Obviously there wasn't just one Mrs Mulai Ismael the Cruel there were lots and lots of them, there may have been 40 or 50 women involved but he was the only male. There must have been lots of Osamas the Kindly in the background there who were feeling very, very depressed because they weren't getting any females at all. One male succeeded which means that lots of other males did not. But most of the females succeeded because in time Mulai Ismael got around to them.

That actually makes a big difference to the search for Adam and Eve. Let's think of Moulay Ismael's court, with all his children. . All his sons will carry his Y chromosome, which originates just one generation back. Moulay Ismael would be their Adam because he is the father of all of them. But if you look at their mitochondria, many different women were involved, each with a maximum of ten children or so. In order to find the shared female ancestor you couldn't just go to the previous generation. Instead you would have to go back into history – perhaps for scores of generations - before you got to the ancestor of all those mitochondrial genes.

In other words, in the rather extreme example of Moulay Ismail's court, Adam lived far more recently than Eve, simply because , men are much more variable in their sexual success than women. In any population, indeed, if some men have lots of children and

some have few sor none, we very soon very soon get back to the Adam of all of us. Because women generally have roughly the same number of children it takes much longer to get back to Eve – so that those two famous individuals could not have lived at the same time.

I can therefore be confident that whoever uttered that famous phrase “Madam, I’m Adam”, didn’t say it to Eve.