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EVOLUTION SINCE SIR THOMAS GRESHAM

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Most people see evolution as something that takes place over millions of years; and Charles Darwin never thought that he would ever see it in action. However, even in the five hundred years since Sir Thomas, plenty of changes have happened in the world of Nature, and even that of mankind. I will talk about evolution then, now, and even in the future.

Sir Thomas was of course an economist; and many of the ideas of evolution come from economics, and economics and the global change that comes from it has done a lot to change the evolutionary future.

Initially I was a bit baffled as to what to talk about, but then I realised that Sir Thomas' personal symbol was a grasshopper; and I have myself done quite a bit of research on the chromosomes of a certain species of grasshopper in the Alps; and I persuaded myself that this would make an ideal theme for an hour's Gresham Lecture. But then I paused, and realised that this might be too exciting for tonight's audience, and decided to talk about the past and future of life on this planet instead.

What is evolution?

What is evolution? Darwin described it as "descent with modification"; a phrase which in modern terms can be re-stated a "genetics plus time". Genes are copied and passed from one generation to the next; mistakes – mutations – happen; and errors, changes, build up.

He also had a second idea, natural selection; inherited differences in the chances of reproducing. If an individual with a particular genetic variant survives better and finds more mates, then more copies of that gene will get into the next generation, it will spread, and in time new forms of life will arise.

That process has gone on for billions of years, but thanks to human interference has speeded up and has changed direction.

Darwin used many kinds of evidence to support his case. Geography, and movement, was among them: indeed, first line of Origin was "When naturalist on HMS Beagle my attention was drawn to some peculiarities in the distribution of the plants and animals of South America.

In the same way, the first chapter of The Origin is called Variation under Domestication – the origin of beef and dairy cattle as an example – and man is the great domesticator, and indeed is himself the most domesticated primate of all, making his own life as comfortable as possible whatever the effects on the rest of the living world.

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One obvious point; it has got BIGGER. Map of his London – tiny; space shot – huge. Now it is back to 1939 levels, at almost 9 million. It had been contracting but is now expanding fast.

True of every other city in the world – massive boom in construction; as seen by amount of cement produced. Now, for the first time in history; more than half the world population lives in cities. This affects their own lives and their patterns of evolution, as it does to many of the creatures that live there.



Also, patterns of life and death have changed: in the 15th Century – there were high birth rates and high death rates, then there was a rapid decline in birth rate and slower decline in death rate (ie high population growth) until both death and birth rates are low – the demographic transition. True almost all over the world – even China and India, but not, as we will see, everywhere.

Also, patterns of sex have changed. In much – but by no means all – of the world people are much less likely to marry their relatives than they were in his day. That too, as we will see, will have dramatic effects on the evolutionary future.

And, most of all, the environment has begun to change, and fast. We are in a new era, sometimes called the Anthropocene, in which the main agent of the future is human behaviour. The story is familiar, perhaps too much so, but the facts need repeating again and again.

Carbon dioxide is at levels never seen for three million years, and is going up fast, with no signs of any success in controlling it. Other greenhouse gases – methane from cows' guts most of all, are doing the same.

The greenhouse effect so produced means that the last four years have been the four hottest ever recorded; and nineteen of the twenty hottest years ever recorded are in the twenty-first century.

The ice is melting; from Antarctica to Greenland (where the whole ice sheet might soon disappear) and sea levels are rising to match.

Soil is being lost as it was when the Fertile Crescent turned into a desert soon after the origin of farming. Sometimes the effects are spectacular a lake was near Peterborough since in the nineteenth century, and a metal post driven through the fertile soil until it touched hard clay deep below. Oxygen got in, making CO₂, and the carbon blew away. The post now stands three metres above the surface.

And, cities have got much dirtier – John Evelyn even by 1661 in his *Fumifugium* pamphlet complained of smoke becoming a problem. Soon, the city was black – and evolution rose to the occasion. It's the textbook example of rapid change, but it is worth reminding ourselves of it, because it has many parallels in other creatures.

No doubt that animals in cities respond rapidly to change in circumstances; indeed evolution of urban forms in a variety of creatures now almost an industry – diagram of animals in cities across the world shows a wide variety moving into cities; and many have changed.

The peppered moth – a famous case of evolution; swifts, mosquitoes, bed bugs, elephants and fish

A famous case – the peppered moth; the first black specimen was observed in Manchester in 1848; this showed a rapid increase until some industrial towns had almost 100%. Then, after the great smog of the 1950s and smoke control; there was a rapid drop in the frequency of melanic; now down almost to zero. Release experiments in unpolluted wood near Cambridge showed a strong selection against melanic form. Twist to the tale – in the past few weeks it has become clear that the dark coloured element was brought into the peppered moth on a piece of mobile DNA – a mechanism once thought impossible but now thought to be common.

Even larger wild creatures in cities can respond rapidly; cliff swifts in southern US; have taken to nesting on motorway bridges; we find that many more long-winged individuals are killed by cars as less nimble when it comes to getting away – so there has been a slow decline in long-winged genes over past 20 or so years.

Darwin's book; *On the Origin of Species* – is in fact not mainly about the origin of species; but there is one remarkable example; *Culex molestus*: the London Underground mosquito; showing the origin of species in cities! This split off from another species *Culex pipiens* as deep basements, and then tube lines, were excavated. It bites mice rather than people, does not need blood meal to lay first eggs, does not need mating swarm; avoids mating with its ancestor. All in c150 yrs!



Plenty of other creatures have changed – when I moved into Islington flat more than forty years ago I faced a bed-bug infestation – a quick dose of powder got rid of them; but they are now resistant to more or less all insecticides. They have done it in an unusual way – they have thickened their skins; but most insects do it by breaking down the chemical. However, fortunately perhaps, I could now no longer afford to move back to Islington anyway!

There are other chemical challenges by man – antibiotic resistance; now there is only one antibiotic left that is universally effective, malaria is coming back; again, transposable elements are important. Drug companies have given up the search for new classes of antibiotic as there is not much money in it.

Human activities have changed the fate of even the largest creatures –the ivory trade means that more than half the elephants in Africa have been killed since the 1940s. Evolution responded to the killing of those with large tusks; and many populations now have no tusks at all. Since 1990 a ban on ivory sales has been quite successful and the number killed has dropped greatly. Will be interesting to see if evolution begins to favour large tusks again! In the sea, also a dramatic effect – more than half of all food fish already killed; food fish eg cod now become sexually mature much smaller than before as more larger fish are killed, and also mature more rapidly than before. Charles Darwin's first chapter of *The Origin* is about variation under domestication. Since farming began about ten thousand years ago, even humans have, in some senses, become domesticated. Populations that have drunk milk for many years are able to digest lactose, but many more in China, Africa and elsewhere cannot digest it in liquid form because they have never herded cattle for milk and lack the enzyme.

The same is true for starches – farming populations have evolved many more copies of a salivary amylase gene than have those in Africa or the Arctic who have been hunter-gatherers until recently; digest starch more effectively. And, bizarrely, so have their dogs; they can digest starchy foods which wolves cannot.

Dogs have changed in many other ways too – there are massive physical difference among breeds; but also all of them share an attribute common to most pets – they are pretty stupid, with far fewer nerve cells in the brain than wild mammals have.

Human activities have affected wild animals too; perhaps most dramatic is side effect of global warming and glacier retreat – marine sticklebacks heavily armoured for defence; have entered new streams and lost spines and plates – and can split into new species feeding on surface and bottom within just a few years.

Human evolution

However, the most dramatic evolutionary event since Gresham has involved *Homo sapiens*, the species to which most of us claim to belong.

The human fossil record is now reasonably complete, although in Darwin's day the only fossil was found in a Gibraltar cave and was described as an ancient human drowned in Noah's flood; now known to be a Neanderthal. However, ancient DNA has revolutionised our view of the past; as most people know, it shows, for example, that many modern Europeans contain a few Neanderthal genes (including that for red hair).

Also Cheddar Man ten thousand years ago still had dark skin. We might assume that he was the direct ancestor of most people in Britain today; but that is not true at all – ancient DNA has revolutionized our understanding of change in the past few thousand years.

Always assumed that genes diffused through populations as neighbours mated with each other and the genes moved on slowly, like a suburban train that stops at every station.

In Europe – a totally unexpected discovery. It was an express train; there was a rapid movement of one group that overwhelmed most of the north of the continent.

A few of the original genes have become more common over the past but even by 800BC are only a fifth of the total (and nearly all Y chromosomes are European).



If you draw a diagram of relatedness among the ancient DNA samples (principal component analysis); there is a great mass in Ukraine and over to Caspian: – the Yamnaya people, bronze age horse riders.

Look at left side of graph – a small group of Eastern and Western European hunter-gatherers.

Now look at the grey dots – samples from modern Europeans; all of them fit in with the Yamnaya and their neighbours; in other words almost none of our genes come from the people who once lived in Northern Europe – a replacement model of human evolution. Rapid movements of people, in large numbers.

Effect particularly strong in Britain, where more than 90% of native genes, and effectively all Y chromosomes, were replaced around 2450 BC. We trace most of our ancestry to Ukrainian and Russian people than to our own ancient relatives.

And what is happening today? Still hard to know, but clear that genes moving across the world at unprecedented speed – most important event in recent human evolution is the invention of the bicycle; you no longer have to marry the girl next door as you have no choice. Can be seen in my case – marriage distance; my wife and I were born 3000 miles apart.

Britain is a microcosm of movement; about one in eight Britons born abroad. In London the figure is more than one in three born abroad. Most of its population growth is still due to international migration. London is much more geographically integrated than eg Paris or Chicago, but there are still marked areas of differing ethnicity.

However, there have been numbers of people of African origin in London for many years – Dr Johnson's servant Francis Barber was black; he married a white woman and their two sons did the same; he has many descendants today.

William Hogarth's painting Noon of 1736 shows a black man without comment. By the 1750s there was talk in the Gentleman's Magazine of 20,000 Negro servants in London. Some became prominent – Nigerian Olaudah Equiano was prominent in the anti-slavery movement; and has a plaque on a UCL building! He too married a white woman, and had two daughters.

Many more of those Africans were in time absorbed into the European population, and the process continues today. For half of today's British-born teenagers with one parent of African or Afro-Caribbean origin, the other parent is white; and that proportion has gone up and continues to do so. In time as a result there may be more or less complete fusion of the two groups.

Perhaps more remarkable, the barriers long associated with skin colour are falling. Choice of a mate is now much more dependent on a shared education level than of shared skin colour; true even in the United States, and even more so in Britain.

In fact the IQ assortment is much greater than that for skin colour; above all education level; one is far more likely to marry someone of same educational level as oneself – 30x as much grad/grad as grad/school dropout.

In the UK too – a black person is 6x more likely to marry white person of same education level as himself or herself, than for a highly educated black person to marry another black person of low educational attainment; admixture more subtle than many people think!

Less true of other groups; many barriers held in the mind in the form of religion, so the future is not yet clear and none of us will be around to see it.

However, if Sir Thomas Gresham – founder of London's first university – was to return today, I think he would be pleased to learn that, as in his day, the key to the future lies in education.



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