Graeme Finlay

Human Evolution: How Random Process Fulfils Divine Purpose

Graeme Finlay

Some people deny that speciation and macroevolution have occurred, and that new genetic functionality can arise from the randomness of mutational mechanism. The genome sequences of many mammalian species are now available for comparison, and have provided a wealth of data that can address these issues. The aim of this article is to show that humans and other mammals share distinctive genomic features that have arisen from singular mutational events. These shared features provide compelling evidence that (1) the human species is descended from ancestors shared with other mammals, so establishing the truth of speciation (our own) and of macroevolution, and (2) new genes have been generated by mutational events that are recognized to occur randomly. This article reflects on how the randomness of natural process achieves God's creative purposes. We can see this pattern in the way God constrains the randomness of history (or indeed of our own lives) into his purposed end.

The opposition of some Christians to evolutionary biology is frequently featured in the media. Positions taken by many in this debate seem to be so polarized as to preclude resolution. But there is an irony to this controversy. Even as some Christians deny that new species can evolve, that macroevolution has taken place, and that complexity can develop through natural genetic processes, the genomic revolution of this century has established the truth of all three evolutionary concepts.

This article is written from the perspective that Scripture possesses the very authority of God.[1] This includes the early chapters of Genesis. Indeed attentiveness to the structure of Genesis 1 has led Old Testament scholars to the conclusion that this text uses rich symbolism to instruct the reader that the incomparably majestic Creator of the universe is the God of Israel, so repudiating all other conceptions of deity. Genesis 1 is arranged in a stylized form. It presents no chronological sequence and implies no mechanism. It describes a transformation from the waters of chaos to the establishment of rest. It reveals to us a God of power, wisdom, purpose, and goodness—a God of order who makes science possible.[2]

Thus one of the key themes of Genesis 1 is that God the Creator transforms chaos into order. This theme is then echoed repeatedly, and in many forms, throughout Scripture. God creatively transformed the chaos of slavery in Egypt into nationhood. Under his creative authority, the turmoil of history led "in the fullness of time" to the climax of the Incarnation. He transformed the Crucifixion into the glory of the Resurrection. He transforms the human state of sin, estrangement, and death into justification, reconciliation, and life.[3]

This theme is compatible with the evolutionary pattern revealed by the post-2001 revolution in comparative genomics. The randomness of genetic process has been shown to underlie the current form of the human genome. Genetic mechanism in all its happenstance has produced the genetic basis of humanness. Genetics describes the process, ordained and upheld by God, to make the creature that expresses God's "image and likeness" (Gen. 1:26–28). That God

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uses the randomness inherent in the natural world to achieve his purposes should be no surprise to people who believe that he is transforming the chaos of history into the new creation.[4]

The following sections describe how our genome shares particular, uniquely arising innovations with the genomes of a range of other species. Shared genetic markers establish the fact that we and other creatures share common ancestry, and delineate the route of our evolutionary development. This approach reveals how familiar mutational processes have constructed new genes and generated novel genetic functionality.

New Genes from Recycled Spare Parts

In female Eutherian (placental) mammals, one copy of the X chromosome in every cell is inactivated, due to the activity of the *Xist* gene. The *Xist* gene is found only in Eutherians, and in no other vertebrates. Part of the Eutherian *Xist* gene arose from segments of DNA left over from a pre-existing gene (*Lnx3*) found in lower vertebrates (Figure 1). Fragments of the *Lnx3* gene were converted into *Xist* gene sequences through mutational events that include the insertion of bases. Such insertion mutations typically destroy the protein–coding function of genes, but in the case of the *Xist* gene (which does not encode a protein), contributed to its formation (Figure 2).[5]

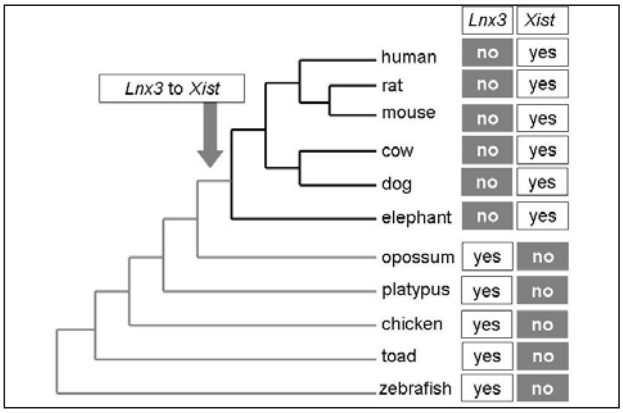

Figure 1. Birth of the *Xist* gene.

The *Xist* gene found in Eutherian (placental) mammals arose in part from the *Lnx3* gene that is found in all the species from fish to marsupial mammals.[6]

This example illustrates how novel genes may arise by mutational mechanisms that are familiar to geneticists. In the brief segment of genetic sequence shown in Figure 2, the original gene (represented by the chicken *Lnx3* gene) has undergone three separate insertion mutations (arrows). These mutations added one base (at two sites) and two bases (at one site) to the original sequence, and are found at the identical positions in all the Eutherian species for which sequences have been obtained. It is highly unlikely that the same insertion mutations would have occurred independently in multiple species. It is vastly more probable that each mutation represents a unique event, and that all the species that now possess the inserted bases received them by inheritance. This means that all Eutherians are descendants of the one individual in which each mutation occurred. And a gene that is integral to our status as Eutherian mammals was formed by the stepwise accumulation of mutations in a lineage of common ancestors.

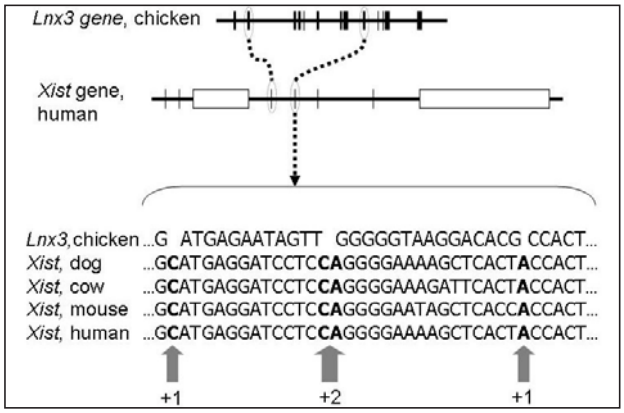

Figure 2. Insertion mutations that converted *Lnx3* gene sequences into *Xist* gene sequences.

The upper part of the diagram shows the layout of the *Lnx3* and *Xist* genes. Horizontal lines indicate segments of DNA; short vertical lines and boxes indicate exons (discontinuous segments of DNA that comprise the parts of a gene used to form an RNA copy). Dotted lines connect those parts of the *Lnx3* gene that have survived in the *Xist* gene. A segment of genetic sequence is shown for part of the chicken *Lnx3* gene and for the corresponding part of the *Xist* gene of four Eutherian mammals. The letters A, C, G and T represent the four units of genetic information (bases). Three insertion mutations (arrows) are common to the four Eutherian mammals, establishing their descent from the one ancestor in which each mutation occurred.[7]

New Genes from Duplications

Five percent of the human genome consists of large segments of DNA that have been duplicated from elsewhere in the genome. Such *segmental duplications* are a familiar feature of genomes, and generate multiple copies of the genes that lie within them.[8] If such duplications provide a survival advantage to the organisms that possess them, they will persist through the effects of natural selection. These duplications have increased the number of copies of some genes over the last few thousand years of human history. For example, human populations that derive much of their food from plant starch (agriculturalists such as the Japanese) have more copies of the salivary amylase gene in their genomes than populations that do not depend on dietary starch (pastoralists and fishermen such as the Siberian Yakut).[9]

Segmental duplications arise randomly. They often arise in cancers, and drive cancer development. If multiple cells in a tumor share the same duplication, they are recognized as descendants of the one progenitor cell in which the

duplication arose.[10] Similarly, if two species share such a duplication, it may be accepted that they are descendants of the one progenitor in which the singular originating event occurred. Genome comparisons have shown that two-thirds of the segmental duplications in our genome are shared with chimps.[11]

If mutations accumulate in each of a pair of duplicated genes, the proteins they encode may acquire different activities. The end result of reiterated duplications will be families of genes of diverse function.

Genes for visual pigment proteins called opsins are required for color vision. New World Monkeys (NWMs) have two opsin genes; apes and Old World Monkeys (OWMs) have three. The third gene appeared when an ancestral opsin gene (and part of a nearby gene of unknown function, *TEX28*) on the X chromosome was duplicated to form the tandem arrangement: red opsin-truncated *TEX28*-green opsin-*TEX28* (Figure 3). Comparison of the uninterrupted sequence to the left of the present red opsin gene, and of the interrupted sequence to the left of the present green opsin gene identifies the exact position of one of the two breakpoints that occurred during the duplication. This breakpoint is common to apes and OWMs, and demonstrates that the duplication arose in a unique event, and that it has been inherited by all the species that now possess it. This finding indicates that trichromatic vision arose in a random DNA duplication event. Subsequent mutations conferred distinct spectral properties on the pair of opsin proteins.[13]

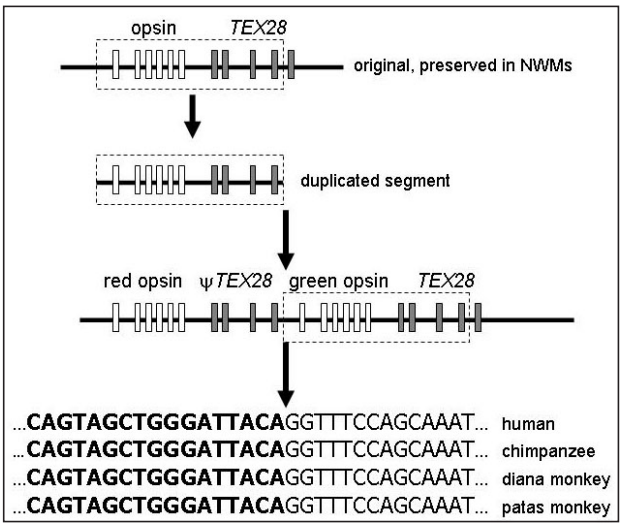

Figure 3. Birth of an opsin gene.
Upper diagram: In lower primates including NWMs, the X chromosome contains one opsin gene, next to the *TEX28* gene.
Second diagram: In an ancestor of the apes and OWMs, the opsin gene and part of the *TEX28* gene were duplicated (segment in dashed box).
Third diagram: The duplicated segment was re-inserted into the chromosome (arrow), generating a second opsin gene and a truncated pseudo (Ψ) *TEX28* gene. The segments of DNA sequence show the junction between Ψ*TEX28* (bold) and the duplicated opsin gene sequences. The junction point is the same in all species investigated, indicating that this segmental duplication arose as a unique event in an ancestor of apes and OWMs.[12]

The *human leukocyte antigen* (HLA) gene complex is critical to the functioning of our immune system. The HLA Class I region is 1,800,000 bases long, and was generated by several rounds of segmental duplications. Many of the genes and surrounding genetic markers (inserted *transposable elements*; see later) are arranged in multiple repeated units, which are shared by multiple primate species.[14] Gene families arising by similar processes of DNA duplication have been documented in a large number of cases.

New Genes from Transposable Elements

Half of the DNA in our genome has been contributed by *jumping genes* or *transposable elements*. These are discrete segments of DNA that reside in the genomes of fungi, plants, and animals. They are units of genetic material that possess the ability to propagate themselves haphazardly within genomes. They insert new copies of themselves into chromosomal DNA at loosely preferred sites, chosen largely at random from the vast number of potential sites distributed throughout the genome. The insertion process is marked by a particular signature: the inserted transposable element is flanked by short duplications of target site DNA. Such *target site duplications* arise from the mechanism by which transposable elements propagate. They can be classified into two main groups called *DNA transposons* and *retrotransposons*.[15]

One in every ten people may have a new insert in their germ-line DNA arising from the activity of these agents.[16] Because transposable elements invade new sites at random, they insert into and disrupt existing genes at an appreciable frequency. These agents are *insertional mutagens*, and their current activity is responsible for a significant burden of human genetic disease.[17] They are relevant to our understanding of human evolution for two reasons.

Firstly, the probability that two transposable elements of the same class would insert independently into the same site in the DNA of two individuals is negligible. Thus, if two (or more) individuals share the same parasitic insert in their DNA, it may be concluded that they are descendants of the one individual in which that unique insertion event occurred. Such instances exemplify the well-established concept of *founder mutations*.[18] Analogously, if two (or more) distinct *species* share the same parasitic insert in their DNA, it may be concluded that they are descendants of the one individual in which that unique insertion event occurred.[19] Genomic science has shown that >99% of the millions of genetic parasites inserted in the human genome[20] are shared with chimpanzees,[21] and the great majority are shared with macaques,

an OWM.[22] Such findings establish that humans, chimps, and (more remotely) macaques share common ancestors.

Secondly, transposable elements are individualistic genetic parasites. The transposable elements scattered throughout our genomes have traditionally been dismissed as "junk." However, it is now established that at least some of this DNA has been co-opted to provide essential genetic functionality.[23] The activities of these insertional mutagens are random with respect to the functioning of the host organism, but they have contributed to the development of complexity.

DNA Transposons

DNA transposons are short segments of self-propagating DNA that reside in the genomes of many organisms. Their origins are lost in remote history. They possess an enzyme called a *transposase* which enables them to cut-and-paste themselves into new sites in the genome. They appear to increase in number by co-ordinating their activities with episodes of cellular DNA synthesis. There are nearly 400,000 individual DNA transposons inserted into our genome, of which essentially all are shared with apes and OWMs.[24]

Many of the DNA transposons scattered throughout our genome have acquired genetic functionality since the time they inserted into the primate germ-line. Some now function as genes that generate RNA molecules involved in widespread and important regulatory functions.[25]

Other DNA transposons have contributed to the information content of genes that make proteins. A DNA transposon of the *Hsmar1* class inserted itself into a pre-existing gene (known as the *SET* gene) in an ancestor of apes and monkeys. This insertion event converted the *SET* gene into the novel *SETMAR* gene. This hybrid gene now makes a protein that may function in DNA repair processes, or in the regulation of genome activity (Figure 4). The portion of the SETMAR protein that was donated by the transposon retains many of the enzymatic functions performed by the original transposon-coded protein.[27]

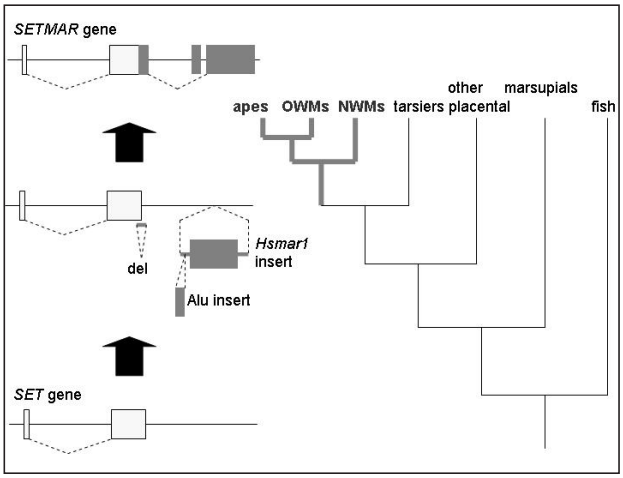

Figure 4. Birth of the *SETMAR* gene.

Lower left: The ancient *SET* gene consists of two segments of DNA.
Middle left: Two events transformed the *SET* gene into the *SETMAR* gene: the deletion of twenty-seven bases ("del") that allowed the second segment of coding DNA to extend to the right, and the insertion of an *Hsmar1* parasitic element that provided new coding information. An Alu element inserted beside the *Hsmar1* element, but did not become part of the gene.
Right: A partial evolutionary tree indicating the time at which the mutational events occurred (thickened line).[26]

Retrotransposons

Retrotransposons are parasitic residents of the genome that copy-and-paste themselves into new sites of genomic DNA via an RNA intermediate (Figure 5):

parent DNA insert →	RNA copies →	daughter DNA inserts

The *LTR retrotransposons* constitute one class of these agents. They are related to the retroviruses that cause human disease. Indeed our DNA contains many segments of retroviral DNA, known as *endogenous retroviruses*, which originally invaded the genome as infectious agents. We have inherited at least 300,000 LTR retrotransposons and endogenous retroviruses in our DNA. Nearly all of them are shared with chimps, and most with macaques. Most of them are genetic fossils that are degenerating into the genetic background, but some have assumed vital genetic functions.[28]

A few endogenous retroviruses have, against all odds, retained one of their genes in a form that can direct the production of an active protein. A gene that has excited particular interest is the *envelope* gene.[29] One of the endogenous retroviruses that retains an active *envelope* gene is the

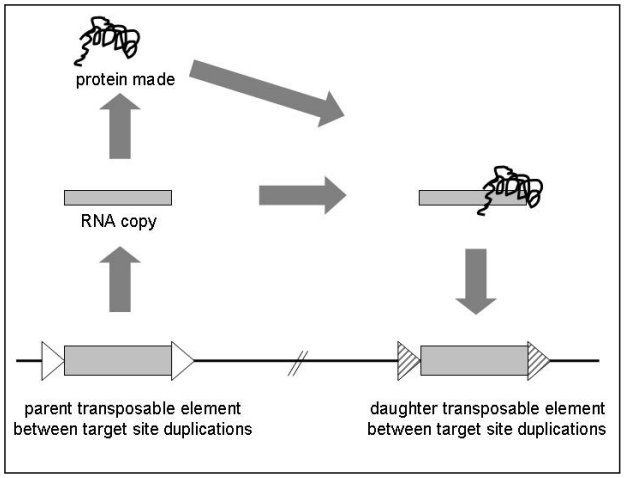

Figure 5. Propagation of a transposable element via an RNA intermediate.

A parent transposable element (situated in chromosomal DNA) is copied into a diffusible RNA molecule. This RNA directs the formation of proteins which remain associated with it, induce a cut at a new target site in chromosomal DNA, and insert a DNA copy into the gap made by the cut. Triangles indicate target site duplications (not drawn to scale).

unique ERVWE1 insert that became resident in primate DNA in an ape-OWM ancestor (Figure 6).[30] The ERVWE1 insert directs the production of an active envelope protein that is made in a specific population of cells in the placenta, and that appears to be necessary for placental and fetal development.[31] A gene added to primate DNA as part of the viral infection apparatus has been transmogrified into a gene that is essential for our life-cycle.

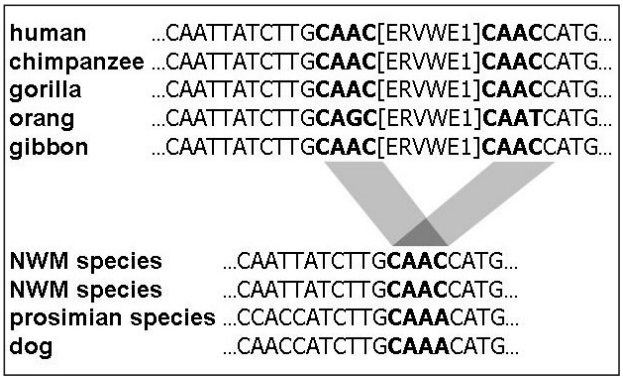

Figure 6. DNA sequence surrounding the ERVWE1 endogenous retrovirus.

All species of ape (and OWMs, sequence not available) have the same insert and variants of the same flanking target site duplication (bold). Other species tested show the uninterrupted precursor target site. Shading highlights the target site and its duplications.[32]

It appears that endogenous retroviruses repeatedly have donated genetic information that has contributed to the form and function of the placenta. The *PEG10* gene arose from a retrovirus-like agent that inserted into mammalian DNA in an ancestor of marsupials and Eutherians. It is also implicated in the formation of the placenta.[33] Mammalian development has been promoted through the exploitation of genetic material contributed by potentially pathogenic insertional mutagens.

Many other classes of retrotransposons in our DNA have contributed raw material that has led to the development of genetic novelty. *Alu elements* are found only in primates. There are at least 1.1 million of these inserts in our DNA. Nearly all of these inserts are shared with chimps (>99.9%) and most with macaques (90%). Alu elements have provided raw material from which new genes have been constructed.[34] They have inserted themselves into pre-existing genes, thereby generating alternative forms of those genes.[35] For example, an insert in the *survivin* gene, which controls life-and-death decisions in cells, entered the primate germ-line in an ancestor of the apes (Figure 7).

Mammalian-wide interspersed repeat (MIR) elements are very ancient and widely distributed in the DNA of all mammals. Essentially all of the 300,000 MIR elements present in our DNA are shared with chimps and macaques. Some genes (including the *ZNF639* and *POMC* genes) contain MIR inserts that have been found in all mammals tested including the egg-laying platypus.[36] Numerous other families of very ancient transposable elements have contributed functional units to our genome and each insert common to mammals establishes that the mammals are monophyletic (descended from a single common ancestor).[37]

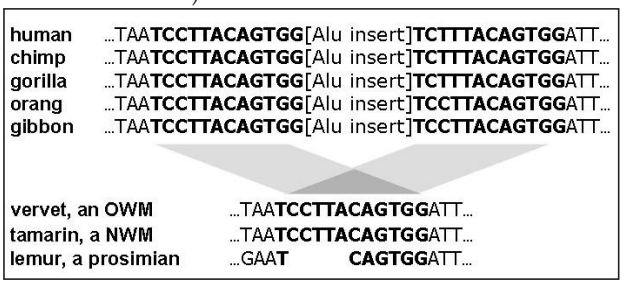

Figure 7. DNA sequence surrounding an Alu insert in the *survivin* gene.

All species of ape have the same insert and variants of the target site duplication (bold). Other species show the uninterrupted precursor target site. Shading highlights the target site and its duplications.[38]

Via Enzymatic Machinery of Retrotransposons

During the normal activities of cells, genes are copied into RNA, which performs housekeeping or regulatory functions, or directs the synthesis of proteins. RNA is normally short-lived, but sometimes, an RNA molecule becomes entangled in the enzymatic machinery of retrotransposons, and a DNA copy gets inserted back into chromosomal DNA. Our DNA contains thousands of copies of such randomly copied-and-pasted genes. Most have lost the capacity to make proteins, and are called *pseudogenes*.[39]

parent gene in DNA →	RNA copy →	daughter pseudogene in DNA

Despite the haphazard nature of this process, some of these copied-and-pasted inserts retain the capacity to direct the production of proteins. These additions to our gene complement are called *retrogenes*.

Our genome possesses a family of novel genes that arose following the insertion of a DNA segment from one gene (encoding a protein called β-actin) into another gene (called the POTE gene). This novel hybrid gene subsequently spawned a family of POTE-actin genes. The presence of a unique β-actin insertion site (with its tell-tale target site duplications) establishes that one original insertion event was followed by a series of gene duplication events. The outcome of this series of mutational events is that our genome possesses seven genes that contain the insertion (Figure 8). POTE-actin genes are found in apes and OWMs. This insertion mutation involving actin gene sequences is an unambiguous marker indicating that a novel gene family, and the complexity of function entailed in the interactions of its members, developed from a random event that occurred in an ancestor of apes and OWMs.[40]

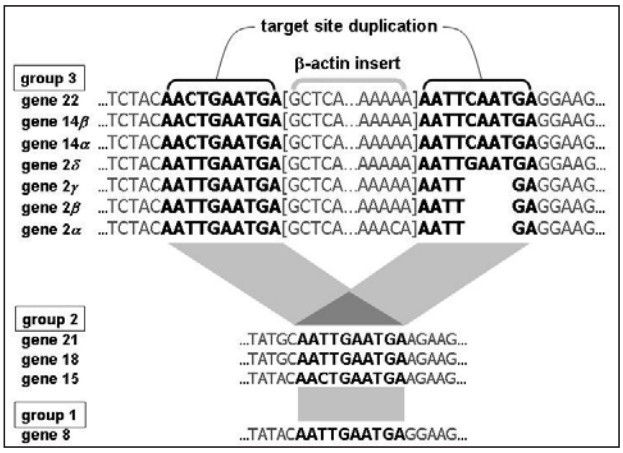

Figure 8. DNA sequences surrounding the β-actin insert in POTE genes.
Seven genes in the family have the β-actin insert and its target site duplication (bold). Apes and OWMs have representative β-actin-POTE genes, indicating that the insertion event occurred in an ape-OWM ancestor.[41]

The *PIPSL* gene (also an interesting hybrid gene) was inserted into the DNA of a great ape ancestor, and the *GLUD2* gene in an ape ancestor.[42] Retrogenes have accumulated in the DNA of our ancestors at a steady rate through primate history.[43] The process of transposable element-mediated gene generation has been in operation as far back in time as we are able to see. The *YY2* and *REX1* genes arose early in the development of placental mammals,[44] and other copied-and-pasted genes shared widely with other mammals are being identified all the time.[45]

These copying-and-pasting events have generated a host of retrogenes from which small RNA molecules are made. These RNA molecules perform a range of housekeeping jobs pertaining to genome function, and act as master regulators of genome activity. Most are shared with chimps; and some with creatures as distantly related as mice.[46] We are at least partially what our parasitic transposable elements have made us.

Genome Data and the Christian Worldview

An outline of the evolutionary development of the human species is depicted in Figure 9. This evolutionary tree has been established by many approaches. The comparative genomic approaches have provided compelling corroboration of the evolutionary relationships depicted. They have resolved long-standing controversies regarding some branch points. They have shown how genes have arisen at particular times through natural processes. Many similar events have been mapped to every point, and together have established the pattern of evolutionary branching.

This discussion has been limited to events in mammalian evolution because it is only in the timescale of mammalian evolution that the unambiguous genetic markers of our evolutionary history have survived. Transposable elements provide tantalizing molecular evidence for human-avian common ancestry,[47] without reporting (for example) any surviving shared transposable elements flanked by target site duplications. However, there is no reason to doubt the reality of earlier evolutionary transitions (inferred through other means) just because they occurred so long ago that unambiguous genetic markers establishing common descent have been eroded beyond recognition. How should Christians respond to such data, which are a small selection of what is available?[48]

An authentically biblical worldview requires that we view the world through *critically realist* eyes. Our mind-set must be *critical* in the sense that the data of experience must consistently challenge and correct our understanding of reality. It must be *realist* in the sense of recognizing that we face a world of which there is an objective truth, even though we will never fully grasp it. This mind-set governs Christian approaches to both the natural world[49] and to Scripture.[50] Transposable elements that disrupt genomes today possess genetic information that is highly similar to that in transposable elements that we share with other mammalian species. We must accept that they all arose through the same elaborate biochemical mechanisms. Genes present in our DNA *really* arose when transposons acquired coding capacity in simian ancestors. Christians have defended critical realism in other historical situations. The earth *really* revolves around the sun (*contra* the Aristotelians, who claimed that Galileo's heliocentric model merely *saved the appearances* as an interpretive device).[51] Christ *really* suffered (*contra* the docetists, who claimed he only *appeared* to do so).

If we are God's creation, then our DNA sequence is an authoritative text that God has written. It is the Primal Testament that describes how God in faithfulness has created, via the randomness of genetic happenstance, the creature that bears his image and that he intends to glorify. Francis Collins has stated that shared transposable

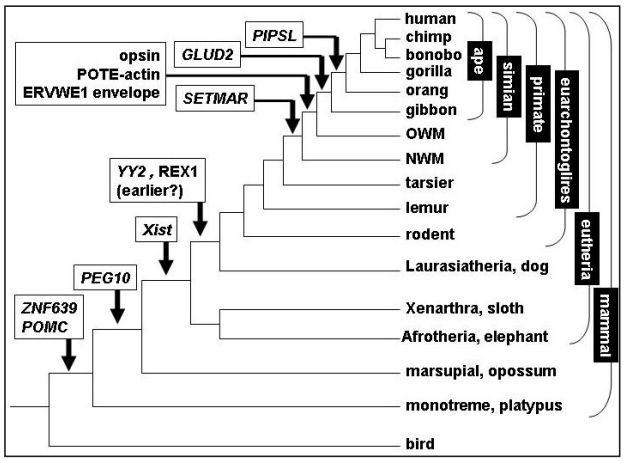

Figure 9. An outline of human evolution, indicating the timing of particular events described in this article.

elements have implications for common ancestry that are "virtually inescapable."[52] We must listen attentively to this text, and respond appropriately.

Creation and Evolution: Agency and Process

It follows that the theological assertion that God is our Creator may not be seen as an alternative to the evolutionary mechanism of human origins. This "either-or" position represents a false dichotomy. *Creation* refers to personal agency (the intentionality and action of God),[53] which may be described in terms such as goodness, love, and grace.[54] *Evolution* refers to material process. God creates. Transposable elements and genomes evolve. Indeed, transposons and genomes evolve in the world that God has chosen to create. *Creation* refers to God's continuous covenantal relationship with the entirety of creation—past, present, and future.[55] *Evolution*, with its physical components (bases, transposons) and its processes (duplications, insertions), describes only relationships within creation.

For Christians, the life, death, and resurrection of Christ constitute the necessary and sufficient basis of faith in the self-revealing God. From this foundation, all presuppositions that inform our interpretation of the world are necessarily theistic. Thus, all scientific descriptions of physical phenomena (such as the molecular mechanisms which gave rise to genes), since they are describable in physical terms, can and must be included within a Christian perspective of *reality as creation*. We dare not exclude any biological process—including evolutionary ones—from the creative work of God.

Neither is the agency of God an alternative to natural law. MacKay stated that "the laws of nature we discover are not *alternatives* to divine activity, but only our *codification* of that activity in its normal manifestations."[56] Similarly, Van Till stated:

> Natural laws are held to be statements describing the patterned behavior that matter and material systems exhibit as a consequence of divine governance. Natural laws are not prescriptive laws *of* nature for its own behavior but descriptive representations of the laws of God *for* nature, which is his creation.[57]

And to Polkinghorne, "Everything in the world—its form and its substance, the nature of law and the nature of matter—is contingent upon his will alone."[58]

Physical laws that describe the behavior of DNA and the way it mutates (no matter how probabilistic their operation may be) are laws that reflect God's faithful dealings with his creation. The lawful processes of segmental duplication and of retrotransposon insertion, responsible for the generation of new genes in now-extinct ancestors, are open to experimental analysis, are starkly molecular in nature, and are inalienably part of that physical reality that we recognize as creation. Thus any claims that "evolution is religion" cannot refer to evolution as description of biological history, but only to the metaphysical (atheistic) denial of God as its Author.

Creation and Random Process

This article has described how random mutations (insertions and deletions of bases, large duplications, and the actions of retroviruses and transposable elements) have arisen during primate history. In the timescale of a human life, they are commonly encountered as disease-causing mutations.[59] But over the timescales of mammalian history, these same events have helped to generate the human genome and humanity. The preponderant harmful mutations have not survived.

The roles of random mutagenic events in the evolutionary development of genes and their regulatory networks present no new issues to Christian theology. Genetic randomization processes are integral to sexual reproduction, and so reflect the creative work of God in the generation of *every* human being. It is axiomatic that sex exists to shuffle genetic material, partly through random assortment of chromosomes into gametes. The biological origin of each one of us is the outcome of the probabilistic segregation of chromosomes: given that humans possess two sets of chromosomes, each of which has twenty-three members, there are 2^{23} (8.4 million) possible ways of assorting them when gametes are formed. And to compound the degree of randomization, elaborate mechanisms exist to shuffle material between chromosome pairs.[60] To the Christian it is also axiomatic that each one of us is a created being (Ps. 139). Scientifically, we are the product of random genetic process. Theologically, we are the outcome of loving divine purpose. Molecular randomness (in scientific terms) and createdness (in theological terms) inevitably go hand-in-hand.

The operation of random (probabilistic) processes in gene and species formation cannot be an alternative to divine creativity, but is an aspect of divine creativity. Indeed, because of their evident role in contributing to the formation of new genes, such random processes (*chance*) in the context of the directing effects of selection (*necessity*) lead to predictable results. This lawful interaction between chance and necessity demonstrates the potentiality inherent in matter. The combination of randomness and determinism, chance and necessity, was God's way of generating life—including humanity.[61] The potentiality of the interaction between chance and necessity is a pointer to the rationality and purpose of God, analogous to the powerful problem-solving capacities of genetic algorithms, computer programs that select optimum solutions from a range that is randomly generated.[62]

Our genome has developed by incorporating novel features provided by random mutagenic events (of which over three million are recognizable as the insertions of transposable elements alone). These genetic processes are part of the divine creative strategy by which the creature that would bear God's image has come to be.

Divine Purpose and Creaturely Freedom

Is it legitimate to suggest that in the random events that transform evolving genomes, God's directing hand acts covertly and immediately to achieve his purposes?[63] Theological justification for this has been suggested by recourse to Prov. 16:33: "The lot is cast into the lap, but the decision is wholly from the Lord."[64] By this reasoning, God determines mutations, and so directs evolution.

But Kidner disallows this interpretation. He states: "The Old Testament use of the word *lot* is not about God's control of all random occurrences, but about his settling of matters properly referred to him."[65] In addition, the postulate that God controls phenomena that are to us random is problematic because the random events that have added novelty to our genome (over the long term) are identical to those that disrupt genomes and cause genetic disease (over the short term). There are good theological reasons for denying that God is the immediate cause of genetic mutations, because if he were, he would be the immediate cause of genetic diseases such as cancer. God is not the author of disease and suffering. Rather he is the implacable foe of disease and suffering. The healing works of Jesus and the cost of Calvary are the guarantee that he is committed ultimately to destroying not only evil but also disease (Isa. 53:4; Rev. 21:4).[66]

God sustains the lawfulness of the world, but is not the direct cause of each event. Thomas Aquinas spoke of God as the first cause. The universe and everything in it depends directly upon him. But a secondary level of causation exists. This is the interlocking and interdependent cause-and-effect network that constitutes the operation of the physical universe. McGrath has stated:

> Events within the created order can exist in complex causal relationships, without in any way denying their ultimate dependency upon God as final cause … This classic approach laid the conceptual foundations for the development of the natural sciences in the later middle ages.[67]

Israel's concept of creation entailed that the universe is subject to a single code of law that has been established for all time. God has devolved a self-sufficient mode of operation upon creation (it is autonomous), but this freedom exists only in relation to God who conferred it on creation (it is relative). Nature possesses *relative autonomy*.[68]

It seems that God has conferred the gift of freedom upon his created world, and upon the molecular processes that mold our genomes.[69] God does not determine DNA rearrangements (duplications, transposon insertions), but they are part of the network of autonomous secondary causation. Evolutionary transformations thus manifest the features of authentic history. The lawful behavior of the world sustained by God has provided channels by which our genome has freely evolved into what it is now.[70]

It is a paradox that the God of love has ordained a way of generating humankind that entails the possibility of disease and suffering. "If God *allows* sin and suffering, he remains answerable for them."[71] God is implacably opposed to pathogens and cancers, and is committed to destroying evil in all its manifestations. The resolution to this paradox is found in the mystery of God Incarnate, bearing the evil of the natural world as well as the totality of our sin. Calvary is the proof that God will eliminate evil from creation. The "Eschatological Doctrine of Providence" stems from the Resurrection and describes the hope that God will transform creation and remove all suffering from it.[72]

Creaturely Freedom in History

Genes describe biological (evolutionary or natural) history.[73] Biological history is analogous to human or biblical history. In each, God achieves his purposes with creatures that are endowed with freedom (the relative autonomy to act through secondary causes). The freedom of evolutionary process thus presents no new problems for Christians.

God is the *sufficient* condition for the existence of the world: he alone is the source of all reality. But God limits himself to being the *necessary* condition for every occurrence in the world: he does not determine everything that happens. If God did not grant such freedom, "neither the relative autonomy of natural processes in the world which we express in the probabilistic statements of natural laws nor human freedom would be possible."[74]

Polkinghorne draws an analogy between the freedom God gives to creation (seen in the randomness of natural process, and which may result in natural evil) and free will exercised by people (which results in moral evil). The "free-process" defense argues that a free world with the capacity for disease and disaster is superior to a wholly deterministic one. The "free-will" concept argues that a world in which people have the capacity to act in evil ways is better than a world of automata.[75]

God does not determine the way in which people will live. He gives people free choice—which is often used in selfish, evil, and irrational (arbitrary) ways that are opposed to his holy nature. And yet in the context of God's faithfulness, history progresses through this chaotic matrix (randomness) toward the glory that God has purposed. Biblical history provides many examples of how

arbitrary human evil, exercised in freedom and contrary to the nature and will of God, has contributed to the fulfilment of God's goals.

Pharaoh acted freely in defiance of God but the biblical interpreters saw his arbitrary evil choices as contributing to the achievement of God's purposes (Rom. 9:17). The Assyrians in all their sadistic ruthlessness were (unwittingly) the "rod" of God's anger (Isa. 10:5), the "bees" God summoned to effect his purposes (Isa. 7:18). The ruthless Nebuchadnezzar was God's "servant" (Jer. 25:9; 27:6; 43:10). Cyrus, acting out of political expediency, was God's "messiah" in allowing the exiles to return (Isa. 45:1). Those who collaborated to murder Christ, acting in opposition to the nature of God, were unwittingly bringing the purpose of history to its fulfilment (Acts 2:23, 36; 3:13–15, 18). The messy "randomness" of history is incorporated by God to achieve his ends. These ends are the ongoing creation of the nation of Israel (Isa. 43:1, 15; 44:2); a reformed Israel after the Exile (Isa. 4:5; 41:17–20); a new, redeemed humanity (2 Cor. 5:17; Eph. 2:10, 15); and the eschatological Kingdom of God (Isa. 65:17; 66:22; 2 Pet. 3:13; Rev. 21:1).

The insights of the Princeton theologian B. B. Warfield are pertinent in trying to understand how God achieves his ends through secondary causes (whether random genetic mutations or arbitrary human agents). Warfield was supportive of evolution as a theory operating under the control of providence. Indeed, natural laws were the expression of divine supervision.[76] This must be true of natural laws which are probabilistic, such as those that describe mutational events.

Warfield emphasized that "evolution could be given a teleological reading, that mechanical explanations in nature were thoroughly consistent with his Calvinistic conception of divine creation" (1889). Moreover, teleology was inseparable from a complete system of natural causation: "Every teleological system implies a complete 'causo-mechanical' explanation as its instrument" (1908).[77] Warfield integrated God's purpose with evolution's freedom using the concept of *concursus*. In the same way as Scripture is at once wholly the outcome of the will of God and the action of humans, so evolution is entirely the work of God and also of the operation of natural causes.

God is not known by Aristotelian "proofs," whether these come from the schools of Thomas Aquinas, William Paley, or the Intelligent Design movement.[78] He is known only by his self-revelation through history, and climactically in Christ. Christians reflecting on the randomness of genetic history as revealed by comparative genomics may marvel that we are here, and so worship God for bringing humanity into being via genetic randomness. Biological evolution, just like the progressive unfolding of God's purposes in the messiness of history, is testimony to the sovereign wisdom and authority by which God brings a freely operating world to fulfilment, and so transforms randomness into glory.

There is of course mystery in this. The achievement of God's purposes in the light of genetic or human freedom is a paradox to which we must hold. The actions of God in history are not obvious to the casual observer. Butterfield wrote that we cannot find the hand of God in secular history unless we have first gained assurance of God's involvement by personal experience.[79] It is Christ who makes sense of Israel's tumultuous past. Once we have recognized how God's blessing for the world arose from Israel's tragic history, we may perceive with worship that he has created humanity by the random evolutionary route attested by our genome.

The vision of God's sovereign action revealed in biological and human history is a comfort to each of us as individuals. For in the chaos of our lives—the "randomness" of accident, sickness, irrational and selfish choices—the God in whom we have placed our trust is faithfully at work to bring those lives to the ends which he has purposed. The God who created the human species through the turbulent genetic history recorded in its genome can be trusted to bring us, through the happenstance of our lives, to completion in his presence. ✦

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