Paper Reference(s)

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Edexcel GCE

Biology (Salters-Nuffield)

Advanced

Unit Test 6 Synoptic Paper

Scientific Article

June 2009

The first question in the synoptic paper will relate to the following scientific article, which you should study during your course.

You may be asked to summarise the information in the article, and explain or comment on the biology and issues within the context of the article.

The question will be worth 20 marks out of a total of 60 marks for the paper.

The article is adapted from the book *The Earth Only Endures* by Jules Pretty.

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Ecolution

One hundred and twenty years after Charles Darwin and Alfred Russel Wallace turned the world upside down, James Lovelock wondered, too, in his Gaia hypothesis, if the Earth had been shaped by life. The new believers wonder why they did not think of it first; the old disbelievers think it all utter nonsense, and sit back and wait. Years can pass before the new comes to be accepted. Max Planck famously once said, 'a new paradigm is often accepted not because it convinces the majority of its opponents, but because it outlives them'. Gaia remains controversial, mainly because some have misrepresented it as suggesting the Earth itself is alive. This was never the intention, but it remains an appealing idea to some searching for a guiding hand. What Lovelock did say was that life helped to make the Earth a place where life could persist. It made its own bed, and it's a comfortable one. At an average current temperature of 13°C (until climate change fully takes hold), the Earth is very hospitable. Mars and Venus, by contrast, are thoroughly inhospitable, one bitterly cold and the other twice as hot as an average oven. Life maintains the Earth's biogeochemical cycles far from equilibrium and this in turn helps to shape and influence the kinds of life that persist.

This makes the biosphere an emergent property of millions of years of interaction between life, the Earth and its environments. And we humans are part of this process too. Hominids emerged some 5 million years ago (our genus about 2.5 million years ago; our species about 160,000 years ago) and we have been shaped by hundreds of thousands of generations to arrive at where we are today. To paraphrase Sartre, all our lives have led us to this very moment. And here is the link back to Darwin, whose shattering idea of evolution driven by natural selection recognized the mechanism by which the many forms of life have emerged, survived and diverged in their specific environments. It is now clear that individual organisms, populations and their species change their environments, often in ways that increase their chances of survival. Survival of the fittest also means survival of those that influence their environments in a favourable way and can then pass on these capabilities to descendents.

At the same time as Darwin's *Origin of Species* was published, a monk in Austria was laying the foundations for modern genetics. Gregor Mendel's experiments with peas during the 1850s and 1860s clearly showed how characteristics, or traits, could be passed from one generation to another (though his work was not recognized until the early 20th century). A half century after this, Francis Crick, James Watson and the mostly forgotten Maurice Wilkins and Rosalind Franklin established the structure for DNA, which later allowed chromosome structure and gene expression to be determined. Another half century of huge collaborative efforts across laboratories in many countries has seen all the genes for a number of organisms fully mapped, including the 30,000 or so genes of humans. For a while, this appeared to suggest we are near to knowing everything about us and these other mapped organisms. But this is far from true. We know more, but also have gained insights into how little we still know.

Mapping and naming genes is like picking up the phone directory for your local town or city. Lots of names and numbers, structured in columns and helpfully all in alphabetical order. But from these lists alone, you can only guess about the structure and functioning of the city. You would need to ring up every person (or gene) and ask them what they do. You would then need to find out what causes that person to get up in the morning. What are their motivations? If it is a rainy day, will that person stay inside; if sunny, go to the beach? Will that person do something when another person (gene) in the phone book calls them and invites them over for tea, or was it to the pub? You may have one contact that calls every day, another only every five years. Today, we have a pretty good gene phone book and have begun to realize that we understand so little about how they interact – both with other genes and with the environments that are internal and external to the organisms which carry them.

This idea about having genes that need to be switched on before they act is beginning to entail some modifications as to how genetic and environmental processes are understood. We have all been taught (at least, we should have been) that traits are either dominant or recessive, that we have two copies carried on different strands of DNA and that inheritance is a pretty predictable game. And for some traits, it is. For blood groups, you can have an A or B gene, which are both dominant, but rare. If you have neither, you are O. If you have one A and one O, you are A. Chimpanzees, by the way, are either A or O, and gorillas are all B types. Thus we can see that you or I have genes for a particular trait. In short, a gene (or both) determines the outcome. Again, this is a simple and powerful idea, but it leads to many popular misconceptions about genetic discoveries. The gene for cancer, we are told, has been discovered. Or for left-handedness, or aggression, or divorce. And this is where the story begins to break down. Most traits, or outcomes, are shaped in very complex ways, and these driving influences can be both other genes and their products and signals in the internal and external environment. Genes do determine things, but they are in turn switched on and off by other things.

This, then, brings us to another enduring controversy: how much do genes or the environment affect who we are? Is it nature (genes) or nurture (environment or culture) that is mostly, or even solely, important? Like all supposedly handy dichotomies, the truth lies in elements of both, not one or the other. But the post-Darwin literature is often less forgiving. And this has led us into many difficult places. A century of polarised opinions seemed to explode in the mid-1970s with the publication of E O Wilson's *Sociobiology*, in which biological explanations were provided for many aspects of human behaviour and society. Many social scientists attacked Wilson, as did some evolutionary biologists. Part of the problem may have come from Wilson's provocative claim that the social sciences would eventually be subsumed into biology, as he indicated that a great deal of behaviour could be explained by biology alone. Even after the dust from this particular controversy has settled, there still remains a wide range of divergent views, from those who appear to reject any cultural explanation of human behaviour, to those memeticists who seek to provide evolutionary perspectives that are essentially cultural.

Even within evolutionary fields, there is considerable controversy and it remains hard to identify the relative roles of genes, the environment and human cultures on hominid and human development. Speculation and prejudice are common, probably because who and what we are actually does mean a lot to most of us. Inevitably, ideas get misrepresented, either accidentally or deliberately, in ways that suit some people's prior political, religious or even scientific interests. It is hard, therefore, to separate out biological fact, or indeed portion out the relative roles for biology and culture (or nature and nurture) in human evolution and our arrival to this point. Moreover, a great deal of discomfort about using genetic explanations for some aspects of human behaviour has arisen in reaction to those in the 19th and 20th centuries, who sought to use genetics to explain differences between races and between the rich and poor. To some, like Darwin's cousin, Francis Galton, this provided an opportunity to put all the differences between human groups down to heredity, and nothing to culture (through education or economic opportunity). Galton pioneered the study of twins, but also wanted to investigate 'the practicability of supplementing inefficient human stock by better strains ', as Matt Ridley has explained. These led to a position that suggests you have a set of genes passed to you, that these determine all that you are and that there is no role for choice (or free will). The slippery slide to eugenics had begun.

If evolutionary perspectives seem to explain so much about human behaviour and society, why are so many people hostile to these ideas – from the creationists and believers in intelligent design to the social scientists concerned about past uses of evolutionary theory to support certain political ideologies? Creationists cannot believe that the complexity we see in the world could have emerged as a result of evolution over millennia. And their opinions seem to be winning in some places – the 'new ignorance', as Steve Jones calls it. In the US, surveys seem to indicate that 40–50 per cent of people during the 1990s and early 2000s believed God created humans in their current form less than 10,000 years ago, 30–40 per cent believed humans developed over millions of years, but that God still guided the process, and only about 10 per cent believed humans developed from less advanced forms of life, with God having no part in the process. Of course, many people believe in one thing and act in contradictory ways. How many evolutionary sceptics, we might wonder, are quite content to have a flu jab that requires evolutionary understanding to develop and redevelop as the flu virus itself rapidly evolves? As Steve Jones also says, evolutionary stories are all around us, from dog and pigeon breeds to HIV – a retrovirus that is bad at making exact copies of itself, 'which is one reason why it does so well'.

One reason for these large numbers of evolution deniers (about a hundred million people in the US alone) is the enduring problem that evolution can appear to have direction. Things go from simple to complex, from worse to better, and at the end of the line, whether evolved or designed, are the humans (who are obviously the best). We should be very careful about the naturalistic fallacy of 'what is should be'. What we see now in the world, in human society, is not what should have happened. Nor is it the best, just because it is now. It is what emerged. As far as humans go, Neanderthals had an advanced and complex society and then disappeared. As for past civilizations, some 40 major ones have come and gone, lasting on average for 900 years, each of which probably thought itself to be the best just before the candles guttered out.

After Darwin, the concept of evolution as a linear and progressive force became widely adopted and remains with us today. Jean Lamarck erroneously believed in the inheritance of acquired characteristics and suggested that species strove to evolve greater complexity, thus the pinnacle of evolution had to be humans. Later, social Darwinism came to suggest that nature was more important than nurture, and that the development of individuals from birth to death (ontogeny) reflected closely the evolutionary development of species (phylogeny). Such ideas of progression (implying that the later is better, the more complex the cleverer), were later applied to human societies. Lewis Henry Morgan's *Ancient Society*, published in 1877, suggested seven stages of human cultural evolution, beginning with lower savagery and progressing through barbarism eventually to reach civilisation. The idea was that all human societies did share a common ancestor, but that some groups (or races) were now higher on the ladder than others. Such ideas fitted very well with prevailing views about the superiority of European and North American culture and again came to be widely accepted (though of course still hotly contested by many).

Setting aside the extreme religious views, the central problems that many people have with evolution and genetics centre on questions of instinct and free will (which, in the light of what we now know about genes, are probably false assumptions anyway). Ethologists, like Nikolaas Tinbergen and Konrad Lorenz showed clearly that many animals and birds responded to cues in very predictable and deterministic ways. Instinct, it would appear, was critical. But instinct implies no thought – it is something an animal, or you, do, driven only by your genes. This is already troubling, especially to those who base their philosophical and political ideas on those of, among others, John Stuart Mill, who indicated that the mind at birth was empty and is gradually filled as we experience the world, implying that we have the ability to choose these experiences and so shape our own lives.

Before E O Wilson, others took a similar line, such as Desmond Morris in *The Naked Ape*, whose hugely popular book suggested that modern humans were shaped in the Stone Age, and that most of our behaviour was explained by reference to those conditions. This has wide resonance, but Morris also treated humans as if current culture played second fiddle to genes. The problem, as in so much of the history of evolutionary thought, is that some people cannot resist slipping into language that says what they believe is right and wrong, or better and worse, rather than explaining what happened or might occur in the future. Evolution does not have a directing hand, or a determined pathway. It is about adaptation to environments, changing environments to make them more suitable and the survival of those genes (and the organisms that carry them) that are best able to do these things.

As we shall see, genes play a fundamental role in shaping who and what we are, but they do not act in a vacuum. They take their signals from the environment, which once was predominantly ecological but now is cultural too, and these signals switch them on and off. What we are is actually an emergent property of both genes and ecological-social environments, and thus we do have choice. We cannot bend our genes to our intentionality, at least not personally, but we can and do affect the environment which indirectly presses our genetic buttons. Thus, as Kevin Laland and Gillian Brown say, 'using evolutionary theory is not the same as taking a genetic determinist viewpoint'. Indeed, says Richard Dawkins, 'the bogey of genetic determinism needs to be laid to rest'.

Decades of binary controversy over either nature or nurture should now lead us to the sensible conclusion that neither alone is explanatory. Both are important. This will annoy both those who have come to believe that culture is predominant and those who would believe that genetics can explain all. It is not my intention here to review all the science behind the many different strands of evolutionary theory (including sociobiology, evolutionary psychology, human behavioural ecology, memetics, gene–culture coevolution and evolutionary anthropology). But what is common to all is the idea that hominids evolved over millions of years, that we spent a long time becoming adapted to environments of our ancestors (as are all organisms), that many complex aspects of culture emerged fairly recently (50,000 to 100,000 years ago) and that the ecological and social environment played a role in influencing which genes succeeded and were passed to later generations.

The controversy over how much genes or the environment affect who we are is curious, as we pretty well accept the fact that genes are units of inheritance. Genes determine a great deal, but strangely we do not seem to find this a comfort. The problem centres on questions of free will, which we would all like to think we have. I am free to choose what I think or like, I am free to be happy or sad, or to choose one person or food over another. I can choose, in other words, my own future. It is not, though, that simple. Genes shape those choices, as we do our environments, which once had antelopes in them, but now have supermarkets and fast food outlets. And how much free will do we actually have when it comes to buying food? Are we not subliminally influenced by advertising anyway? Do the stores not seek to influence your choices in subtle ways? Of course they do. The average American child will have seen 360,000 TV advertisements and 200,000 violent acts by the age of 18.

Both genetic determinism and the idea of being born with a blank slate are wrong. None of the commonly used binary oppositions – genes or environment, nature or nurture, innate or acquired, individuals or culture – are alone correct. The problem is that false insights into these questions have led to the expression of many political and social prejudices, and in the hands of tyrannical leaders allowed many atrocities to be justified. Some believed they could, and should, create a master race (as if the environment did not matter), others that they could rewrite human nature if social circumstances were changed (as if genes did not matter), though most, it is true, have not occupied such extreme territory. The worries about genetic determinism, though, are centred on false ideas about genetics. As Matt Ridley has rightly put it, genes are not gods. Just because you or I have a particular gene does not mean it will necessarily be expressed (it may sit quietly doing nothing); equally, if we lack a certain gene, it does not mean we will lack a trait or characteristic (another gene may step in and do the job instead). As Ridley rightly says:

> *genes spend just as much of their time responding to our actions as they do causing them. Genes do not constrain human freedom, they enable it.*

The central dogma of genetics has long been that information flows out of the gene, not back to it. Experience (the environment) does not change gene sequences (DNA), otherwise Lamarck would be correct. But information does flow back to genes to affect their expression. Genes are switched on and off by signals from the environment. These signals can be transcription factors (themselves encoded by genes) that bind to the promoter sequences of genes, or a range of other molecules, such as proteins, that transmit external environmental cues into some form of internal signal. For example, the 17CREB genes are part of the mechanism of learning and memory. If one of them does not work, then long-term memory cannot form. These genes alter the connections between nerves and are switched on when the brain lays down new memories. If you create no new memories, then these genes will not be used. The act of learning turns on these genes, and learning is affected by what we do as whole organisms in our environments.

Each of us carries our own phone-book set of genes, but not all of them are expressed in a lifetime. It depends on the external and internal signals that switch genes on and off. One example is the changing of skin colour. Over time, pale-skinned people living in environments with plenty of sunshine will become dark skinned. This is not because they acquire this characteristic and then pass it on to their children. It is because melanin production in the skin is very sensitive to exposure to sunlight. Sunlight switches on genes that individuals might have carried for their lifetime without expression (had they stayed out of the sun). Descendents have the same sets of genes, but they are switched on early in life, producing darker skin. Over time, whole populations living in sunny places will become dark skinned.

Philosopher Daniel Dennett has called the concern about genes and free will ‘the panic that lies underneath the surface’. Are we fully responsible for our actions? We may more often come to hear the cry ‘it’s not my fault, it’s the fault of my genes’. Indeed, this has already happened in the US, where in 1994 the lawyers for a convicted murderer, Stephen Mobley, argued in his appeal that he came from a long line of criminals and that he committed murder because his genes made him do it. In short, he wanted to pretend he had no free will. This raises more fundamental philosophical questions. People generally want to be responsible, want to have the choices to avoid a behaviour that may be coded for by a particular set of genes. Yet knowing about how genes and the environment interact could actually increase free will, not constrain it further, as some people worry. Ridley argues that ‘knowing you have an instinct makes it possible that you will decide to override that instinct’. When we know that certain genes are associated with certain kinds of behaviour, it does not mean that someone with that gene is locked into a certain and inevitable pathway. They still have choices. We rewrite ourselves as we grow.

Organisms do not evolve in a static environment. They are constantly changing it, and therefore changing the course of their own evolution. This is what Kevin Laland and John Odling-Smee have called 'niche construction'. Organisms modify the environment and so modify the sources of natural selection too (often to make them more favourable). All organisms constantly interact with their local environments, and so change them over time. Earthworms change the structure and chemical composition of soils by dragging leaves and other organic matter into the soil, thus mixing organic with inorganic materials. Thus 'contemporary earthworms live in worlds that have been partly niche-constructed by many generations of ancestors'. Other niche modification examples include elephants that uproot whole trees, open canopies, create parkland and recycle the herbage through their bodies, which in turn reduces the incidence of fires. Hippos create close-cropped riverside grasslands and, as large browsers, trample vegetation and keep the understorey open. Wild boar create open ground and aid tree germination, and beavers form riverside water meadows and coppice willows. Thousands of spectacled eider duck assemble on the Arctic Sea during winter, keeping the sea ice open through their continuous movement on the surface, so allowing them to dive down 60 metres to get food throughout the winter.

The idea of niche construction is similar to Dawkins' idea of the extended phenotype. Genes build environmental states beyond the organism to increase their chance of survival. Some extended phenotypes can be inherited, if the environment is changed, and benefit future generations, which then continue to maintain the environment in a favourable state. Ecological inheritance does not depend on just biological replicators (genes), but on the persistence of physical changes too. Organisms modify environmental resources. They effectively try to change their worlds to make them more favourable to their own survival. Laland and Odling-Smee suggest that organisms shape environments as surely as environments shape organisms, with the result that 'evolution is transformed from a linear to a cyclic process'.

But Odling-Smee and Laland also suggest another concept – that of negative niche construction, when organisms destroy their habitats. Could we humans be driving ourselves to extinction by harming the very environments in which we evolved so successfully? It is now an increasingly common conception that humans are well adapted to the ancestral Pleistocene environment, but not particularly to the industrialized environment. But this is only partly correct. Foundations were indeed laid in the Pleistocene, but evolution has been working since then. We have also been modifying the later environments, and these must have been having an effect on us too. Niche construction also suggests that the initial environment of savannahs was in the first place shaped by hominids. We did not simply evolve in one environment and then stop. We continued to change.

Time, though, is a key factor. We spent many thousands of generations in the savannahs before moving out across the world some 100,000 years ago, and so many design solutions of that time could be expected to have persisted to today. During most of our history, natural selection was the key determinant of who survived to pass on their genes – presumably those of us who jumped the furthest when the scimitar-toothed cat leapt, or those who knew where to find or catch food. Later, more complex components of culture came to play an important role, with the richest and most powerful having the resources to ensure their progeny survived best. Only recently, however, has culture come to dominate and build a new environment that is increasingly hostile to the genes we carry.

For most of our time, in other words, we have survived in a world rich in biological diversity. We have, of course, been part of this diversity, shaping it and being shaped in return. We change the environment – burn the grasses to prevent scrub encroachment, channel the water to trees, collect the fish with care – and it shapes us. The natural environment is not a fixed entity that does not change over time. We amend it and the environment affects which of us will survive. But if the shaping is harmful, does this mean we eventually harm ourselves? Are humans now, by causing massive species extinctions and changing the global climate, actually threatening the survival of modern civilisation? And it would be good to know now, as it might still be possible to do something about it.

Ancestral humans did clearly play a significant role in reducing biological diversity before this generation's extraordinary extinctions. We hunted the mammoths to extinction in Europe, the ground sloths in the Americas and the slow-moving ground marsupials in Australia. But nothing compares with today's losses – called by many, the sixth great extinction. The previous five were all caused by global geological or climatic catastrophes. This one is being provoked by humans alone.

One question might be, then, 'Are we still evolving?' Many would like to believe that human evolution stopped some 50,000 years ago, before races and groups diverged. But recent research on single nucleotide polymorphisms (SNPs) has shown that many versions of the same gene (called alleles) have evolved during the past 10,000 years. Genes known to be evolving include those for skin colour, skeletal development, hair formation, food metabolism (especially leptin control) and susceptibility to Alzheimer's disease. Bruce Lahn of the University of Chicago discovered a gene called microcephalin that emerged 14,000–60,000 years ago and is carried by 70 per cent of us, and another, ASPM, which is carried by a quarter of the world's population, even though it emerged only 500–14,000 years ago. If we are still evolving, then this may paint a different picture for how the future may unfold.

Another example is language acquisition. On chromosome 7, the forkhead box P2 gene (or FOXP2) codes for a transcription factor (switch for other genes) which, when broken, leads to severe language impairment. FOXP2 is necessary for the development of normal grammatical and speaking ability. In all mammals (including mice, chimps and humans), the gene is the same. But since humans and chimpanzees split, there have been two very small changes to the protein products. One mutation substitutes a serine molecule for an arginine at the 325th (of 715) position in the protein. The mutation appeared about 200,000 years ago and was so successful that it quickly came to dominate in all human populations. Humans and higher apes use completely different parts of the brain to produce calls compared with those that humans now use for language. This language centre is on the left side of the brain in a part of the motor region used for gestures.

A variety of other human traits have emerged as a result of recent evolution. These include the increase in myopia following the invention of spectacles, the spread of the ability to digest milk sugars after the invention of dairy farming, and the extension of our physical abilities without having to get bigger muscles after the invention of stone tools. We are now changing our environments even more and these changes will inevitably have some influence on future human evolution. This raises a variety of interesting questions. What types of environments shape which genes? Which environments are better for us and which worse? What is the effect of certain environments on our health? Moreover, what is it to be human, when so many of our genes are shared in identical fashion with other organisms? For example, the difference between two humans is 0.1 per cent of the genome (3 million base pairs); it is 1.5 per cent between a human and a chimpanzee (45 million base pairs). Humans and chimpanzees have some 30,000 genes, with only 450 differences. We also now know that the genetic variation between human populations is small compared with the differences within populations.

A good reason to be humble about our hominid status is the striking uniformity across species when it comes to genes. Humans share 3000 of our 30,000 genes with the fruit fly and round worm. We also share 1000 genes with unicellular yeast and 500 with bacteria (these are universal to all living things as they mediate DNA, RNA and protein links). Many of our genes and development pathways are thus shared with other organisms. For example, the hox (homeotic) genes lay down the body plan and work in identical fashion in flies, frogs and fish as well as us. As they are shared widely across species, the clear evolutionary implication is that these organisms share a common ancestor. We now know that one gene can do different jobs at different times and different genes can do the same job. Thus the presence or absence of a particular gene does not guarantee the presence or absence of a particular trait. It may do; it may not. It will depend on transcription factors and how they switch genes on and off. The Eve gene in fruit flies is switched on ten times in a fly's lifetime. It has 8 promoters and each promoter requires 10–15 transcription factors to switch it on. Thus a small number of genes can interact in very complex ways to do different jobs.

How, then, do some of these interactions occur? It is now known that early activities can change us for life. The behaviour of mother rats can influences the expression of genes in their offspring. If young pups are not licked and groomed, then methyl groups are added to the DNA of a receptor gene expressed in the hippocampus of the brain. This gene normally helps to mediate responses to stress, but when methylated, rat pups produce higher levels of stress hormones and are less confident in new environments. The effects last for life. Moshe Szyf and colleagues at McGill University in Montreal found that a common amino acid and food supplement, L-methionine, has a similar effect in adults: it methylates the gene and makes people more stressed. In theory it should be possible to find compounds that demethylate, though the problem is that most such compounds do many jobs and it may be very difficult to predict wider and unintended effects (methylation is not all bad – it helps to shut down human endogenous retroviruses that are inserted into our genes). We may find that a walk in the country acts in an equally good way to reduce stress.

Sarah Hardy, at University of California at Davis, believes that the way modern adults are rearing their children is likely to have long-term emotional effects. Society may be becoming less empathetic, especially as fewer people live in extended families. It is known, for example, that men who spend time with infants have lower testosterone levels. Without families or mixed communities, this natural control over high-octane behaviour is lost. In one-year-old children, the higher the testosterone level, the less eye contact is made by the baby with the mother. Females seem to have more interest than males in faces, and this gradually forms into a preference for social relationships. There are also other predictors. The more testosterone in the womb, the longer the ring finger of the embryo, as the hox genes that control the growth of genitals also control digit size. Men with long ring fingers have a greater risk of autism, dyslexia, stammering and immune dysfunction and have more sons. But men with very short fingers are at greater risk of heart disease and infertility. Like all of these types of correlation, though, it is very difficult to be clear about causality.

Some genes are also known to shape components of personality. The gene for brain-derived necrotrophic factor (BDNF) is on chromosome 11 and is a short gene of 1335 base pairs. The protein it produces encourages the growth of neurons in the brain. In three-quarters of humans, the 192nd letter is G; in a quarter, it is A. The G causes a methionine amino acid to be put in the 66th position on the protein; the A puts in valine instead. As we all have two copies of each gene, there are three kinds of people: met–met, who are likely to be the least neurotic, met–val, who tend to be intermediate, and val–val, who are the most neurotic. But, again, it does not mean we are stuck with these labels with no choice. We can still decide to behave in different ways. Owen Flanagan of Duke University has found that Buddhists who practise meditation have significantly increased activity in their left prefrontal lobes, indicating positive emotions and good mood (the right prefrontal lobe is for negative emotions). But Buddhists are not born happy. They develop the characteristic by learning and practised behaviour. Buddhist training also seems to change the way the brain responds to other stimuli. As a result of their distinct pasts, they are much less likely to be shocked, surprised or angry.

As knowledge of gene function increases, many new questions are raised about environmental influences. It is now known that weight is partially heritable: the correlation in weight between identical twins is 80 per cent, against only 43 per cent between fraternal twins. Thus, given the same access to food, some people will put on more weight than others. Food shortages during pregnancy change the likelihood of the embryo suffering from obesity in later life. A poorly nourished embryo is born expecting to live in a state of food deprivation throughout its life. Its metabolism is geared to being small and is good for hoarding calories and avoiding excessive exercise. If this individual finds itself with plenty of food all the time, then it responds by growing rapidly, putting on weight and straining its heart. If there is famine in the first two trimesters, then babies with normal birth weight themselves give birth to small babies. On the savannah and other locations where food is sometimes scarce, they survive. In cities populated with junk food outlets, they will not.

Genes and the environment shape IQ too. In studies of 350 pairs of twins, it was found that virtually all the IQ variability among the poorest group was accounted for by the environment and not genetic type. Among the richest, the opposite was true. Thus raising the safety net of the poorest does more to equalise opportunity than reducing inequality among the middle classes. Ironically, too, the more equal we make society and the environment, in other words the less wealth and background matter, the more genes define differences between us.

Ever since the earliest hominids stepped into the savannahs, some 250,000–350,000 generations ago, a dance of genetics and culture has determined which genes have survived to reach us today. In some circumstances, the fittest have survived – those that caused their bodies to run the furthest when prey needed chasing down. In others, the richest or most powerful survived – those with the resources to ensure their progeny survived best. It is the poorest who are more likely to suffer high levels of infant mortality; it is the richest who are more likely to pay their way out of a problem – buying clean water rather than relying on sewage-contaminated ponds. The balance between biology and culture changes through human history, but will it change again? What will the future bring? There are two certainties: environmental destruction will continue for some time, perhaps the whole of this century, and, at the same time, medical and biological technology will transform us internally, perhaps even bringing mergers with silicon technology to produce new cyborgs. We may bring on an age of destruction and an age of isolation at the same time.

When great civilisations fall, for whatever reasons, who among their people are most likely to survive? No longer does a particular bundle of cultural values or symbols of economic power guarantee survival. Indeed, those most likely to survive will be making a living without relying on the large infrastructure and institutions of a dominant civilisation. They will survive if they can grow and collect their own food, if they have families and neighbours who can work collectively, if they have the knowledge and skills to make a local livelihood. But is the inevitable outcome of our current civilisation to charge towards the precipice with our eyes closed, damaging the very environments that produced us? Will modern globalized society become number 41 on the list of departed civilisations? Or might there come another phase in human history, where we recognise the critical importance of the environment in making us who we are, and appreciate that harm to this world harms us too? Such a new phase may rely equally and intelligently on a mix of evolutionary and environmentally sensitive cultural influences. But is there any possibility of a further phase of human history centred on survival of the greenest, a process we might call ‘ecolution’?

For ecolution to happen, it is going to take some pretty big leaps of imagination. We will need to recognize that green places are important to us and then look after them. We will need to be more humble about ourselves and step off the comfortable plinths. 'There is nothing', as Laland and Brown have put it, 'about natural selection that supports a progression of population towards an end goal or higher state.' We will have to have a sensible adult debate about genetics and free will. And we will have to ask some tough questions about what it is we want to sustain. As David Orr asks, do we wish to preserve an 'intimate relation with nature or total mastery'? Do we want to preserve an ever richer world, but one that can only become richer by converting natural resources to monetary values, and also by increasing the gap between the poorest and richest? Or is their another way?

Natural selection produces diversity, but only because a variety of environments or conditions means that a range of genes are required. If the environment becomes a monoculture, then inevitably a more limited set of genes will be selected. Monocultures are not just bad because they are not diverse. They undermine the fundamental nature of the biological world itself. Today's industrialised processes have often come to mean a desire for homogenisation. Yet a diversity of environments, or opportunities, drives evolution, so not only are we destroying species through habitat destruction, we are undermining the likelihood of the persistence of the world as we know it. Evolution increases information content and increases intelligence. Will ecolution continue these processes after our current age of destruction – of biodiversity, of nature, of languages and communities, of stories? Good communities are places where imagination grows and memories persist. Does imagination, like intelligence, grow over time? And has it now stopped growing in the modern age? Has, in other words, normal evolution been put on hold (while we destroy and are destroyed)?

The key to ecolution is imagination, knowledge and interest; the same thing, time after time, no longer keeps us interested and we become bored. The modern homogenised world has reduced our understanding of the natural world, our daily connections, our capacities and desires to care. It is true that we develop other interests – and there is nothing inherently wrong in these, whether electronic games or films, or celebrity goings-on; the problem only emerges if we come to think of these as a replacement for the real world, and that there is no other reality that matters any more. Diversity of places (and their associated memories) is good, as it provokes imagination and desire and provides stability at the same time. It makes us think about how to solve new problems, how to understand things. After all, we all have genes passed on from a group of hominids that left the savannahs of Africa and dispersed across the world – discovering new environments, learning sufficiently rapidly to prevent consumption by larger predators and changing the world to suit us.

Evidence suggests that we have some innate connections to nature and also to diverse environments. When, then, do we lose heart and interest? When we no longer feel we can influence the future. When we have a repetitive and boring job, or when the commute to work is the same, day after day. We then yearn for something else, something new, an escape. Why do we go to different places for our holidays and in our leisure time? Why do we wish to visit the big city when we grow up in the country? Why do we wish to follow our relatives to another country? Of course, finance and opportunity play a role. That cities have streets paved with gold is an enduring component of many myths and stories. And when we do not move, then we do something else to keep up the interest and provoke imagination – we tell stories and create myths. We make the world more interesting by telling stories, which may carry important messages, but which most importantly seem to make our lives have more meaning. They are fuel for our minds. And without this, we are diminished, and our mental well-being suffers. We need mysteries and questions, as memories link the present to the past, compressing time into space. But a monoscape has no mysteries and no memories.

If we no longer have a big story that matters, we may no longer care. Despite great scientific consensus on the harm being caused to our planet, there is extraordinarily little macro-political or economic imperative that something fundamental might need to change. Why is this? Is it so easy to ignore the evidence or bodies of opinion on the effects of pollution or harm to the environment in the name of economic need or greed? We are going to need, at the very least, a better story. Increasing disconnections from nature mean more urbanisation and fewer rural communities, a more corporate world and less community spirit, more speed and less time, more simple solutions that do not recognise the world's complexity and diversity. As disconnections increase, we must in the end suffer a personal loss – in emotional well-being and in common identity. This will create a positive feedback, especially if we collectively do not realise why we face physical and mental ill-health. It is difficult enough to specify the effects of increased ultraviolet light on the skin because of diminished atmospheric ozone. But what about the effects of living by a forest compared with a concrete-dominated urban landscape? Or walking to work along a leafy lane versus a daily commute inside a half tonne of metal on rubber wheels? And so things will get worse, not better, unless we tell a different story and act differently, every one of us.

A phase of ecolution is now required, in which the value of cultural diversity is reaffirmed and the value of biological diversity is recognised and increased. But will this lead to the survival of the greenest – or simply once again the richest (or even the most environmentally destructive)? A preserved, green world has more opportunities for emotional well-being for the people in it – and different people like different environments, from the tundra to tropical rainforests, from the savannahs to the sands (and theatres, cafes and concert halls). If we lose these environments, then we lose the opportunity to express some of our genes, and thus these will decrease in frequency over time. And we will change. An environmentally impoverished world will be a post-human world. As the poet Gary Snyder says:

> *how could we **be** were it not for this planet that provided our very shape? The land gave us a stride, and the lake a dive [...] We should be thankful for that.*

Ecolution, then, suggests the need to recognise the tightly coupled nature of ecological and social systems and to develop new opportunities for creative self-organisation for enduring with this world. Our condition is linked to that of the planet. Now they are both in crisis, on a collision course, with the potential for destruction of biodiversity, cultures and life on this planet as we know it. In an imagined post-industrial world, human populations will fall, perhaps to as low as half of our current numbers. Many pressures will then have been lifted. But can we make it across this century, possibly the most critical of all human history?

Put simply, we collectively have the choice. Our genes are saying nothing. T S Eliot said that 'humankind cannot bear very much reality'. Our genes are at the mercy of the environment, as Matt Ridley points out. What kind of natural and social environments will we now create – ones that are harmful to us and our genes, or ones in which we can co-evolve and survive?

'The Earth only Endures' by Jules Pretty, chapter 15, 'Ecolution' – pages 197–211

Salient points from synoptic article, paragraph by paragraph

18/5/09 20:53

1. The gaia hypothesis: 'life helped make the erath a place where lfie could persist'
    - Average temperature of 13 C
    - Life alters Earth's biogeochemical cycles

2. Our genus emerged 2. 5million years ago, the species about 160'00 years ago
    - 'Survival of the fittest also means survival of those that influence their environments in a favourable way'

3. Mendel did peas, Crick, Watson, Franklin and Wilkins discovered DNA structure
    - We have 30'000 or so mapped genes

4. But we don't really know how to intepret all the data, the 30'000 mapped genes mean little
    - Like a phone book doesn't give you the full picture of a functioning city

5. Our genes have to be switched on or off (inducted)
    - E.g. Blood groups, A & B are dominant but rare alleles, have neither and you are O
    - Other primates share this blood typing (gorillas are all B type)
    - Personality, intelligence, cancer; all are influenced by genes
    - And genes in turn are influenced by the environment

6. Nature versus nurture debate
    - Wilson's **Sociobiology** claimed to explain everything in terms of nature
    - Not true, of course
    - The idea of a meme, an idea which, like a gene, is passed on and mutates

7. Misintepretation and controversy, notably eugneics
    - Sir Francis Galton pioneered twin studies but was also keen on 'improving human stock'

8. Creationism is still widely accepted despite evolutions support from authorities
    - Only around 50% of us believe in evoliution
    - 40% in creationism, 10% don't know
    - Yet evolution is all around us, in the flu jab, domestic breeding, HIV etc

9. Evolution can appear to have a direction
    - But it doesn't, although simple does tend to complex
    - We are just another stage of the evolution of the species, not the end point, nor the 'best model'

10.Lamarck and social Darwinism, ontogeny mimics phylogeny
    - The idea of **recapitulation**, where the developing embryos of 'more advanced species' appear to resemble those of 'less advanced species' during development
    - Which is balls
    - Morgan's **Ancient Society** suggested 7 stages of human cultural evolution, very suited to racism and Europeancentric views

11. Determinism in evolution; if we are all nature, do we have any free will?
    - Ethologists such as Konrad Lorenze showed instinct in animals, determinism (we have no free will, all prior cause and effect)
    - Whereas philosophers such as John Stuart Mill (and Stephen Pinker) think that we do have free will, and that we start with 'a blank slate'

12. Desmond Morris' **The Naked Ape** proposed that we evolved in the stone age, and thus that our behaviour could be explained by reference to those conditions
    - However, this fails to take into account culture and free will
    - There is a problem because everybody is so strongly opinionated

13. 'We are an emergent property of both genes and ecological-social movements
    - So genes don't act in isolation
    - And since we can alter the latter, we 'have a choice'
    - 'The bogey of genetic determinism needs to be laid to rest' – Dawkins

14. Evolutionary theory has spawned many strands
    - Sociobiology, evolutionary psychology, memtics tc.
    - Generally recognized that although we evolved physically to suit a stone age environment, but recent cultural and social situations still effected evolution

15. How much choice do we really have, if genes don't play the lone fiddle?

16. More stuff about how neither nurture or nature is purely correct
    - And 'false insights' have led to loads of bad stuff, namely tyranny and fascism
    - 'genes spend just as much of their time responding to our actions as they do causing them. Genes do not constrain human freedom, they enable it'- Matt Ridley

17. Information flows out of the gene, not back into it
    - But although base sequences aren't altered, transcription can be
    - E.g. the 17CREB genes are part of learning and memory
        - And by using them we boost their transcription (I think this is what he's saying?)

18. Stuff about melanin production being controlled by genes which are only expressed in the sun, so populations living in the sun become dark skinned over time?
    - This is crap, according to an eminent dermatologist

19. Can we use genes to excuse our actions?
    - Stephen Mobley, a murderer, claimed that his genetic heritage as the latest in a family of criminals deprived him of free will
    - However, understanding our genetics more thoroughly should instead allow us to more thoroughly suppress those unsavoury behaviours we know we have tendency towards

20. Niche construction is where organisms modify their environment to make it more conductive to their own survival (suggested by a pair called Laland and Odlin-Smee)
    - E.g. Earthworms munch up the soil
        - Elephants smash up trees
        - Beavers create dams
        - Eider duck keep ice open on the Arctic Sea to facilitate their migration

21. Similar to Dawkin's idea of the extended phenotype
    - Some extended phenotypes can be inherited
    - 'Evolution is transformed from a linear to a cyclic process'

22. There is also the question of 'negative niche construction'
    - Where organisms destroy their own environments

- Like us

23. Only recently have we started to create an environment detrimental to the genes we carry

24. We have evolved in an environment with lots of biodiversity
    - And it has shaped our development too
    - So if we harm it, do we harm ourselves (duh!)

25. We've been doing it for a long time, hunting mammoths, ground marsupials and ground sloths to extiniction
    - We are in 'the sixth great extinction', this one human made

26. Are we still evolving?
    - Single Nucleotide Polymorphisms (SNIPS) show that there is still lots of genetic variation
        - Including skin colour, hair formation and metabolism (especially Leptid control, involved in obesity)
        - Some gene called ASPM is carried by a ¼ of world population, though it only emerged 500-14,000 years ago

27. Language acquisition is also interesting
    - The FOXP2 gene controls langueg; if you don't have it, you can't communicate fully
    - We have a slightly different gene from chimps; this single amino acid mutation is entirely dominant in the human gene pool

28. Other traits are results of recent human evolution
    - Myopia is up since spectacles were invented
        - (Surely this is due to improved diagnosis, as those people still at the cutting edge of evolution don't have provision of spectacles)
    - Lactose tolerance improved after the spread of dairy farming
        - (Again, surely you can't tell as pre-dairy farming barely anybody would have eaten lactose anyway?)

In a seemingly unrelated point, humans and chimps have only 450 differences in genes, sharing 30,000, and the difference between two humans is just 0.1% of the genome.

- Genetic variation within populations is far greater than that between populations

29. We share loads of genes with humble animals such as the fruit fly and round worm, yeats, and bacteria.
    - E.g. The homoebox (HOX) genes which control and orchestrate physiology and expression of genes are identical in flies, fish, frogs and us.
    - This implies that we all share a common evolutionary ancestor
    - There may be loads of transcription factors, too; having a gene is a far cry from having it expressed
        - The EVE gene in fruit flies has 8 promoter regions, each requiring 10-15 transcription factors!

30. Early experiences can alter our gene expression for lfie
    - If young rats aren't licked and groomed, methylation of DNA groups in the hippocampus leaves them unable to cope with stress and extremely shy
    - For life
    - Similarly, the amino acid L-methionine methylates the same gene and makes people more stressed
    - But methylation is also useful; it also helps combat retroviruses…

31. The way families rear children can have long lasting effects on society
    - Lack of extended familes and decreased child-parent contact leads to higher testosterone in men (I would question whether men really do spend less time than ever before with their children)
    - The more testosterone you have, the more likely you are to be autistic, dyslexic or have immune dysfunction
    - But if you don't have enough, you are more likely to get CHD or be infertile!
    - Question of causality vs. correlation

32. Genetics also influence personality, as evidenced by the BDNF gene which influences how neurotic you are
    - With three common alleles, met-met, met-val, val-val; the more val you have, the more neurotic you are!
    - However, we can still control our personalities; for instance, Buddhist monks meditate and become happier, less shockable and more stable! (What about causality vs. correlation here?)

33. Weight is partially heritable

- 80% the same in identical twins, 43% in fraternal (non-identical) twins
- Food shortages during pregnancy make you more likely to be fat
    - As you kick into some kind of energy saving mode
- And famine for the first 2 trimesters produces smaller, more energy efficient babies!
- Again, our altered environment is to blame for problems such as obesity; we aren't evolved to eat in McDonalds

34. IQ also varies. In studies of twins, the variation among the poorest sets of twins was mostly accounted for by environment, whilst among richer twins, genetic variation played more of a role.

- (I can't make head or tale of this. Why is there genetic variation between twins, and if you have 'poorer sets', won't they both just grow up in a poor enviroment? Lack of experimental clarity here!)

35. We should be scared because we are destroying the earth, and will continue to do so for quite a while.

36. Who will survive this great big collapse?

- We have lost lots of the relevant skills which would help us to survive a fractured society
- Could we be entering an age of survival of the greenest. 'ecolution'?
    - (No, if some go, we all go)

37. We will have to be very wise if we are to survive

- And be nice to each other and the environment

38. Monocultures (i.e. a lack of biodiversity) are bad because they reduce genetic diversity and hence our ability to respond to new situations

- And we may have also hindered our imaginative and intellectual diversity

39. We have lost the intellectual edge that allowed us to evolve so successfully.

40. We feel sad because we have ruined the world and we live in boring places and lead boring lives.

41.We also stand to suffer from mental ill health and lax government if we sever our connection to nature completely

- And there is positive feedback as we get laxer, lazier and more miserable, and become less likely to change things
- And macro-political change is hard to come by; we can never agree on anything globally

42. So we must reaffirm the value of cultural and ecological diversity and preservation

- And develop more integrated systems of society and environment
- Both we and the planet are in trouble

43. Our genes merely facilitate, not dictate, the choices we have to make.

- It is up to us to produce positive natural and social environments.

Sample questions & answers for the SNAB Unit 6 exam, based around the synoptic article, from Jules Pretty's 'The Earth Only Endures'

Unofficial!

Archy de Berker www.deberker.com 2009

1.

a) Pretty states *'survival of the fittest also means those that influence their environments in a favourable way'* **How does this relate to, and what is an example of, niche construction?**

(3)

b) Which environment does Pretty claim that humans are evolved to survive in?

(1)

c) Explain the idea of recapitulation, or 'ontogeny mimics phylogeny', and explain why it has since been proved outdated.

(3)

2.

a) What is genetic determinism?

(1)

b) Ridley states *'genes spend just as much of their time responding to our actions as they do causing them. Genes do not constrain human freedom, they enable it.'*

i) What is a transcription factor?

(1)

(ii) What is a promoter region?

(1)

(iii) In what way can our treatment of the environment affect genetic diversity, and why is genetic diversity important?

(3)

(c) What is your understanding of the term 'epigenetics', and which chemical group does Pretty cite as being a chemical effector of epigenetics, and in what way?

(3)

3.

a) What role does a FOXP2 gene play in humans, and why has it been so successful?

(2)

i) Describe the mechanism by which the FOXP2 gene became predominant in the human gene-pool.

(3)

ii) What evidence is there that evolution has taken place in the last 10,000 years, and why would many argue that selection of the fit test is no longer relevant to modern society?

(2)

b) What role do Hox, or homeotic genes, play, and in what way do they lend support to the idea of descent from a common ancestor?

(2)

4.

a) What does Pretty mean by his phrase 'Ecolution', and in what way is this theory obviously flawed?

(2)

b) Which type of study does Pretty use to discuss the nurture/nature debate, and which does he declare to be the dominant force?

(2)

c) What might be the physiological basis for diseases such as depression, and how might they be treated?

(3)

Total Mark: 32

ANSWERS

1.

a) Pretty states 'survival of the fittest also means those that influence their environments in a favourable way' How does this relate to, and what is an example of, niche construction?

- **Niche construction is modifying the environment to facilitate your own survival**
- **Therefore, Pretty implies that the successful creation of niches is a selection pressure**
- **Examples of niches: Beavers creating dams, Hippos trampling grassland, Eider duck keeping ice open for migration, earthworms changing edaphic conditions etc.**

(3)

b) Which environment does Pretty claim that humans are evolved to survive in?

- **The Pleistocene environment.**

(1)

c) Explain the idea of recapitulation, or 'ontogeny mimics phylogeny', and explain why it has since been proved outdated.

- **The idea that developing young within the womb pass through a series of stages that resemble its less developed relations e.g. Human foetuses might look like fish at one point.**
- **However, once we recognize that evolution has NO DIRECTION, then we must abandon the idea of more or less 'developed' or 'advanced' relations, and the idea of recapitulation.**
- **Additionally, it just isn't true; a close examination of anatomy reveals very few similarities between embryotic animals and their adult relatives.**

(3)

2.

a) What is genetic determinism?

- **The idea that our genes determine our fate, and that we are powerless to influence it ourselves.**

(1)

b) Ridley states 'genes spend just as much of their time responding to our actions as they do causing them. Genes do not constrain human freedom, they enable it.'

i) What is a transcription factor?

- **A molecule which must be present for the induction, or 'switching on' of a gene.**

(1)

(ii) What is a promoter region?

- **The region to which a transcription factor binds during gene induction.**

(1)

(iii) In what way can our treatment of the environment affect genetic diversity, and why is genetic diversity important?

- **The environment influences selection pressures**
- **So more varied environments lead to a more varied gene pool, and more genetic diversity**
- **Genetic diversity is important as it offers flexibility and an ability to adapt to new situations**

(2)

(c) What is your understanding of the term 'epigenetics', and which chemical group does Pretty cite as being a chemical effector of epigenetics, and in what way?

- **Epigenetics is the idea that there can be a changes in gene expression and phenotype involving the genome but not in terms of the order of bases in our DNA**
- **Methy groups/ Methylation is cited as an epigenetic factor**
- **Methyl groups are added to receptor genes**
- **And can influence the stress levels of rat pups and people**
- **Methylation also helps suppress retroviruses**

(3)

3.

a) What role does a FOXP2 gene play in humans, and why has it been so successful?

- **FOXP2 facillitates language/ communication**
- **The ability to communicate is extremely useful, allowing cooperation in terms of hunting, building houses, and tribal warfare etc.**
- **Thus giving a selective advantage**

(2)

i) Describe the mechanism by which the FOXP2 gene became predominant in the human gene-pool.

- **Natural selection**
- **A mutation (arginine replaces serine at 325th position) caused the FOXP2 gene to exist**
- **This mutation provided those humans that had it with a selective advantage**
- **They therefore outbred and outsurvived those unfortunate early humans who didn't have the mutation**
- **To the extent where it has become ubiquitous in human populations**

(3)

ii) What evidence is there that evolution has taken place in the last 10,000 years, and why would many argue that survival of the fittest is no longer relevant to modern society?

- **The fact that SNP (Single Nucleotide Polymorphisms) analysis has revealed that new alleles have developed in the last 10 000 years indicates that evolution is ongoing**
- **However, in modern society there are few selection pressures**
- **As we keep those who can't survive, alive through advanced healthcare**
- **The Malthusian population pressure is therefore removed (bar in some LEDCs), so natural selection can't take place.**

b) What role do Hox, or homeotic genes, play, and in what way do they lend support to the idea of descent from a common ancestor?

- **Hox genes are involved in anatomical development**

- **Laying out the body in segments, and directing ontogeny**
- **Since they are unanimous in nature, they support the idea that we all evolved from a common ancestor**

(2)

4.

a) What does Pretty mean by his phrase 'Ecolution', and in what way is this theory obviously flawed?

- **'Survival of the greenest'; those who take care of their environment with most diligence and success survive**
- **It is flawed because the actions of others impact our environment massively**
- **And so there is no uninterrupted causal link between our actions and our environment, so natural selection on the basis of 'the greenest' is impossible**

(2)

b) Which type of study does Pretty use to discuss the nurture/nature debate, and which does he declare to be the dominant force?

- **Twin studies**
- **Pretty asserts that both are involved to varying extents, neither is universally dominant**
- **With some variation in how important both are depending on the situation**
- **Examples such as IQ, height, weight.**

(2)

c) What might be the physiological basis for diseases such as depression, and how might they be treated?

- **Corrupted neurotransmission in the brain**
- **Serotonin affected (serotonin synthesis low)**
- **Treated with SSRIs (Selective Serotonin Reuptake Inhibitors)**
- **Which prevent the reuptake of serotonin from synapses**
- **Hence boosting serotonin levels in synapses, and boosting transmission in those pathways**

(3)

Total Mark: 32

Topic 1

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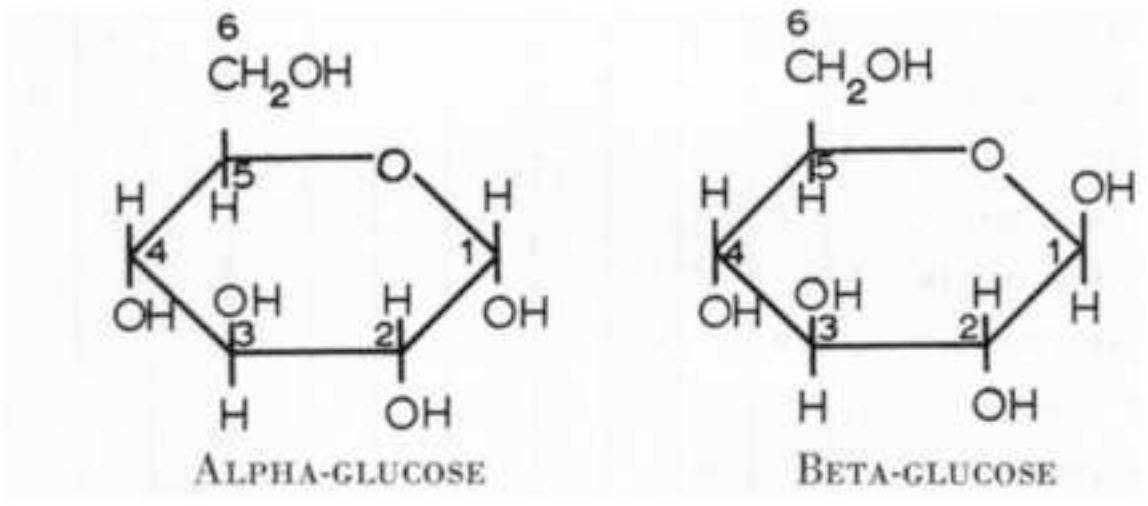
Risk perception

- We get scared by things we don't understand
- And can't control

- Monosaccharides:
  - Glucose: hexose sugar, below



- Galactose- mainly in milk.
- Sucrose- found naturally in fruit, honey and veg

Disaccharides:

- Maltose: 2 x glucose molecules. Found in germinating seeds.
- Lactose: Glucose + Galactose
- Sucrose: Glucose + fructose

Polysaccharides

- Form glycosidic links in condensation reactions
- Starch in plants
  - Amylose (straight) + Amylopectin (forked)
- Glycogen in humans
  - Lots of branches, like amylopectin
  - Stored in the liver
    - Both insoluble storage units
    - Both high energy

- Cellulose
    - Insoluble, dietary fibre
    - Straight chain. multiple glucose molecules

Lipids

- 3 x fatty acids, one glycerol
- Saturated without double bond, unsaturated with
- Insoluble
- High energy
- Good insulator
- Combine with phosphate group to produce phospholipids

HDL

- High density lipoproteins
- Made from unsaturated fats
- Takes cholesterol to the liver for break down
- Good

LDL

- Low density lipoproteins
- Transport cholesterols to cells, binding to LDL receptors
- Too many LDLs overload receptors, causing cholesterol to be deposited in vascular tissue, forming atheromas.
- Bad

BMI

- Weight in kg / (Height in m)^2

Proteins

- Multiple amino acids
- Joined by condensation reactions to form peptide bonds
- Structure
    - Primary: Order of amino acids
    - Secondary: alpha helices or beta pleated sheets, held by H-Bonds
    - Tertiary: Folding due to disulphide bridges, h-bonds and ionic bonds.
    - Quaternary: Multiple proteins in one, e.g. haemoglobin
- Haem is a prosthetic group (non protein)

Blood pressure = hydrostatic pressure (pressure exerted by a liquid)

- Systolic/ Diastolic (Contracted/ Relaxed)
- Greater peripheral resistance = Greater blood pressure
- High blood pressure = hypertension
- More likely to damage vessels
- Can cause OEDEMA
    - Tissue fluid forced out of the blood by high pressure and cannot get back in at venous end
    - Often associated with left sided heart failure

Risk factors:

- Hereditary
- Age related
- Gender related
- Stop smoking (hypertension, reduced O2 in blood, damage to epithelium walls from CO)
- Do exercise: raises HDL levels, reduces likelihood of diabetes and lowers body mass
- Antioxidants prevent free radical damage (causes senescence and cancer)
- Lower salt intake; salt increases fluid in the blood, raising pressure & CHD risk
- Stress
- Alcohol consumption raises blood pressure, increases fibrillation and obesity. LDLs may also be created from ethanal.

Diet

- Low salt
- Low sat fat
- High unsat fat
- Soluble fibre
- Low cholesterol
- Fruty & veg for antioxidants & soluble fibre
- Oily fish (for unsat fats)
- Sterols and stanols lower blood pressure

Drugs

- Anticoagulants such as aspirin or clopidogrel
- Stanols in margerine

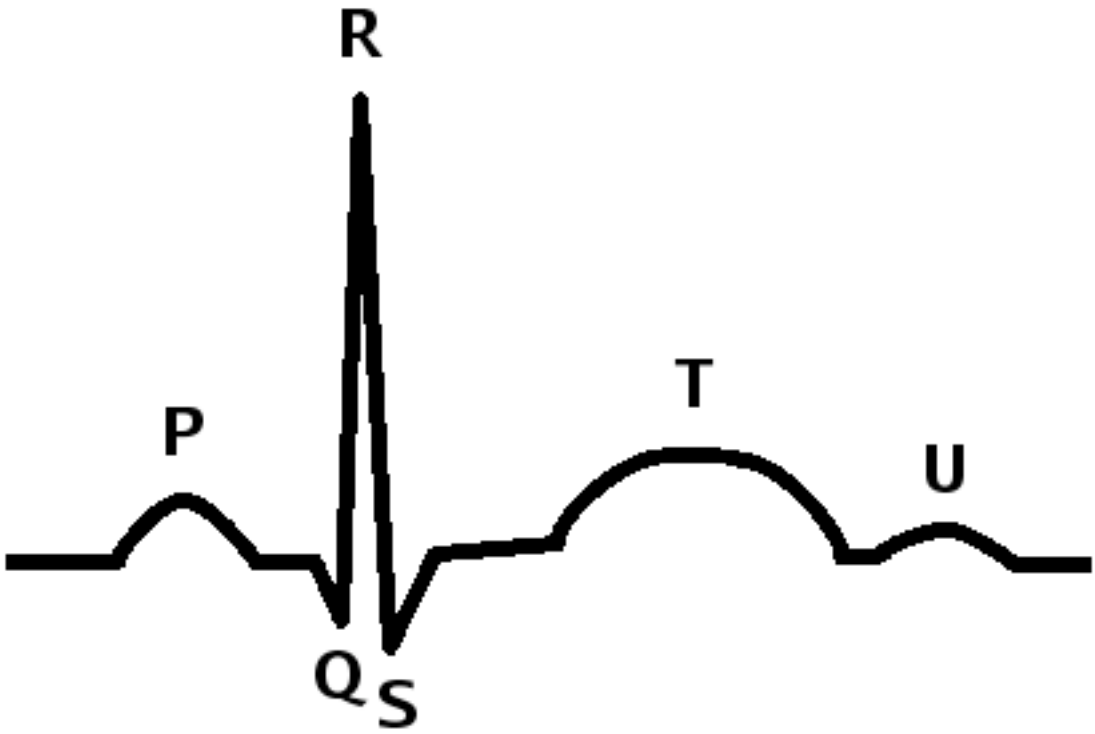
Surgery

- Coronary angioplasty
    - Small balloon on catheter forces vessels open
- Cardiac bypass
    - Blood vessel, usually from leg or chest, is grafted onto blocked artery, bypassing the blockage

ECGs

- Can identify tachy- and brady- cardia (high and low heart rates)
- Bradycardia can indicate
    - Hypothermia
    - Ischaemic heart disease
    - Medicine/drug use
- Tachycardia
    - Coronary heart disease
    - Heart failure
    - Anaemia or fluid loss
- Can identify arrhythmias
- And fibrillation
- Areas of damage and irregular blood flow
- QRS complex

- P wave is depolarisation of atrium, leading to atrial contraction



- QRS complex shows ventricular systole
- T is repolarisation of the ventricles

The heart's electrical activity

- SAN node (pacemaker)
    - Is controlled by the medulla oblongata via the vagus and sympathetic nerves
    - Generates a signal which spreads across the atrium, causing rapid depolarisation
- AVN node
    - Situated on the non-conducting wall
    - Transmits signal along bundles of his/ purkyne fibres to the apex of the ventricle
    - Depolarisation then spreads upwards

Symptoms of CHD

- Angina

    - Sharp chest pains and shooting pains down left side
    - Caused by build up of lactic acid through anaerobic respiration
- Breathlessness
- Burning chest
- Eventually, risk of **myocardial infarction,** or heart attack, if coronary artery is properly blocked.

The threats

- Embolism
    - When a blood clot breaks off and flows in the blood until a smaller arteriole, which is then blocks
- Thrombosis
    - A clot
- Aneurysm
    - Where a plaque leads to a ballooning and often breaking of a blood vessel especially if it is under high pressure.

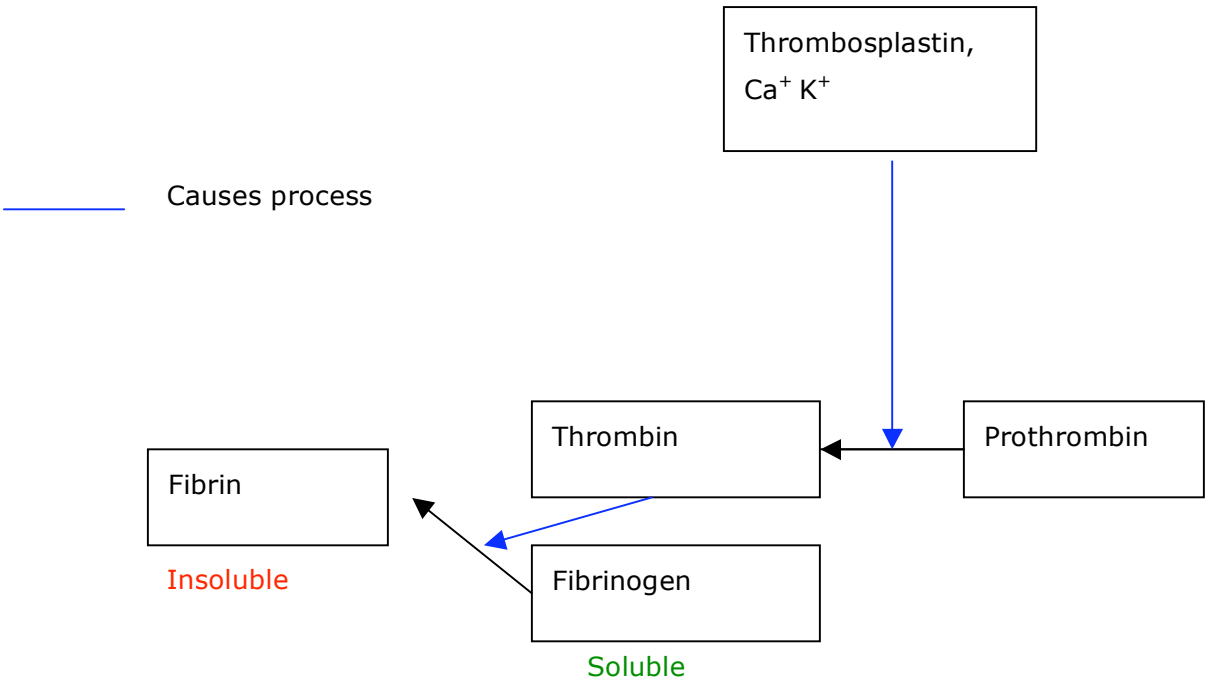
Stroke

- Caused when the brain becomes oxygen starved
- Symptoms
    - Numbness
    - Dizziness
    - Confusion
    - Slurred speech
    - Blurred or loss of vision, often in only one eye
    - Paralysis in opposite side of body
- If blood flow is only slightly interrupted, a mini stroke, or transient ischaemic attack may occur

Clotting

1. The lining of the lumen becomes damaged
2. The damaged endothelium releases clotting agents (**thromboplastin & Ca^+ K^+)**
3. A cascade of chemical changes occurs, with soluble fibrinogen being convert to insoluble fibrin
4. A platelet plug forms, causing a clot, or **thrombosis.**

thromboplastin & Ca^+ K^+



Atherosclerosis

1. The endothelium becomes damaged
2. There is an inflammatory response, caused by the cessation of NO production, which causes monocytes to leave the blood to become foam macrophages in the endothelium. These accumulate LDL, or 'bad cholesterol'.
3. An atheroma is therefore formed
4. The atheroma hardens into a plaque as calcium salts and fibrous tissue build up.
5. This narrows the artery, raising blood pressure and creating positive feedback.

The heart

- One complete sequence of filling and pumping out of blood is called a cardiac cycle
- Three stages:

1.1. Atrial Systole

- The atria contract, forcing blood through the atrioventricular valves into the ventricles

1.2 Ventricular Systole

- ventricles contract from the base of the heart upwards
- AV valves are forced closed

2.1 Diastole

- Both atria and ventricles then relax
- Elastic recoil lowers pressure in both chambes
- Semilunar valves are forced shut to prevent backflow
- Low pressure in the atria helps draw blood in from the veins

It is the sound of the closing of the AV and semilunar valves that create the heartbeat.

Vessels

Arteries	**Veins**
Narrow lumen	Wide lumen
Thick walls	Thin walls
More collagen, elastic fibres and muscle	Less collagen, elastic fibres and muscle
No valves	Valves
High pressure	Low pressure

Both have:

- Endothelium
    - Made from epithelial cells
    - Inner layer of cells in the lumen
    - Sensitive to damage
    - Prevent blood from touching the muscle and elastic tissue
- A tough outer coat made from connective fibres and collagen

Capillaries are only a single epithelial cell thick, allowing easy diffusion in and out of them.

Blood flow

- Artieries
    - Stretch during systole
    - Contraction in sections during diastole forces blood along
- Veins
    - Blood flow aided by the contraction of skeletal muscle through movement
    - Valves prevent backflow
    - Lower pressure

Why have a heart? (Circulatory System= Mass flow system)

- If you are too big for diffusion to provide you with oxygen and water
- Closed circulatory system
    - Allows high pressure by using narrow tubes
    - Valves ensure unidirectional flow of blood
        - Single circulatory system

        - E.G in fish
            - Heart → Gills→ Body → Heart
- Double circulatory system
    - E.G in mammals
        - Heart → Lungs → Heart → body → heart
        - This means that during a cardiac cycle, blood passes through the heart twice
        - Allowing higher pressure and larger bodies/ high BMR

Topic 2

15/4/09 14:12

Mucus

- A thin layer coats the airways
- This captures pathogens
- And is shifted out of the lungs by the movement of cilia on epithelial cells
- CF mucus is drier, and so more sticky and thick
    - This increases the likelihood of lung infection
    - And reduces the efficiency of gas exchange

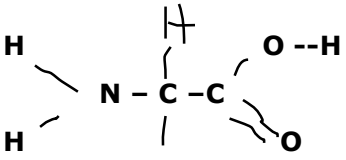
Gas exchange

- Features of the alveoli that make them brill for gas exchange:
    - Large surface area
    - High vascularisation
    - Vey thin
    - Slightly moist
- Fick's Law:
    - Rate of diffusion $\propto$ $\frac{\text{surface area x difference in concentration}}{\text{Thickness of gas exchange surface}}$
- People with CF
    - Have thicker mucus
        - This blocks the tiny bronchioles
        - Preventing efficient gas exchange

Pathogens in lungs

- Usually the mucus is shifted out by the cilia and coughed out or swallowed, removing pathogens from the airways
- CF mucus cannot be shifted so easily
    - The mucus is also anaerobic, breeding dangerous microbes
    - And white blood cells also contribute to the sticky mess

Amino acids & Polypeptides: 20 amino acids



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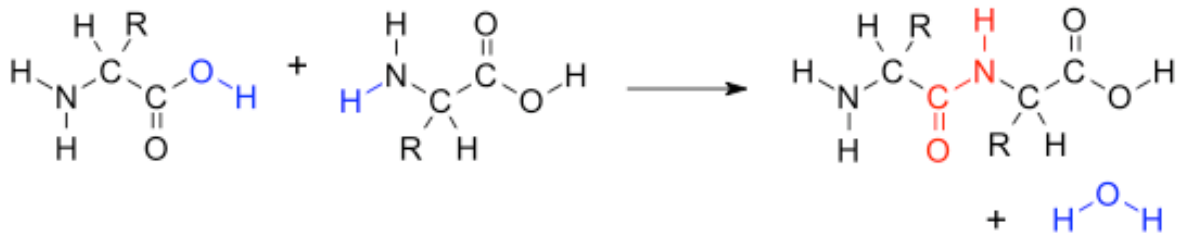
Joined in condensation reactions



Proteins

- Multiple amino acids
- Joined by condensation reactions to form peptide bonds
- Broken by hydrolysis, often with the aid of enzymes
- Structure
    - Primary: Order of amino acids
    - Secondary: ∝-helices or ß-pleated sheets, held by H-Bonds
    - Tertiary: Folding due to disulphide bridges, H-bonds and ionic bonds.
    - Quaternary: Multiple proteins in one, e.g. haemoglobin
- Haem is a prosthetic group (non protein), in a conjugated protein- one that has another chemical group associated with the polypeptide chains
- Fibrous
    - Long chains, often with cross linked multiple polypeptide chains. Insoluble and important structurally; keratin, collagen.
- Globular
    - Compact spherical shape achieved due to hydrophobic side chains
    - Important for metabolic reactions; examples such as enzymes.
    - The 3D shape of these proteins are very important; antibodies, enzymes and transport proteins all rely upon active sites with a specific shape.

Cell membrane structure

- The main structure is a phospholipids bilayer (phosphate group replacing one of the fatty acids in a triglyceride)
    - These have hydrophilic heads (rendered so by the phosphate group)
    - And hydrophobic tails

    - And so form with heads outwards, either in a bilayer or a globe called a micelle.
    - They allow small lipid molecules to pass through
- Fluid mosaic
    - The structure of the cell membrane is often described as a fluid mosaic; it is a dynamic environment chock a block with other molecules. These include
        - Glycoproteins
            - Proteins + A polysaccharide
        - Glycolipids
            - Lipids + A polysaccharide
        - Cholesterol
        - Transport proteins
            - These are specific fit, and can be active or passive transport
        - Channel Proteins
            - Larger molecules and charged ions pass through these. They are often in tandem with a receptor protein, which opens or closes the channel depending upon the nature of the substrate to be transported
    - The fluidity of the membrane depends upon the % composition of unsaturated fatty acids; the more there are, the more fluid it is. This is because the kinks in the unsaturated tails prevent them from packing together. Cholesterol also affects fluidity, reducing it by preventing phospholipids movement.
- Temperature dependent
    - Test with chunks of beetroot, examine speed of departure of purple dye at different temperatures. Test resulting solution with colorimeter.

Transport

- Passive
    - Diffusion
        - Down a conc gradient
            - Osmosis is a special case, involving water and a semi-permeable membrane, which doesn't allow the solute through

        - In the phospholipids bilayer, only small, uncharged molecules can pass through by diffusion
    - Facilitated diffusion
        - Similarly, down a conc gradient, but aided by channel proteins (gated or not) or carrier proteins (still down a conc gradient due to increased likelihood of binding in increased conc)
        - This is for charged molecules or those too large to pass through the bilayer
- Active
    - Specific carrier proteins, aided by ATP, carry substrates AGAINST a concentration gradient
- Bulk
    - Achieved by endo & exocytosis
    - Part of the cell membrane engulfs the substrate (endocytosis) and travels through the membrane, releasing the substrate and reuniting with the other layer of the bilayer on the other side (exocytosis).

CF sticky mucus

- Caused by a fault in the CFTR protein, which leads to water being continually removed from the mucus by osmosis, as Na^+ and Cl^- are also continually removed into the tissue fluid
- This impacts:
    - Gas transfer (see above)
    - Digestive system
        - The mucus blocks enzymatic ducts in the pancreas and liver (the pancreatic duct), preventing full digestion of food
        - Therefore, you get highly nutritious stool
        - And CF sufferers find it hard to gain and sustain weight (malabsorption)
        - There may also be a damaging build up of enzymes in the pancreas, inhibiting insulin regulation and leading to diabetes
    - Reproductive system
        - Sperm ducts are blocked by mucus, reducing fertility, or even absent
        - Cervix is blocked with a thick plug of mucus

- Salty sweat is a sign of CF, as the CFTR protein works in the opposite way in sweat ducts, preventing salt from being pumped back into the tissue fluid

Enzymes

- Specific fit
    - Due to active site shape
    - Specific substrate causes an enzyme-substrate complex to be formed
- Lock and key theory
    - Absolutely specific fit
- Induced fit theory
    - Mostly specific, slight adaptation on the part of the enzyme to fit the substrate
- Provide an alternative reaction pathway with a lower activation energy
- Remain unchanged at the end of the process
- Rate testing
    - Done by testing the time taken for a certain substrate to be metabolised
        - E.G H_2O_2 with catalase (from peas or potatoes), test breakdown into constituent gases at different temperatures

DNA

- Consists of multiple mononucleotides, linked by condensation reactions to form a polynucleotide
- A nucleotide unit consists of a phosphate molecule, a deoxyribose sugar and a nitrogenous base.
- Purine (2 ring)
    - Adenine
    - Guanine
- Pyrimidine (1 ring)
    - Thymine/ Uracil
    - Cytosine
- Arranged in triplet code
- Degenerate
    - Multiple codes per amino acids
- Semi-conservative replication
    - In mitosis, the new cell has one old and one new strand of DNA
- It is non overlapping

    - The codons are distinct from one another, read in non-overlapping blocks of 3

Protein synthesis

- Transcription
    - mRNA in the nucleus creates the sense strand from the antisense template strand of DNA
    - RNA polymerase helps create the complementary strand
    - mRNA chain leaves via nuclear pores
- Translation
    - mRNA attaches to a ribosome, free or on the rough ER
    - tRNA anticodons with attached amino acids join them, starting with the start codon AUG and ending with stop codon UAA, UAC or UGA
    - The amino acids are joined via condensation reactions, forming peptide bonds

DNA synthesis

- Helicase enzyme unzips the DNA
- DNA polymerase builds a new strand, building 5' to 3'; one strand is therefore built completely, the other in small chunks.
- These chunks are later joined by ligase enzymes

Mutations and sickle cell anaemia

- Most mutations occur in non-coding DNA, and so have no effect
- Sickle cell anaemia sees glutamic acid replacing valine
- Rendering the haemoglobin less soluble, and distorting the red blood cells into sickle moon shapes which carry less oxygen and can block blood vessels, causing bad joints.

CF mutation

- There are many different mutations that can give rise to a faulty CFTR protein, and hence CF
- The most common one is a deletion of three nucleotides, causing the loss of phenylalanine and destroying the 3D structure.
- Other problems include
    - ATP not being able to bind and open the ion channel

- Blocked channel

Mendelian inheritance

- Genotype
  - The combination of alleles inherited
- Phenotype
  - The physical expression of these genes; the interaction between the genotype and the environment
- Recessive allele
  - Will not be expressed if a dominant allele is present
- Dominant allele
  - Will always be expressed if present
- Homozygote
  - Containing two copies of the same allele
- Heterozygote
  - Containing two different alleles
- Locus
  - The same position on a pair of homologous chromosomes (1 paternal, 1 maternal)
- Monohybrid inheritance
  - Where the inheritance of a characteristic depends only upon a single gene. Most are controlled in more complicated ways.
    - E.G. Thalassaemia is caused by recessive alleles of a gene on chromosome 11, and affects the manufacture of haemoglobin. However, heterozygous people are somewhat resistant to malaria, giving a slight advantage to heterozygotes.
    - Other recessive illnesses
      - Albinism
      - Phenlyketonuria
      - Sickle cell anaemia
    - Dominant illnesses
      - Dwarfism
      - Huntingdon's
- Mendel
  - Worked with peas

- Particularly height and texture of pea
- Discovered monohybrid inheritance

Gene therapy

1.1. Desired allele is inserted into a target cell via a viral vector or liposomes
1.2. The normal form of the gene is therefore transcribed, translated and expressed
1.3. The functioning protein is provided in target cells

Viral insertion

- Replication sequence removed to prevent widespread infection
- Replaced with desired gene and promotor region
- With CFTR, the virus used has independent DNA, non incorporated into our cells
- But is still transcribed

Liposome insertion

- Desired DNA in plasmid
- Plasmid combined with liposome micelles
- The positive phosphate heads join to the DNA, which is negatively charged
- These complexes are breathed in with a nebulizer
- The liposomes fuse with epithelial cell membranes and carry the DNA into the cell

These are all varieties of somatic cell treatment in that they effect existing body cells.
Ethical objections prevent germ line therapy.

Testing for CF

- Test for salty sweat
- Test for the protein trypsinogen
- Genetic screening
  - Gel electrophoreisis

1. Restriction enymes are used to separate the DNA into fragments
   - These are usually found in bacterium to cut up viral DNA
   - They cut at specific base sequences
2. Gel electrophoreisis is used to separate the fragments according to their size
   - Occurs on an agarose gel layer
3. Southern blotting sees the fragments transferred to nitrocellulose or nylon paper
   - An alklaline buffer solution is used to separate the DNA strands

4. This allows a DNA probe of the desired sequence to be added, binding to any complementary sequences (hybirdization)

- Usually incorporates a radioactive tracer such as ^{32}P

5. The unbound sequences are washed away, and then the paper is viewed under an X-Ray to reveal the presence, or not, of the desired sequence

The uses of genetic screening

- To identify a carrier
- To confirm a diagnosis
- To test an embryo
    - Using amniosentesis to obtain embyrotic fluid
    - Or Chorionic villus sampling (CVS), taking a placental sample through the vagina or wall of the abdomen
- Testing pre implantation (PIGD)
    - Before in vitro fertilisation (IVF)

Four ethical frameworks

1. Rights & Duties: We have rights, and our duty is to satisfy ours and those of others
2. Utilitarianism: Maximise the amount of good in the world; no moral absolutes.
3. Informed consent: Allow people to make their own choices.
4. Leading a virtuous life: Being just, prudent, moderate , brave, charitable etc.

Topic 3

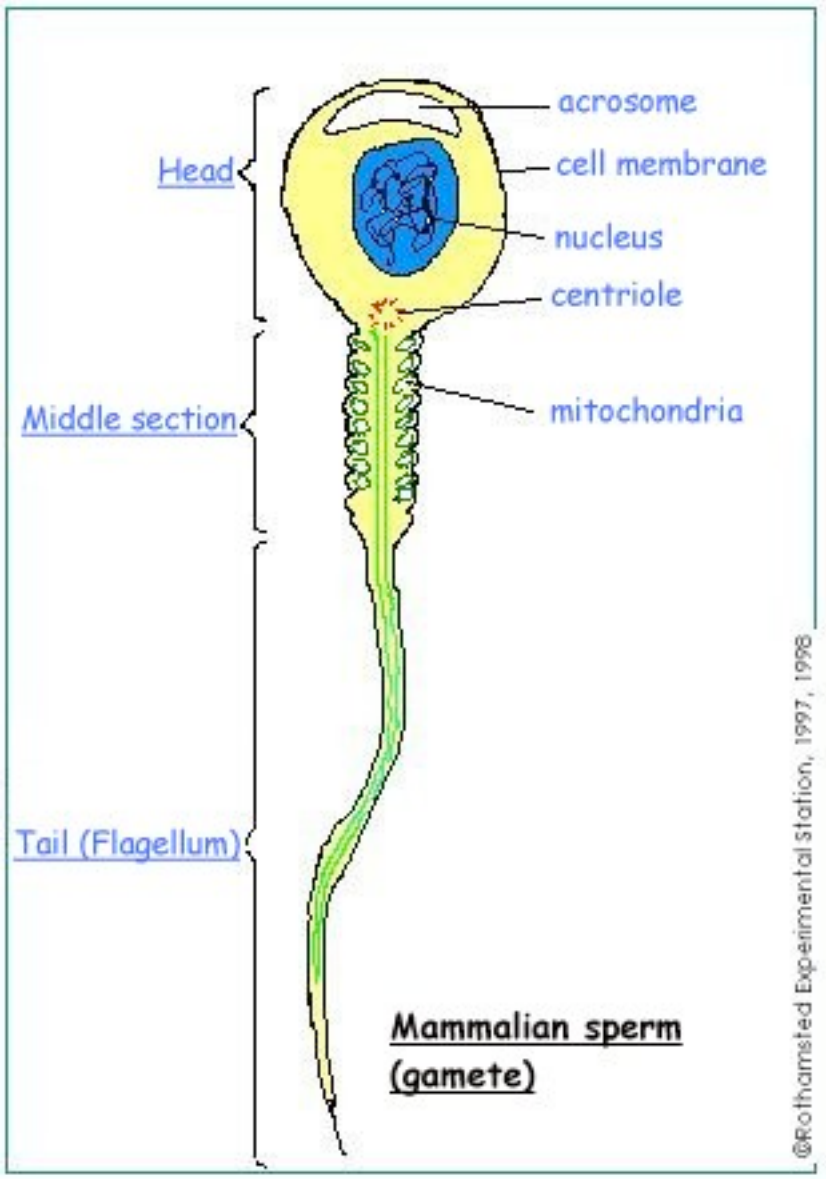
15/4/09 14:12

Zygotes

- Ova
  - Structure
    - Follice cells outside
    - Zona Pellucida inside them
  - Releases hormones, attracting sperm and triggering lysosome reaction
    - Acrosome swells and fuses with ovum
    - Penetrating Z.P
    - Z.P thickens to prevent other sperm entering

Sperm	**Ovum**
Acrosome	No acrosome
Tail	No tail
Mitochondria	Mitochondria
No lipids	Lipid stores
ATP store	No ATP store
Haploid nucleus	Haploid nucleus

  -
- Sperm



- Lysosome
    - Digestive enzyme triggered by Z.P hormones
    - Causes 'jelly-like' ovum coating to thicken, denying entry to other sperm

Newly fertilised egg = ZYGOTE

Mitosis

Produces 2 ('to') diploid cells

- **I**nterphase
    - Organelles & DNA replicate
        - No Interphase in zygote
        - Appearance

        - Nondescript, no obvious chromosomes
        - Dark patches = nucleoli containing ribsomes
        - DNA is unravelled for replication
- **P**rophase
    - Chromatids thicken
    - Spindle forms, centrioles acting as anchors
    - Centromeres join chromatids
    - Nuclear Envelope disintegrates
- **M**etaphase
    - Centromeres attach at equator
- **A**naphase
    - Centromeres split
    - Spindle shortens
    - Spindle breaks down when chromatids reach poles
- **T**elophase
    - Reverse prophase
    - Chromatids lengthen
    - Nuclear envelop reforms
- **Cytoplasmic Division**
    - Protein filaments & microfibrils condense cell at neck, pinching cytoplasm apart
    - In plants, ribosomes build a **new cell plate** between the two cells

Mitosis

- Ensures genetic stability
    - Every cell has the same DNA in a body
    - Growth and repair
    - Asexual reproduction
        - Binary fission in bacteria

meiosis

- Produces 4 haploid cells
- Promotes genetic variation through random assortment

Stem Cells

- Totipotent
    - <8 cells in embryo

- Pluripotent
    - <50 cells in embryo, BLASTOCYST
- Multipotent
    - E.g Bone marrow; can form multiple nerve cells
- Uses
    - Tissue Typing
        - 20 tissue lines would provide for 90% of the pop
    - Immunosuppressants
        - Suppress immune system
    - Therapeutic cloning
        - Diploid nucleus from adult into embryo
        - Therefore forming a blastocyst which matches the patient
        - Ethics

For	**Against**
To alleviate human suffering	Pandora's box; slippery slope
Ovums from IVF wasted	Other cells viable
Could improve understanding	Embryo = person
Embryonic cells most versatile	Odd side effects?
Save children with congenital diseases	Pressure to superovulate

Promoter region

- The location for RNA polymerase to bind on a gene
- If blocked or absent, expression won't take place.

FOP

- Caused by misproduction of BMP-4 hormone which stimulates bone growth in monoctyes. If a repressor is missing, bone grows everywhere.
-

Homeobox genes

- Master genes which control differentiation of organs and orchestrate development

Melanin stuff

- Tyrosinase synthesizes melanin
- When stimulated by Melanoctye Stimulating Hormone (MSH)
    - MSH receptors increases in UV light
- Melanin produced in melanoctyes, then put → melanosomes, which gather around nucleus to protect it

Cancer

- Inherited
    - Comes from lack of repairing genes for DNA
    - Breast cancer
        - Looking for specific, hereditary mutations
        - Preventative surgery may be possible
- Mutagens
    - Asbestos
    - Tar
    - UV light
- Viral
    - Viral infections can trigger cancer, possibly due to transfer of oncogenes
- Free radicals
    - Cause mutation by oxidising stuff
    - Combated by free radicals
- Humane Genome project
    - 30 → 40 000 genes
    - 50%= Junk DNA
        - Shows evolution
    - Uses
        - Identification of new genes and identifying threats
        - Identifying new drug targets
        - Personalised drugs
        - Understanding basic biology better
        - Showing and understanding evolutionary progress
    - Issues
        - Insurance
        - Who should use them; better not to know?
        - Obligatory?
        - Should it determine eligibility for treatment?

        - Egenics

Screening

- Can combat diseases such as Duchenne muscular dystrophy
    - Which is sex linked

Germ line therapy

- Inserting desired genes into germ cells i.e. zygotes

Protein Trafficking

1. DNA –mRNA, mRNA moves out
2. mRNA attaches to ribosome
3. Proteins made on rbosomes, enter RER
4. Protein assumes end shape and is packaged as it moves through ribosomes
5. Vesicle is pinched off
6. Enters Golgi apparatus
7. Proteins modified to fulfull final function
8. Final vesicles are pinched off, containing final protein
9. Exit cell by exocytosis

Acetabularia

- 2 strains, different hats
- Nucleus and stem separated, hybiridzed
- Stem in the short term determines hat
- If hat chopped off, new, regrown hat matches nucleus

Cloning

- Dangerous; **oversized babies**
- Develop diseases such as arthritis quickly

Gene Expression

- Attaching a methyl ($-CH_3$) group to a gene deactivates it
- Gene expression requires **RNA polymerase & suitable transcription factors** to attach to the **promoter region on the DNA.**
    - Transcription factors
        - Some always present

- Some specially synthesized
- Some only activated by hormones (growth factors etc)
- Expression can be prevented by protein repressor molecule
    - Which prevents transcription factor binding by blocking the promotor region
        - . E.G. in **B-Galactosidase in E.Coli**, lactose inhibits the repressor molecule, allowing the transcription of lactose digesting enzyme (B-Galactosidase)
- Signalling
    - Direct
        - Signal protein passes into nucleus, acts as transctiption factor
    - Indrect
        - Signal protein binds to receptor, causing messenger molecule to be released in cell, which acts as transcription factor

Nature Vs. Nurture

- Height
    - Nat + Nur
        - Taller men more attractive/ reproductive
        - More protein in diets, less inbreeding, better medicine, less child labour, better heating & housing
            - All lead to increasing height
- Cancer
    - When cell multiplication > apoptosis
    - DNA damaged through mutagens (UV light, asbestos, tar) or incorrect gamete formation
        - **Oncogenes**
            - Code for stimulating proteins in the cell cycle, perpetuating it
            - Too many = Cancer
        - **Tumour Suppressant Genes TSG)**
            - Produce cycle stopping proteins.
            - If inhibited, → cancer

- At checkpoints in the cell-cyle (perpetuated by clin & cyclin dependent kinases)
- Chemicals are released to continue the cycle
- The build up of CDK catalyses **phosphorylation of other proteins, making them active**
- **Cancer**

Natural	**Inherited**
Chemical: tar in bronchi causes mutation in epithelial cells	About 5% is inherited
Physical: UV light, moles → Tumours	Lack of DNA repairing proteins, or odd ratios of onco/TSG
Diet: Free radicals	Mutations accumulate in the sperm of older men

-
- **Metastasis**
  - The spread of cancer
  -

Topic 4 15/4/09 14:12

The fact that plants can't move means that they must be excellent adaptors, and makes them useful records of climate change

Plant structure

- Strong walls made from sugar polymers
- Specialised tubes run vertically
- Cells stiffened with **lignin**
    - Lignification occurs one year
    - Forming a strong and flexible polymer
- Specialised componentry
    - Chloroplasts
    - Rigid cell walls
    - Vacuole
        - Which controls the flaccidity / turgidity of the cell, and affects the rigidity of the plant
- Types of plant fibre
    - Parenchyma
        - Packing fibre
    - Cellulose
        - Made from B-Glucose molecules
        - Broken by hydrolysis
        - Unbranched
            - Solely 1,4 glycosidic bonds
        - Versus starch
            - Which is alpha-Glucose, branched with 1,6 & 1,4 links
    - Microfibrils
        - Hydrogen bonds between cellulose chains form microfibrils
        - Make up the cell wall
        - Microfibrils are bound helically and held together by amylopectin and hemicellulose glue
        - Multiple angles creates toughness
    - Plasmodesmate
        - Fluid filled channels which link cytoplasms, often found in pits in the cell wall, where there is a lack of cellulose
    - Xylem
        - Stiffened cell walls provide rigidity

        - Often dead
        - Become increasingly lignified, and the **tonoplasts**, which separate the cells, break down to allow flow
    - Phloem
        - The 'nutrient sieve'
    - **Schlerenchyma** is the fibrous outer layer of a plant's stem
        - Columns of which help provide support
- Mass transport
    - Why is water brill?
        - Good solvent; the 'universal solvent'
        - High heat capacity, so useful for stabilising temperatures
- Transport
    - Cohesion between like molecules
    - Adhesion between different ones
        - Water and wall
    - Provides a 'mass flow' system
- Ions
    - Magnesium ions
        - Lack = No chlorophyll, yellow leaves
    - Calcium ions
        - Lack = stunted growth
    - Nitrate ions
        - Lack= stunted growth
        - Needed for nitrogenous bases
- Stems are kept rigid by turgid cells + parenchyma

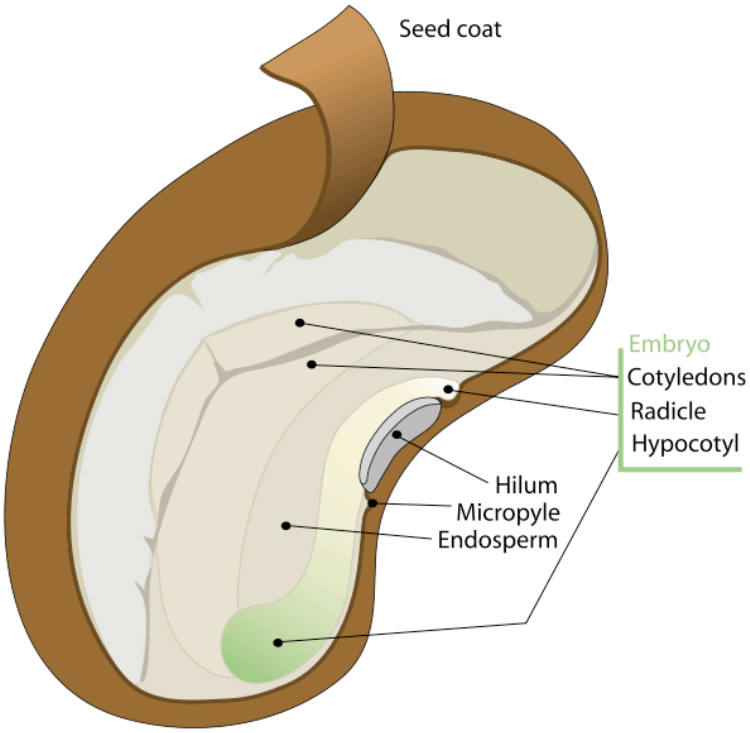
Human use of plants

- Fibres
    - We use **retting** to separate the plant fibres from one another
    - This allows us to remove the lignin
- Natural antibiotics
    - For instance garlic
- Foxgloves & Digitalis
    - To treat dropsy, caused by oedemas
    - Digitalis is a diuretic, causing all the excess fluid to be weed out!
    - Withering kept upping the dose until somebody died

    - Worked out that the efficacy of the digitalis was proportional to urine output
    - Side effects were nausea & vomiting. When these were exhibited he dropped the dose again
- Drug testing today
    - Preclinical tirals
        - Animal and labs
    - Clinical Phase 1
        - Small group of healthy volunteers
        - Mainly to assess how the body absorbs and processes the drug
    - Clinical Phase 2
        - Small group (100-300) of disease sufferes
    - Clinical Phase 3
        - Double blind procedure
        - 1000-3000 sufferers tested

Seeds

- Tough outer coat called **testa**
- Protects seeds
- Dormancy terminated in response to
    - Chilling
    - Gut activity
    - Heat
    - Abrasion
    - Light
- Anatomy of a seed



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Plumule = A young shoot

Cotyledons = Side leaves

Endosperm= External food supply, separate from the embryo)

Seed dispersal

- Wind
  - E.g. sycamore seeds, spinny!
- Water
  - E.g. Coconut seeds, which float
- Animal
  - E.g fruit trees
- Self propagating
  - E.g. peas, which explode!

Germination

- Seeds absorb water through **micropyle**
- Swelling, rupturing the testa
- The enzymes AMYLASE and MALTASE convert starch into sugar
- This sugar is utilised by the plumule for growth

Uses of starch

- Expanded foam
    - E.g. For packaging
- Thickening agent
    - E.g. Wallpaper glue
- Stiffening fabrics
    - Shirt collars
- Super absorbents
    - Tampons
- Soap

Selective breeding of plants

- Mate the best plants with the best plants, or self-pollinate the best plants
- You sometimes get **inbreeding depression**
- But F2 hybrids (breeding two inbred plants)
- Gives hybrid vigour

GM crops

- Insertion by
    - Viral vector
    - Bacterium (DNA in a plasmid)
    - Gold plated bullets from a gene gun
- Development
    - Herbicide resistant marker genes allow the calluses to be nurtured in herbicide rich environments, killing plants which have failed to have the gene incorporated into their genome
    - Then use **micropropagation** to grow your lovely GM plants
- Uses
    - Tougher tomatores (delayed ripening)
    - Herbicide resistant crops
    - Pest resistant crops
        - E.g Corn boring weevils thwarted by toxin producing corn
    - METABOLIC ENGINEERING
        - This is the alteration of the expression of various genes, changing whole metabolic pathways
            - E.g. Ligning removal

- Concerns
    - Antibiotic resistance could spread to weeds
    - The new genes could produce unexpected, harmful products
    - Increased herbicide use is bad for the environment
        - E.g. DDT build up killed loads of kestrels

CLIMATE CHANGE

The effects of temperature change

- Migration patterns chaning
- Alien species alter the community
- Faster photosynthesis leads to faster growth
- Life cycles messed up
    - Spawning, hatching, sex determination in reptiles
- Plants may start flowering at different times, causing pollination problems
- **Photoperiod** means day length
    - Some animals judge by temp, others by photoperiod, which could cause dichotomies, most damagingly between predator and prey

- Monitoring:
    - **PHENOLOGY**
        - The study of natural indicators of season
            - Such as hatching times, migration periods, etc.
    - **Dendrochronology**
        - The study of tree rings
        - Examined on a **skeleton plot**
        - Tall spikes indicate bad seasons
        - Ring width
            - Bigger rings in spring
                - The 'early growth' wood, growth spurt after winter dormancy
            - Smaller rings in summer
                - The 'late growth' wood, more dense and slower grown
    - **Pollen sampling**
        - Made possible by the plentifulness and enduringness of pollen

        - Tested by **carbon-14** dating
            - Comparing ratio of C14: C12; since C14 decays into C12, the more C14, the older it is.
        - Allows us to assess which plants were alive when
        - Giving data on succession
    - Peat beetles
        - Insects react faster to climate change due to their **short life cycles**
        - So the **exoskeletons** of peat beetles can be useful indicators of climate change (bigger beetles usually mean warmer period?)

- Extrapolation
    - This is what we do to predict future climate
    - Weaknesses
        - Relies upon the continuance of current trends
        - There are lots of factors, making it difficult
        - We don't really understand how various factors interact
        - The computing power is often inadequate
- CO_2
    - Comes from:
        - Volcanoes
        - Combustion
        - Emitted by decomposition of limestone (calcium carbonate)
            - Worsened by acid rain
        - CO_2 is bound up in exoskeletons in the sea

Topic 5: On the Wild Side

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Biodiversity

- Species richness (number of different species)
- Diversity within the species (genetic diversity)
- Diversity within specific ecosystems

There are 5-30 million species on Earth

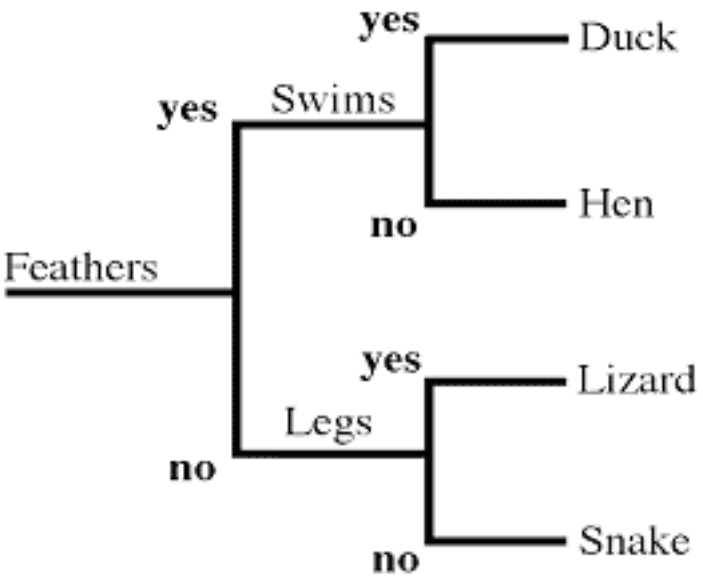
Species:

- ` A group of organisms with similar morphology, physiology and behaviour which can be interbred to produce fertile offspring, and are isolated reproductively in place, time or behaviour from other species'

- Estimates of species numbers come from multiplying up the results of an intensive survey of a small area
- Or using known ratios e.g. 1 Butterfly : 3000 worms, count the butterflies to estimate the number of worms.

Dichotomous key

- The key where there are always just two options:



- Above is a traditional, linear dichotomous key
- A multiple access key allows you to enter from any direction, but is still based on the dichotomous options.

CAT= Computer Aided Taxonomy (or Computerised Axial Tomography, depending on which unit we are talking about!)

Taxonomy: 'Placing animals into groups based upon shared features'

Kingdom	Animalia
Phyla	Chordata
Class	Mammalia
Order	Primates
Family	Homonidae
Genera	Homo
Species	Sapiens

The Kingdoms:

- **Animalia**
  - Heterotrophs
  - Can't photosynthesises
  - Can move
- **Plantae**
  - Autotrophs
  - Can photosynthesize
  - Can't move
- **Fungae**
  - Heterotrophs
  - Can't photosynthesize
  - Can't move
  - Have CHITIN in their cell walls
  - And multinucleate HYPHAE (long thing arms….)
- **Prokaryotae**
  - Small!
  - Store DNA in genophore, not a standard nucleus
  - No cell bound organelles
  - Can move
- **Protoctista**
  - Very simple eukaryotes
  - Have movement

        - There is also the question of **archeabacteria**
        - Which have been proposed as a third group, alongside eukaryotes and prokaryotes

Why bother classifying?

- To keep track of biodiversity
- To understand evolution and relation better
- To aid chemical & medicinal research
    - E.g. The moreton bay chestnut tree produced antiviral fluids that were toxic, so chemists turned to the related Alexa, which was less toxic.

Biodiversity hotspot

- An extremely biodiverse ecosystem
- Reefs are a common example
- Surprisingly, the Mediterranean Basin is the most biodiverse hotspot on earth

Endemic = Only found in a single particular area

Phenotype= The result of the genotype interacting with the environment around; the physio and morphological expression of the genotype in a given environment.

Genetic diversity= The variety of different genotypes in an environment

- Often referenced to number of SNPs; Single Nucleotide Polymorphisms
- Which is the number of single bases that consistently vary within a population
- Another tool to measure genetic diversity is number of different alleles for a loci
- % Of the population with 2+ alleles
- % Loci heterozygous in individuals in a pop (heterozygosity index). 2 bands on gel electrophoresis= hetero, 1 band = homo

Sources of diversity

1. **Mutations** during meiosis
    - Inversion
        - A codon or two are flipped
    - Translation
        - A codon, or base, moves

- Deletion
    - A number of bases are removed

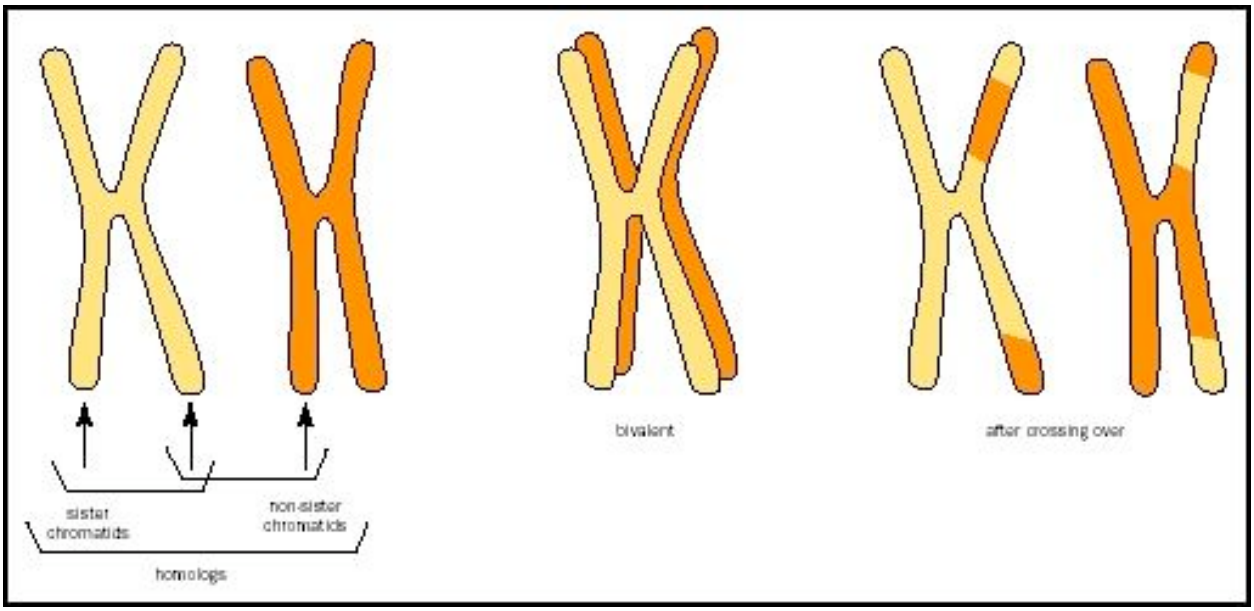
2. **Independent Assortment** of chromosomes during meiosis (the gamete gets a random selection of chromosomes from the producer's own paretnts)

3. **Crossing over** between homologous (equivalent) chromosomes

4. **Mate selection**

5. **Random** (well…. It's not truly random) **fertilisation**

CROSSING OVER



The points at which the chromosomes cross over are known as **chiasma**; points of crossing over.

DIHYBRID INHERITANCE: Where two alleles, inherited independently of one another, both combine to affect a single aspect of the phenpotype.

Common Ratios

Hetero + Homo = 1 : 1 : 1 :1 Genotypes

Hetero + Hetero = 9:3:3:1 Phenotypes

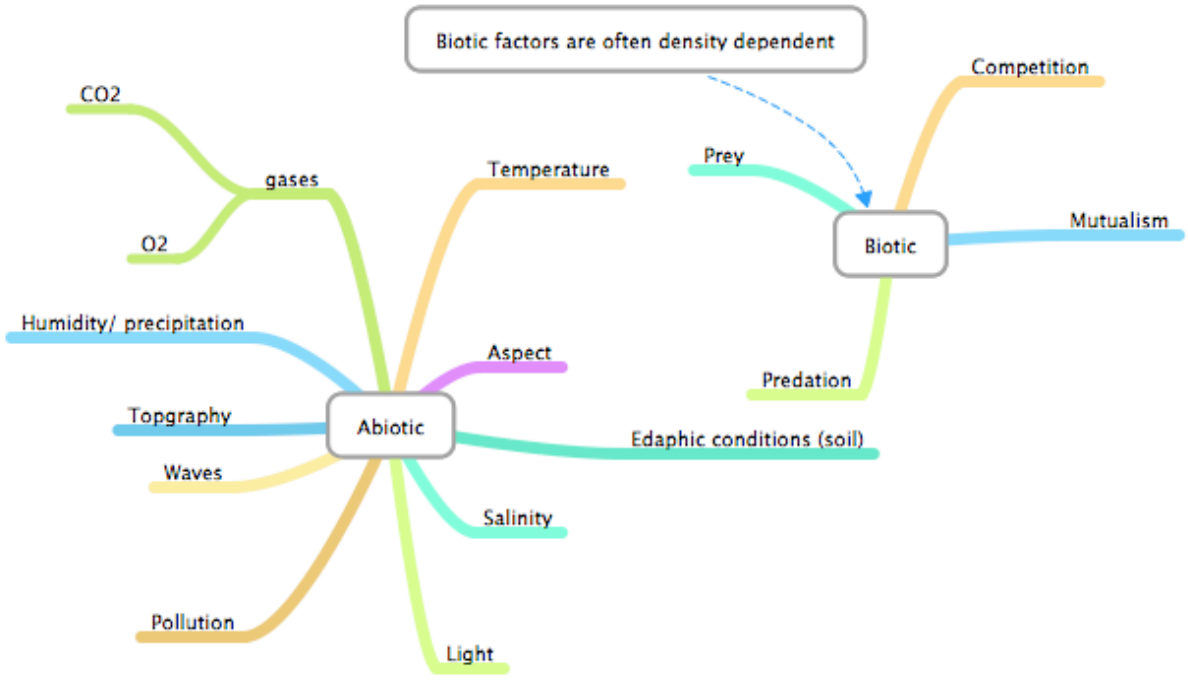
F1= Filial one; the first generation of offspring. F2= the next, and so on.

CODOMINANCE= The phenotype of the heterozygote reflects the presence of both alleles; they are codominant, the dominants doesn't merely override the recessive.

Biosphere= The part of earth and the atmosphere inhabited by organisms

Population= Number of a given species

Community= The number of different species/populations in an ecosystem



There are also anthropological factors; our ecological footprint.

Littoral zones on beaches present similar, but not identical environments, and show how much diversity you can have within a small space.

Adaptations:

- Daisy
    - The basal rosette of leaves allow the daisy to be decapitated by still survive
- Pitcher plant
    - Slippery, waxy coating on leaves causes ants to slip down, particularly in rainfall

Autotrophs are either **photosynthetic** or **chemosynthetic**; some, for instance deep sea extremophile bacteria, can use H_2S without light to chemosynthesise…

Photosynthesis:

- **$6\ H_2O + 6CO_2 \rightarrow C_6H_{12}O_6 + 6O_2$**
- In the presence of UV light

- The energy of the products is significantly higher than that of the reactants, due to the new, strong, energy rich bonds formed.
- That is where the light energy has gone; into chemical energy
- Split into **LDR (**light dependent reaction) and **LIDR (**light independent reaction)

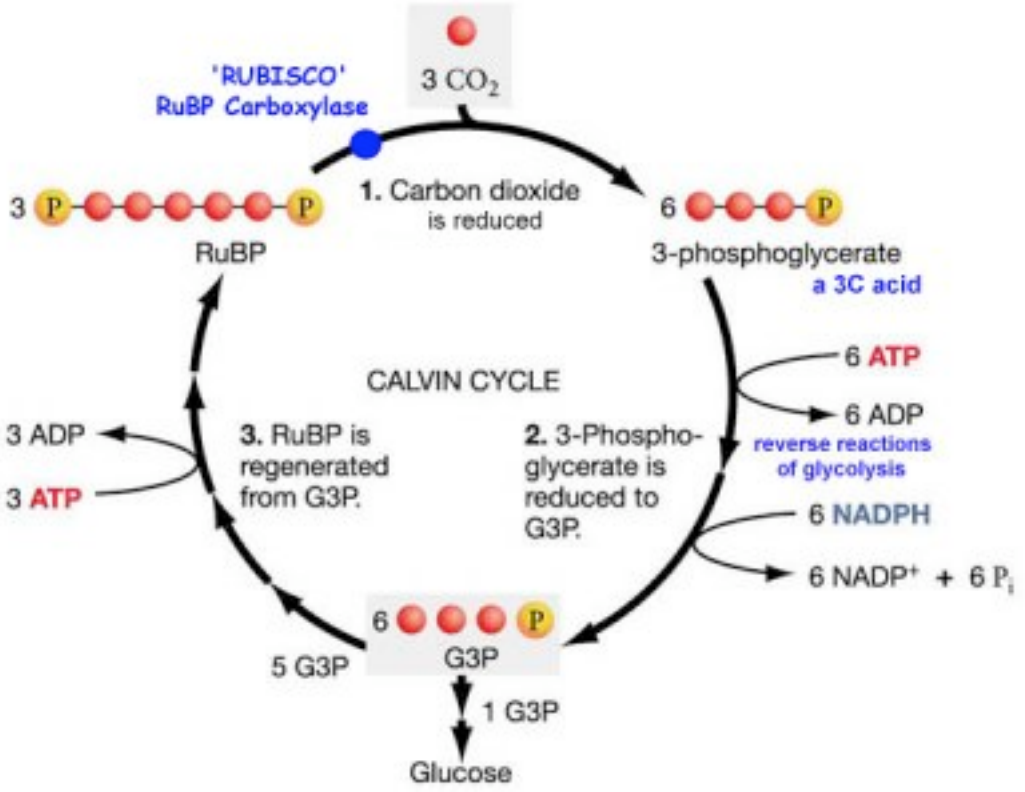
LDR

- Carried out on the **thykaloid membranes**
- Photolysis
    - $H_2O \rightarrow 2H^+ + 2e^- + O$
    - This is used to replenish the electrons used in photosynthesis from the chlorophyll
- The Electron Transfer Chain
    - Sunlight excites electrons from chlorophyll
    - Which are transferred to the electron transfer chain
    - Where, by a series of redox reactions
    - They are passed down energy levels
    - Pumping H^+ out and allowing it to diffuse back through the thykaloid membrane

- Creating ATP & NADH + H^+
- Which are whisked through to the LIDR…

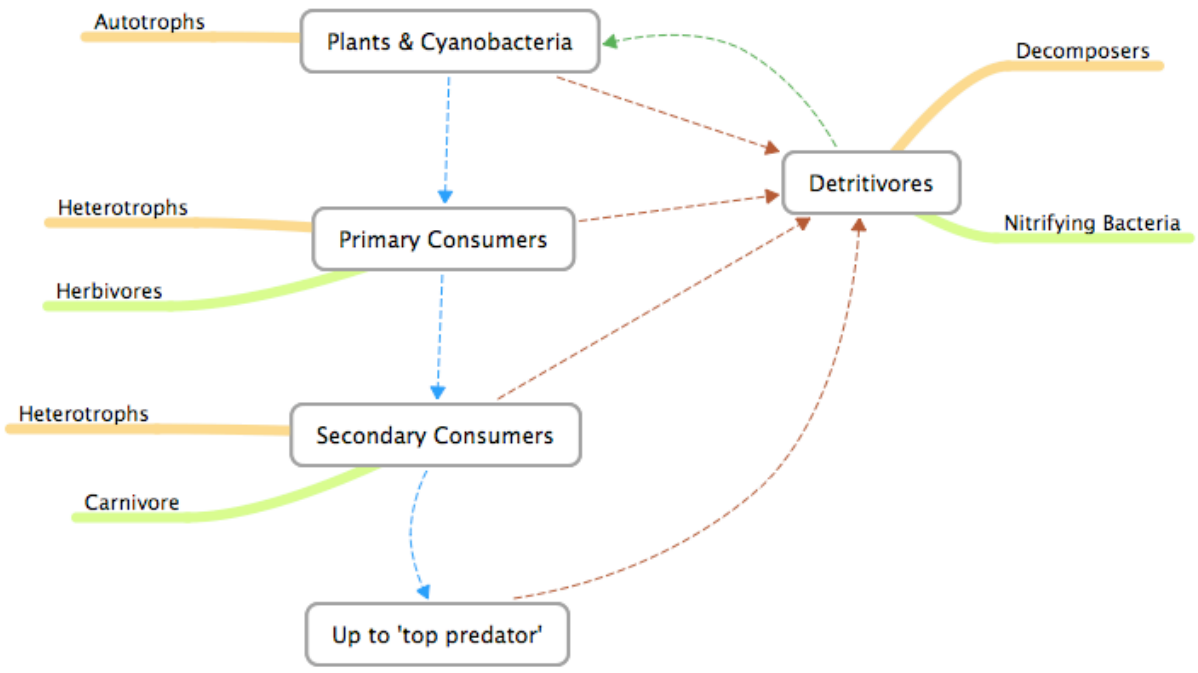
LIDR

- The Calvin cycle (also known as the carbon fixation cycle)



- Basically, RuBISCO is the key enzyme, incorporating CO_2 into the cycle, which then involves ATP to provide energy and NADP + H^+ to provide energy
- The ATP provides energy, allowing **energetically unfavourable (negative entropy)** reactions to take place; the building of carbohydrates- glucose.

Energy transfer within ecosystems

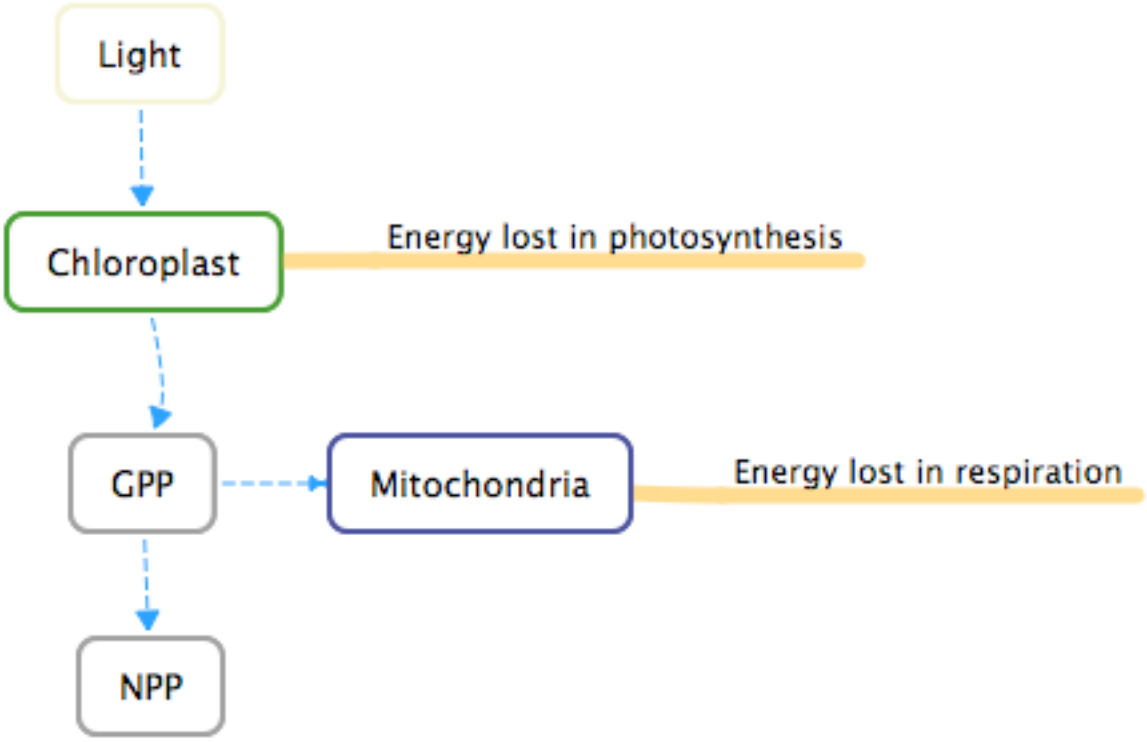


GPP

- The **Gross Primary Product**
- The total amount of energy incorporated into organic molecules by an autotroph

NPP

- **Net Primary Product**
- The amount of energy actually stored as plant biomass
    - So after respiration and transpiration.



Imperfect transfer of energy:

- Not all available biomass is edible
- Energy is lost by the consumed through faces, movement, growth, reproduction

The following trends thus assert themselves

- Decreasing biomass through increasing trophic levels
- Decreasing population through increasing trophic levels
- Increasing size through increasing trophic levels
    - This one is interesting; is it because you need to be bigger than something else to eat it? Probably.

Carnivores are also more efficient at eating than herbivores, because protein is more easily digested than carbohydrate.

Evolution

Darwin & Wallace

- Random mutations are given direction through selective advantages conferred, leading to 'survival of the fittest'
- Which subsequently reproduce, producing fit children

Lamarck

- Changes happen according to the envinroment, and these adaptations can be passed onto offspring.
    - DNA evidence against this; DNA transfer is one way only.

Malthus

- More offspring are born than can possibly survive
- Therefore, there is a struggle for existence

Speciation

- Usually occurs after an initial geographical isolation
- Then, if species come back into contact, the follow isolation prevents interbreeding
    - Ecological Isolation
    - Temporal Isolation
    - Behavioural Isolation
    - Physical Incompatibility
    - Hybrid Non viability
    - Hybrid sterility

ALLOPATRIC= Geographical, isolation based speciation
SYMPATRIC= Genetic divergence of a population purely due to polymorphisms and new niches

CONVERGENT EVOLUTION= Different species ending up looking similar due to similar niches
ADAPTIVE RADIATION= Very closely related species looking wildly different due to different niches

Conservation

4 main reasons to conserve:

- Economic

    - We need biodiversity and sustainability to continue to facilliate economic growth
- Aesthetic
    - The biological world is pretty!
- Ethical
    - We don't have a right to decimate the ecological world
- Ecological
    - Everything is interdependent, and we don't fully understand these links; thus, destroying things could have unpredictable and catastrophic consequences.

Ex situ = Off site, e.g. in a zoo
In Situ= On site, e.g. in the rainforest

Flagship species

- E.g. Pandas
- These raise money for zoos and conservation efforts by being cuddly and attractive, which allows the money to be spent on other, less glamorous species, e.g. beetles.

NNR= National Nature Reserve

SSSI= Site of special scientific Interest

GLTCP= Golden Lion Tamarind Conservation Program

- Captive breeding and reintroduction
    - Must be careful to maintain genetic diversity
    - And necessitates raising them in synthetically wild conditions
- Education of locals
- Translocation of species into reserve
- Research
- Habitat managament

Succession

'The change of a community over time reflected in the dominance of different species and usually accompanied by changes in edaphic conditions'

- Pioneer Stage
    - Poor nutrients in the soil
    - Usually low organic and low moisture content
    - Species such as grasses are good
- Climax Community
    - Won't be displaced unless abiotic conditions change
    - Usually lots of trees

Secondary Succession

- Happens on a brownfield site that has been fertile but is now not e.g. after a forest fire
- There is often an existing seed bank, and the conditions favour plants with
    - A short life cycle
    - Lots of seeds
    - Wide seed dispersal

Deflected Succession

- This is where succession is artificially halted, and a climax community enforced and maintained…. by us
- E.g A Golf Course

Zoos

- The 'mountain chicken' frog was saved by taking 13 frogs to Jersey Zoo and studying it's nocturnal life, along with a captive breeding program
- Captive breeding
    - Increases abundance
    - Maintains genetic diversity
    - Ultimately, the aim is reintroduction
- The loss of genetic variation
    - Zoos must be careful; genetic drift can see useful alleles drift out of the gene pool, with less flexible options being 'fixed'
    - Genetic variation is extremely important if reintroduction is to be successful
        - Stud books are used to prevent in breeding

Topic 6

15/4/09 14:12

Fingerprints

- Sebaceous glands secrete oils
- Unique fingerfolds = unique fingerprint

Dental records

- Teeth don't rot
- Usually have a reasonable unique dental history
- Also, age can be estimated by root and tooth development

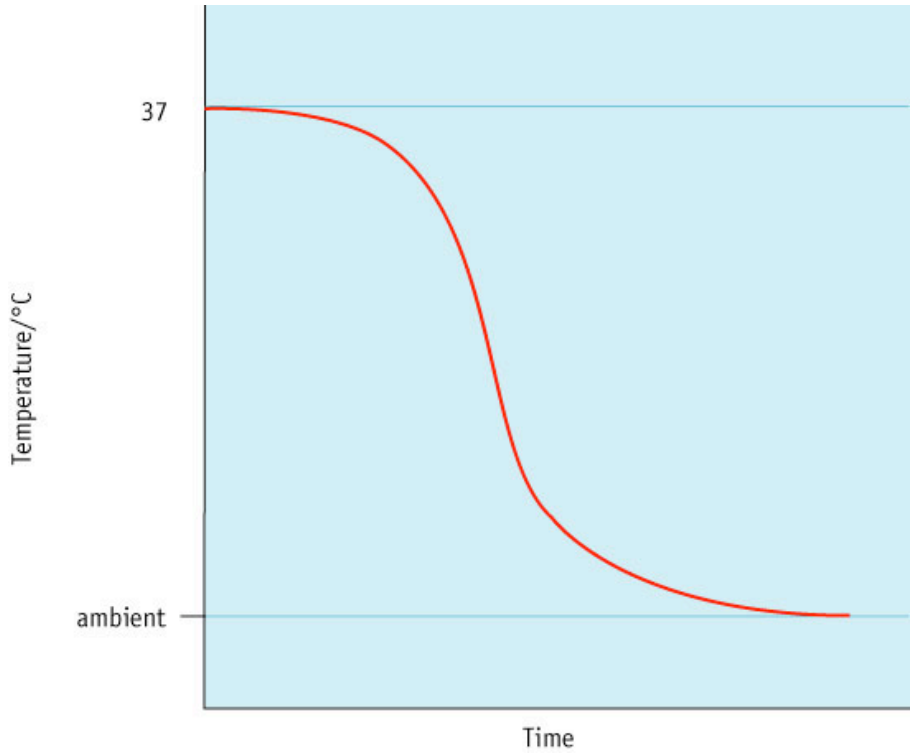
DNA fingerprinting

- Chunks of DNA from introns (non coding sections)
- Contain satellites
    - Mini: 20-50 base pairs, repeated 5—300 times
    - Micro: 2-4 base pairs, repeated 5-15 times
- Our combination of satellites are unique; the number of times a satellite is repeated varies from person to person
- But since 50% of them are inherited from each parent
- They can be used for paternity tests
- The process
    - Restriction enzymes are used to cut the DNA at specific points, either side of the satellites which are to be tested upon
    - Testing is done on 10 or so satellites
    - Fragments separated by gel electrophoresis
        - On an agarose gel plate
        - A current causes the fragments to move towards the anode
        - And smaller fragments move further
        - Thus separating the fragments
    - Strands split into two by alkali buffer solution
    - Fragments are transferred to a nylon membrane by southern blotting, and then placed in a bag with a series of DNA probes
    - Which bind to complementary satellites
    - Then the fragments are detected using fluorescence or x-ray; only fragments that have bound to probes show up
    - And the **DNA fingerprint** is formed
        - If double bands are formed for a single loci, it indicates that the subject is heterozygous; they have inherited slightly different satellites from mother and father.

PCR

- Polymerase Chain Reaction
- Allows very small fragments of DNA to be amplified through a series of heat cycles and fluorescent DNA primers, with the help of DNA polymerase enzymes from a deep sea thermophile bacteria
    - Allowing the rates of reaction to be kept high, as enzyme can tolerate high temperatures
- So there is enough for DNA fingerprinting!
    - Which isn't infallible
    - Identical twins and close family members present problems
    - And for legal viability, confidence must be high, $p<0.05$

Determining Time of death

- Body temperature
    - Follows a sigmoid curve
    - 

    - Dependent upon
        - Body size
        - External temperature
        - Body position

        - Clothing
        - Air movement
        - Humidity
- Rigor Mortis
    - Death → Total relaxation → Stiffening → Total relaxation
    - Stiffening:
        - As muscles become oxygen starved, anaerobic respiration kicks in
        - Causing lactic acid production, and the pH to fall
        - Which in turn inhibits anaerobic respiration too
        - The crossbridges between myosin and actin solidify due to ATP starvation
        - Leading to rigor mortis
- Decomposition
    - Tissues start to deteriorate originally due to **autolysis** of cells by the body's own digestive enzymes
    - Then bacteria from the gut and respiratory tract invade tissues
    - Particularly anaerobic bacteria
        - The body goes from green→ reddish green → purple black
        - Toxic gases are produced, H_2S, methane, ammonia etc. cause the body to swell
        - The body then begins to deflate and dry out as soft tissues shrink
            - All of this is faster at higher temperatures; but at extremely high heats, autolytic enzymes are denatured, slowing the initial rate of decomposition
- Entomology
    - By analysis of conditions, in relation to the growth speeds of insects found on the body, an estimate of time of death can be attained
    - Flies
        - Egg → Larva → Pupa → Fly
    - The size of the larva is directly proportional to it's age
    - But one must take into account temperature; larvae develop much faster at warmer temperatures
    - There is also **succession** on corpses
        - Insects feeding off a dying corpse inadvertently change the conditions, making them more suited to a different set of organisms

        - Which out compete the original set
        - And so on…
            - Therefore, the type of species found on the body can indicate how long the corpse has been dead for.

Bacteria Vs. Viruses

- Both are pathogens
- **Bacteria**
    - Cell wall
    - Capsule
        - Slimy outer layer
    - Ribosomes
    - Pili
        - Little protein tubes for movement
    - Flagellum
        - A tail
    - Mesosome
        - Infolding of surface membrane
    - Plasmids
        - DNA in rings
    - Main genophore
        - A tangle of DNA
- **Viruses**
    - Cannot produce proteins
    - Simple strands of DNA/RNA
    - Some antigens
    - Reverse transcriptase enzymes
        - Allow virus to incorporate DNA into the host's genome, to produce proteins from the host's machinery
    - Protein coat
    - Capsid
        - Slimy layer
    - Cause lysis in host cells

HIV

- Transmission

- Needle sharing
- Sex
- Blood to blood transfer
- Maternal transmission
    - Breast milk
    - Or blood from birth (reduced likelihood if caesarean used)

Immune response

- Non-specific
    - Lysozyme
        - An enzyme which causes **lysis,** the bursting of pathogenic cells
        - Found in tears, saliva, nasal & vaginal secretions, mucus in airways
        - Protects us from cellular pathogens i.e bacteria, but not viruses
    - Inflammation
        - Damaged white blood cells and mast cells release **histamine**
        - Dilating arterioles floods area with white blood cells; an **oedema** may develop as tissue fluid at site increases
        - And more blood raises temperature, aiding the action of phagocytes and inhibiting bacterial replication
    - Phagocytes
        - Neutrophils (arrive first, short lived), macrophages (harder, better, faster, stronger)
        - Engulf pathogens and use vesicles full of lysozyme to cause lysis
    - Lymph system
        - The lymphatic fluid carries bacteria and detritus to the lymph nodes
            - Nodes in armpit, neck, groin.
            - And many more, minor ones
        - Where intense populations of phagocytes destroy them
        - When the lymphatic system fails, **septic poisoning** is caused
    - Interferon
        - Emitted by virally infected cells
        - It inhibits viral synthesis
- Speciffic
    - Lymphocytes
        - Produced in the bone marrow

- Respond to antigens on the surface of foreign, infected, or phagocytic cells
- Either B, or T, which mature in the thymus
    - B
        - Produce antibodies, which are **immunoglobins**
        - When activated, differentiate into clones and then plasma cells
            - Activated by antigens
            - Become APC (antigen presenting cells)- the antigens are stuck to the MHC
            - And interacts with cytokines from T-Helper cells
            - To differentiate, producing antibodies to fit the antigen
                - Antibodies label antigens so macrophages can engulf them
                - And also to clump them
                - And to make them too big to enter other cells; for intracellular threats- viruses.
            - Produce memory B-Cells, which will respond to a secondary infection extremely quickly
    - T
        - T Helper Cells
            - Once activated by APCs, these release cytokines
            - Which boost the activity of phagocytes and stimulate B-Cells to divide and differentiate
            - Have CD4 receptors on their surface
                - Which are what makes them to the gp120 proteins on HIV
                - But they also use them to bind to antigens on APC, activating them
            - T Memory Cells are also produced
        - T Killer cells
            - These destroy pathogen infected cells

        - And destroy foreign cells
        - Activated by infected APC cells
            - Clone & differentiated to active T-Killer cell and T-Killer Memory
- Immunity
    - This is where the secondary immune response, after initial infection, is so fast and thorough that the subject doesn't even display any symptoms. He/ she is said to be immune.
- Avoiding attack by our own immune system
    - The MHCs on our cells help to mark them out as friendly
    - Any B&T cells that have MHCs which would lead to them destroying our own cells are removed by **apoptosis,** in the thymus or bone marrow.
    - If this mechanism fails, then **an autoimmune disease** occurs; like multiple sclerosis, where the immune system attacks the Schwann cells coating neurones

TB

- Primary infection
    - The first phase of infection
    - A mass of tissue forms called a **granuloma**, containing lots of macrophages, attempting to destroy the bacteria
        - These masses are anaerobic, and, in TB, are known as **tubercules**
    - 90% of primary infections go unnoticed
- Active TB
    - TB bacteria are extremely clever, hiding *inside* macrophages, aided by their tough cell walls, which are thick and waxy. They can lie dormant for years.
        - They can also suppress some aspects of the immune system, namely T-Helper cells, which impacts B & T Cell activation
    - Active TB occurs if the infected party's immune system cannot initially control the infection, or if an old infection breaks out again after a weakening of the immune system; 80% of active TB is resurgent infection.
        - The immune system may be weakened by age (very old or very young), malnutrition, stress, or HIV.

- In active TB, the bacteria multiply rapidly, destroying the lung tissue and creating holes & cavities. If the sufferer isn't treated, they will die.
- Symptoms
  - Coughing- particularly blood in sputum
  - Shortness of breath
  - Loss of appetite, weight loss
  - Fever
  - Extreme fatigue
- **Fever**
  - Fever is part of the inflammatory response, released by neutrophils and macrophages
  - It raises the body's core temperature
  - Which aids phagocytes and suppresses viral & bacterial replication
  - However, above 40 degrees Celsius, human enzymes begin to denature, and above 42, death threatens.
- TB can also effect other parts of the body
  - Glandular TB is the most significant, bar pulmonary (lung) TB

Homeostasis & Negative feedback

- Negative feedback works by sensors (thermo, chemo, baro, stretch) detecting a deviation from the norm, and causing effectors (muscles, glands) to reverse the trend
- This usually results in going *too far* in the other direction
- And thus the opposite response is called into action
- This method of feedback, sensing you have 'gone too far', is **negative feedback.**
- **Heat gain**
  - Vasoconstriction
  - Erection of hair pilli
  - Increased skeletal muscle activity (shivering)
  - Metabolic changes in the liver, causing more metabolism and more heat productiono
- **Heat loss**
  - Flattening of pili

    - Sweating
        - Which leads to cooling via evaporation and conduction
    - Vasodilation
        - Diverting hot blood to the surface allows heat to be lost via radiation
    - Liver metabolism slows
    - Skeletal muscles relax
- Homeostasis effects:
    - Temperature
    - Water levels
        - Through ADH
    - Glucose levels
        - Through insulin

The **hypothalamus** is the part of the brain responsible for most homeostatic activity

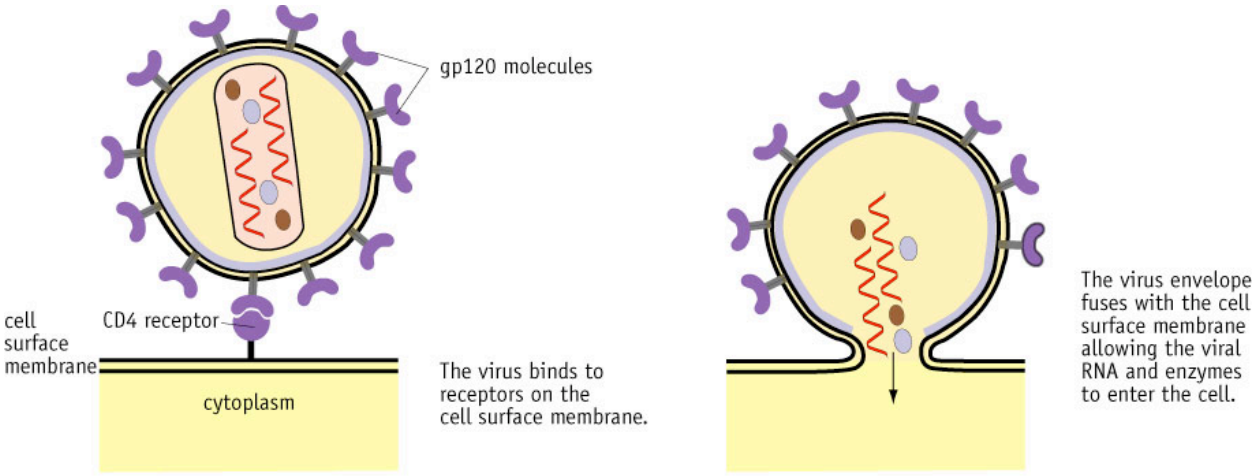
Diagnosing TB

- Skin & blood tests
    - A small attenuated sample of TB is injected
    - Inflammation indicates anibodies are already present, and that active TB (latent TB is sometimes missed) is present.
- Identification of bacteria
    - Sputum can be cultured to grow bacteria, which can be tested with stains
- Chest X-Rays
    - These reveal the extent of the damage to the lungs
    - Other organ x-rays may also be necessary if the disease has spread

AIDS

- Acquired Immuno Deficiency Syndrome
- Causes the patient to become vulnerable to **opportunistic diseases**; such as TB or pneumonia

- Caused by the **HIV** virus (Human Immunodeficiency Virus) infection:



- HIV infects cells by using gp120 proteins to join to CD4 receptors on the surface of certain cells; macrophages and T-Helper cells
- HIV is an **RNA retrovirus**, meaning that it copies it's RNA into two strands, forming DNA, and then sneaks the DNA into the host cell's genome, allowing certain proteins to be transcribed
    - **Reverse transcriptase**
        - This is the enzyme used by HIV to copy its RNA into DNA; changing RNA → DNA = reverse transcription
    - **Integrase**
        - This is the actual enzyme that incorporates the newly formed viral DNA into the host DNA
    - HIV then uses the cell machinery to produce proteins viral proteins needed for the viral envelope, as well as glycoproteins and nuclear material
    - Which are spat out onto the cell's own membrane
    - And then when the viral replicates 'bud off' the hosts membrane (**causing lysis)**, they reclaim these viral proteins.
- **T-Helper cells** are the chief victims of DNA infection and lysis
    - This cripples both B& T cell activation

- Leaving the patient highly vulnerable

- THE COURSE OF THE DISEASE
  - **Acute phase**
    - There is rapid replication of HIV viruses, and a massive loss of T-Helper cells
    - After a few weeks, T-Killer cells recognize the infected T-Helper cells, and start to kill them, subduing but not eradicating the infection
  - **Chronic phase**
    - The latent phase
    - HIV hangs around, not doing much
    - But can lead to the reactivation of dormant diseases such as TB or shingles
    - **The chronic phase can last for up to 20 years or more**
    - Especially in fit and healthy young people
    - However, in the developing world, the chronic phase usually gives way to the disease phase, and AIDS, much more quickly
  - **The disease phase**
    - Eventually, the viral load (the number of viral particles in circulation) and the decreasing T-Helper cell count causes the onset of **AIDS**
      - When the T-Helper cell count falls **below 200/mm^3** of blood
      - The patient is now massively vulnerable to opportunistic diseases
        - And the rare **Kaposi's Sarcoma**
        - Identified by purple-black patches on the skin
      - **AIDS** is nearly always fatal

Preventing pathogen entry

- Skin
  - The **keratinous layer** is effective in preventing the entry of microrganisms

    - The **skin flora**, a large collection of 'friendly' microbes, also help block their malicious cousins' entrance. Our flora is particularly well suited to the salty, pH varying conditions on our skin
- Mucous Membranes
    - Within our upper respiratory tract, mucus is produced by **goblet cells** and traps pathogens. The mucus is held and moved by cilia, which, once it has been used, shift it into the stomach to be destroyed
    - Mucus also contains **lysozyme**
- Stomach Acid
    - **pH Is around 2.0**
    - Which suits the pepsin digestive enzyme
    - But not foreign microbes!
- Gut Flora
    - Found in the small and large intestines
    - Lots of E.coli strains
    - We have a mutualistic relationship
        - They aid the digestive process
        - And feed off some of the less useful biproducts of digestions
        - They also secrete chemicals such as lactic acid, which help protect against pathogens

Immunity

- **NATURAL**
    - Active
        - Being infected, producing memory cells and antibodies
    - Passive
        - Being given antibodies from your mother's breast milk, or placenta
- **ARTIFICAL**
    - Active
        - Being given a vaccine, usually in the form of an attenuated virus, killed bacteria, antigen fragment or altered toxin.
    - Passive
        - Being injected directly with antibodies to fight the infection
- **Herd immunity** also occurs if a critical number of people in a population have immunity; the virus has nowhere/ not enough places to hide. This is how polio was eliminated.

- You can test the effectiveness of vaccines by doing skin tests with samples of the pathogen being combated

treatments

- AIDS
    - Reverse transcriptase Inhibitors
        - Prevent the RNA from entering the host's genome
    - Protease inhibitors
        - Inhibit enzymes used to build viral proteins from larger polypeptides
    - Membrane fusion inhibitors
        - These prevent the HIV virus from entering host cells altogether
    - **Drug cocktails** are often administered, because HIV's high error rate leads to the evolution of resistant strains very quickly
        - So cocktails are used to kill off viruses that may have developed immunity to one of the treatment forms
        - It is also important that treatment is thorough and over a long enough period of time, to prevent further resistance developing in the viral population
- TB
    - Antibiotics
        - Penicillin, discovered by Alexander Fleming, is produced by fungi
            - Most antibiotics are produced by fungi, or other microrganisms
        - There is a constant race to discover new antibiotics, as bacteria are constantly mutating and gaining resistance
            - MRSA, for instance
                - Superbugs such as these tend to develop in hospitals; unfortunate to say the least
            - Bacteria use **conjugation** to allows **horizontal inheritance** of genes, in addition to the standard **vertical, or cross generational** inheritance
            - This allows plasmids for antibiotic resistance to spread through a population extremely quickly
            - Finding new antibiotics

        - An increased understanding of the mechanism used to resist antibiotics, a sort of pump which removes antibiotics from the bacterial interior, offers an interesting drug target
        - Also, our increasing understanding of the bacterial genome allows us to understand which genes are working in which environments, and perhaps how to prevent their transcription
- Antibiotics tend to **be effective against bacterial cells but leave eukaryotic cells unharmed.**
- How they work
    - Bactericidal
        - Kill bacteria
        - By preventing them from synthesizing their cell wall
        - Leaving them weak and vulnerable to bursting
    - Bacteriostatic
        - Inhibit bacterial replication
        - So halt the spread of, but don't eradicate, bacteria