Transposons: the good, the bad and the ugly

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Introduction

We often think of DNA as a long chain of genes that are the blueprints of an organism. However, the results of the project to sequence the human genome show that only a small amount of DNA is needed for the actual genes that are believed to make all the proteins an organism requires. The rest of the DNA is non-coding DNA, i.e. it does not code for any known proteins. This non-coding DNA has been called junk DNA and some evolutionists believe that this is either the remnants of past evolution and / or parasitic DNA. However, many people are now finding evidence that some of the non-coding DNA has very important functions. Indeed, a lot of research suggests that this so called junk DNA is there for a very good reason and we suggest that it has or had some very useful functions. For this reason the term non-coding DNA is becoming more popular than junk DNA.

There are several types of non-coding DNA and one of the most common is transposons.

What are Transposons?

Transposons are bits of DNA that can move around chromosomes. Some are "cut and paste" and others are copied and put into a different chromosome or into a different place on the same chromosome.

The first transposons were discovered in the 1940s by Barbara McClintock who worked with maize. She found that they were responsible for a variety of types of gene mutations. The most obvious was the mutations that occur while the corn develops and produces the variegated pattern which is so prized in "Indian corn".

It took about 40 years for scientists to fully appreciate the significance of Barbara McClintock's discoveries.

We now know that transposons make up more than 50% of the maize genome. Transposons are found in the DNA of bacteria, plants and animals. More than a third of human DNA consists of transposons. The fact that transposons seem to be located in specific parts of chromosomes of both plants and animals suggests that they have functions.

Functions of Transposons

The initial characterisation of transposons as one form of junk DNA has undoubtedly slowed research into their functions. Recently, however, many functions have been proposed for transposons, ranging from control of development of the embryo to production of antibodies. Some transposons definitely have a useful function, while others appear to be less useful and some cause genetic disease.

The Good

About 10% of the maize genome is made up of many copies of one transposon and another 40% consists of other transposons. The most well known function is switching genes on and off which produces different coloured grain.

However, this does not mean that there is no other function for these transposons and as more work is done on transposons to look for function we would expect to find that they are essential for the proper control of the genome at various stages of the life cycle of the plant. As maize is a very important food crop, it is interesting to think that transposons have had a role during the selective breeding that has maximised its potential as a food source.

One very interesting recent report has provided evidence that transposons have a key role to play in the control of genes in the developing embryo. (Pearston *et al*, 2004). They studied mouse eggs and early stage embryos and found that a lot of the messenger RNA is made from transposons. It is suggested that these transposons are part of the regulatory mechanisms that switch genes on and off as the fertilised egg develops into an embryo. Different transposons could possibly have a significant effect on the way genes function during the development of the new individual and contribute to biological variation. As this process occurs during early embryonic development it would not be observed later in the life of the organism. This is one reason why the evidence for transposon function has taken a long time to be published.

In some insects transposons are involved in the maintenance of DNA during cell division. Every time a cell divides each chromosome has to be copied and when this happens sequences of DNA called telomeres, which are at the ends of chromosomes, become shortened. Various mechanisms exist to extend the telomeres so that cells can keep dividing. Experiments with the fruit fly (Levis *et al,* 1993) and the silk worm (Takahashi *et al,* 1997) suggest that in these insects a type of transposon moves bits of DNA to the ends of the chromosomes, to prevent the loss of telomeres following chromosome replication.

Antibody production seems to be dependent on transposons that have a role in shuffling the genes which code for the variable region of antibodies (Agrawal, 1998). Antibodies are complex protein molecules, manufactured by white blood cells, that are part of the process by which the body fights infections. Our white blood cells produce millions of different types of antibodies and as there are only around 30000 genes in the human genome it is obvious that we do not inherit a gene for each antibody. The antibody coding genes of mature white blood cells are made up of two sections, one of which is constant and is shared by all antibodies and the other of which is variable. There are as many variable regions as there are antibodies. However, each immature white blood cell starts with the same set of three gene segments that code for

the variable part of antibodies. These have been labelled V for variable, D for diversity and J for joining. The variable region of the mature white blood cell is manufactured by the recombination activating genes (RAG). The proteins produced by the RAG genes are able to cut and paste DNA from these three segments to produce an almost infinite number of combinations of different bits of the V, D and J segments, which is why this process is called V(D)J recombination. This process occurs in the white blood cell producing tissues of the embryo and without it our bodies would not be able to produce the many different antibodies we need to fight infections. Test tube experiments with the RAG proteins have shown that they cut and paste pieces of DNA in the same way as transposons. These results suggest that a fundamental component of the vertebrate immune system requires transposons, which because of their capacity for DNA rearrangement are able to produce extensive genetic variability in specific cells.

Apart from this very specific role of transposons in white blood cells, there is an increasing amount of evidence consistent with the idea that transposons are very important generators of other types of genomic changes. Kidwell and Lisch (2000) have reviewed some of the ways that transposons can rearrange chromosomes. These rearrangements mostly occur during meiosis, the process that produces gametes (eggs and sperm).

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Transposon activity has also been observed in a case of hybridisation between two species of wallaby (O'Neill R.J. *et al.* 1998). Examination of the genome of the hybrids revealed a massive increase in the number of a certain type of transposon and an associated rearrangement of the chromosomes.

It has been found that the rate of mutations due to transposons is not constant (Kidwell and Lisch, 1997). The cause of these sudden bursts of activity is not well understood but they appear to be related to inbreeding and other forms of genomic stress. This happens in plants when cell culturing techniques have been used and when plant cells become infected. Therefore, genetic variability increases when the survival of the organism is threatened. This mechanism might produce increased variability of the offspring in populations that are facing some sort of environmental challenge.

This role of transposons in the generation of genetic diversity and the fact that this can occur at a variable rate is consistent with the AGEing process proposed by Wood (2002). He has suggested that transposons, which he calls altruistic genetic elements (AGEs), were responsible for producing new species after the global flood. It is also suggested that AGEs can explain a range of biological phenomena that can not be satisfactorily explained otherwise.

The ability of transposons to produce additional copies of a gene suggests that they may have a "back up" function to prevent the loss of genetic variability. This might allow organisms to carry more than two alleles of any particular gene, while at the same time only a maximum of two alleles would be detectable by normal methods. This role of transposons is hypothetical but is consistent with the known functions of transposons.

The Bad

One piece of information that supports the idea that transposons may have had a role in the origin of harmful features comes from study of the genome of the Anopheles mosquito. It appears that the chromosome of this mosquito has been rearranged in ways that are consistent with the activity of transposons (Mathiopoulos K.D. *et al.* 1998). It is tempting to suggest that the annoying life style of the mosquito may have come about because of transposon induced genetic modifications.

Genetic decay appears to have made some transposons defective. Some seem to be remnants of viruses that have been permanently added to the DNA of plants and animals. These transposons have been called parasitic DNA and might be true junk DNA, the existence of which can be interpreted as one of the results of the curse rather than evidence of evolution. This type of transposon appears to be mostly harmless and there are systems that chemically modify transposons to keep them inactive. It is interesting to note that the hybridisation of wallabies (mentioned above) appears to have only been possible because this mechanism was switched off, so it may be premature to conclude that they have no useful role.

We should bear in mind that just because we do not know the function of some transposons it does not mean that they have no function. It is worth noting that the complexity of the processes that involve transposons could hardly have been imagined when they were first discovered. Indeed the evolutionary perspective of many scientists might well have discouraged research into the function of transposons. The creation paradigm, however, would indicate that transposons have or had a function. Furthermore, we would not be surprised to find that some transposons have malfunctioned, as the result of the fall of mankind.

The Ugly

Some of the transposons have been found to cause genetic disease. These are a type of transposon that functions in the same way as viruses which insert DNA into the host chromosomes. Haemophilia, high cholesterol and some forms of heart disease are all
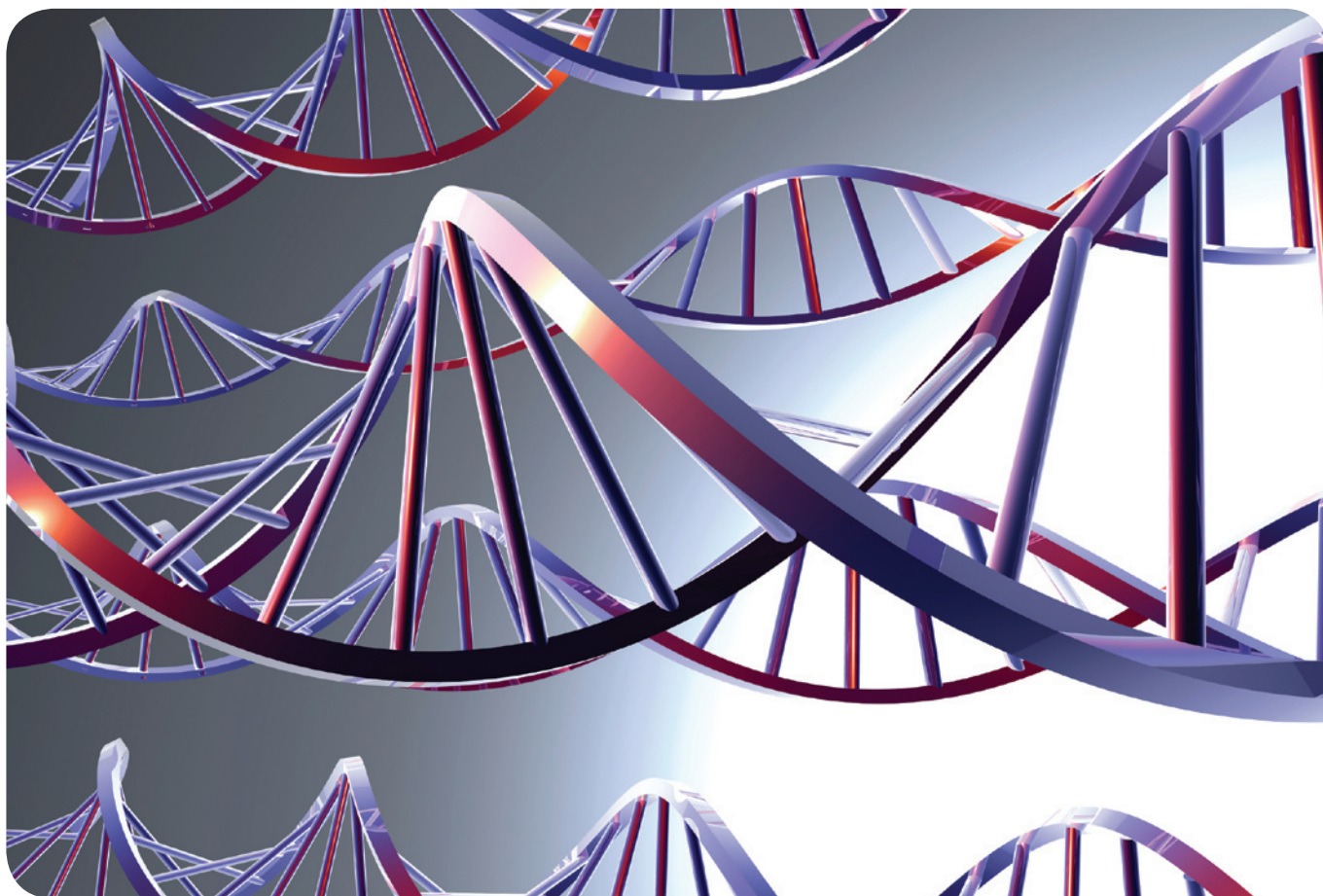
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associated with these transposons.

Other transposons are involved in tumour formation in animal cells. There is also evidence to suggest that oncogenes (genes that cause tumours) may be activated by transposons that are copied to a position adjacent to an oncogene.

Discussion and Conclusions

It is clear from the evidence that has been accumulating over the last 10 to 15 years that transposons have very important functions. Their ability to produce genetic variation on a large scale and with an amazing degree of sophistication is a design feature that should be taken into account by scriptural biologists when trying to understand the variability of the genome. We also need to be careful to remember this when examining the theories of evolutionary genetics. Furthermore the ability of transposons to produce programmed beneficial genetic changes means that we need to move on from the paradigm that attempts to refute Darwinian evolution by stating that random point mutations only produce defects and loss of genetic information. Especially as scriptural biology needs to be able to explain the vast variety of species that has been derived from relatively few animal kinds that passed through the flood bottle neck.

The genome is an intricate information processing system that stores, modifies and transmits the information required to keep a cell functioning correctly. It is also designed to transmit that information to the next generation. Transposons are part of the system, that when functioning correctly, ensures the survival of the cell, organism and population. Defects of this system can result in no harm but can also cause devastating genetic diseases depending on the genetic networks that are affected. ▪

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