Scientia*et*Fides 12(1)/2024 ISSN 2300-7648 (print) / ISSN 2353-5636 (online)

Received: July 17, 2023. Accepted: September 9, 2023 DOI: http://doi.org/10.12775/SetF.2024.009

Why Biological Evolution Should Inspire Worship

GRAEME FINLAY
University of Auckland
g.finlay@auckland.ac.nz
ORCID: 0000-0001-8853-8187

Abstract. The theory of biological evolution has often provoked disagreement, which has frequently been divisive and counterproductive. At other times this scientific paradigm has been discussed with an apologetic intent, to explain why the science of biology and the theology of creation cannot be seen to be mutually exclusive. This paper urges Christians to move decisively to a third type of discourse. The new field of comparative genetics has provided conclusive evidence that biological evolution has given rise to the diversity of living forms, including human beings. Consequently, Christians should, with confidence, gladly accept the evolutionary paradigm and look upon evolution as a divinely ordained historical process that develops through random (stochastic, free) process, but that leads to a divinely purposed consummation. As a result, biological history in its freedom but directedness to God's final purposes should elicit wonder. People who have come to faith in the God revealed redemptively in Jesus should uninhibitedly offer adoration and praise for evolutionary fruitfulness. Worship should characterise the human response to biological history.[1]

Keywords: endogenous retrovirus, transposable element, comparative genomics, randomness, creation, worship.

[1] In appreciation of Professor Tom McLeish FRS, scientist, teacher, theologian.

Introduction

Mistrust of science is widespread in Christian communities. Such mistrust relates especially to the historical sciences such as biological evolution. But there is an irony in this rejection of evolutionary science. As historian Mark Noll has noted, when Christians have rigidly adhered to long-held beliefs concerning how God had made physical and biological reality, they have actually "forfeited the opportunity to glorify God for the way he had made nature" (Hanes 2021). Scientific discoveries may require mental adjustment, but can only point to the grandeur of God's creative work.

Human beings of all civilisations have marvelled at the phenomena of nature, but the invisible presuppositions underlying science originate from belief in a creating God whose authority is unchallenged, who is rational, faithful, good, who acts freely and who is redeeming (Finlay 2022). As Denis Alexander has stated, "the very notion of 'natural laws' is rooted in the understanding of a rational Creator God who sustains an intelligible universe with moral laws that, ipso facto, must also be characterized by scientific laws" (2019, 120–121; also Harrison 2021).

1. Science and the wonder of creation

Biblical writers express praise for the wonder of the cosmos and its creating God. "The heavens declare the glory of God; the skies proclaim the work of his hands" (Ps 19:1). Brueggemann states that the glory of God is present locally in Israel and in its largest theatre, the whole of creation. "Israel in its testimony must utilize the most sweeping doxological language available in order to witness to the largeness and unrivalled awesomeness of Yahweh's wondrous, sovereign presence." Israel perceives "creation as a witness to Yahweh's glory" (Brueggemann 1997, 287). Israel's God, revealed in judgment and salvation, is also the God to be worshiped for the wonders of the physical creation (Amos 5:8): [2]

[2] Also 4:13; 9:6; Jer 51:15–19; 31:35–37 Isa 40:12–14, 21–22, 25–28; 42:5; 45:5–7, 12; 48:12–13; 51:12–13; this God is also identified in the worship-inducing actions in history, Isa 47—48.

> He who made the Pleiades and Orion,
> who turns midnight into dawn
> and darkens day into night,
> who calls for the waters of the sea
> and pours them out over the face of the land—
> the LORD is his name.

It is not surprising that Augustine could say: "Some people read books in order to find God. But the very appearance of God's creation is a great book." The "two books" metaphor has endured. Thomas Willis (1621–75), a pioneer of neurology, said that in the books of scripture and of science "there is no page certainly which shews not the Author, and his Power, Goodness, Trust and Wisdom" (quoted by Joel Green in Jeeves 2011, 271).

The pursuit of science and the worship of the God of science should be mutually reinforcing. On the one hand, a knowledge of God, the loving author of the world, should enhance the wonder of scientific discovery. Three physicists have written "while any scientist can experience the intense joy of understanding something for the first time, those who know in some measure the creator whose works they are studying experience a hugely significant additional experience of pleasure" (Briggs et al. 2018, 80). They have stated, "if God is the creator and He created the world then there's a pleasure and enjoyment in studying His creation" (Briggs et al. 2018, 339–340). To Alister McGrath, faith in the God revealed in Jesus provides a "remarkable conceptual lens" which enables people to "look at the natural world, appreciate its beauty to a far greater extent than would otherwise be the case, and also appreciate the intellectual capaciousness of the Christian way of thinking which helps make so much sense […] of what we observe without us" (Ashby et al. 2018, 194).

On the other hand, the disclosure of the nature of physical and biological reality, in all its mind- and purpose-evincing rational coherence, should inspire the worship of God. Chris Mulherin has stated that, for Christians, creation's Author is revealed "in the wonder and beauty of the natural order"—which should be a huge inducement to caring for it (Ashby et al. 2018, 123). Such worship is amply illustrated by those who

have studied the physical cosmos. It is evident in pioneering scientists, such as Copernicus: "To know the mighty works of God, to comprehend his wisdom and majesty and power; to appreciate, in degree, the wonderful workings of His laws, surely all this must be a pleasing and acceptable mode of Worship to the Most High" (in Hutchings and McLeish 2017, 153).

Many of the contributors to classical and quantum physics expressed their worship of the divine Source of material reality. To Michael Faraday, "a glorious discovery in natural knowledge, and the wisdom and power of God in the creation, is awaiting our age." James Clerk Maxwell stated that "Christians whose minds are scientific are bound to study science that their view of the glory of God may be as extensive as their being is capable" (in Hutchings and McLeish 2017, 86–87). Maxwell, founder of the Cavendish laboratory, placed the words of Psalm 119:2 above its entrance: "The works of the Lord are great, studied by everybody who has pleasure in them." This quote was perpetuated by Andrew Briggs on the new Cavendish laboratory (Wagner and Briggs 2016, 439–440). "If you believe the Psalms and you take them seriously, that's what science is. It is studying how God makes the world work" (Briggs et al. 2018, 333).

Heino Falcke studies black holes, cosmic sinks that are inconceivably strange in nature. He has written: "Physics reveals new wonders to me, but it doesn't take away my faith; rather it expands and deepens it. If I look upon Jesus Christ the person, I discover the human side of creation and the creator" (Falcke 2021, 291). We can marvel at the universe, but faith, hope and love "make us stardust of a very special kind" (Falcke 2021, 293).

We may concur with John Polkinghorne (2004, 180) that "the explanation of the success of science in exploring the intelligible universe is ultimately theological rather than philosophical." His conviction arises "from the fact that this specific universe is a creation endowed with a rational order that is accessible to creatures who are made in the image of the Creator." We may worship God through the discoveries of science because science is God's gift (Hutchings and McLeish 2017, 22).

New understandings of the condensed repository of genetic information embodied in the base sequence of DNA have elicited worship (Collins 2006). DNA is a polymer once thought to lack the variety needed for he-

reditary function. Aspects of our phylogenetic development are inscribed in the genome, as described below. This history provides reasons why Christians should worship the God of evolution.

2. The evolving genome and its colonisers

Our DNA is packaged into forty-six chromosomes and, if linked end-to-end, would extend for two metres per cell. This DNA contains six billion information-carrying chemical units called bases. The order (or *sequence*) in which the four different bases occur constitutes the information-carrying medium of the genome. Genomes contain a cumulative record of formative events. The new science of comparative genomics—multispecies genome comparisons—is illuminating genetic mechanisms of evolution.

Genomes have been colonised by parasitic units of DNA. Such inhabitants of genomes are of two classes: *endogenous retroviruses* and *transposable elements*, the study of which provides elegant and unambiguous markers of phylogenetic relationships of species, and insights into how novel capacities arise. They illustrate the role of random mutations in phylogenetic development. They demonstrate how randomness emerges into order.

(a) Endogenous retroviruses

Retroviruses modify the genomes of infected cells by inserting their genetic material into cellular DNA. The prefix *retro* indicates that RNA in the virus particle is reverse copied into DNA which is spliced into genomic DNA of infected cells. The insertion event occurs at a randomly selected *target site*. As the viral DNA is spliced into the host DNA, a copy of the target site is generated at each end of the insert.

Retroviruses may infect *somatic* cells (those not in the direct lineage of reproductive cells) to cause diseases (leukaemia, AIDS). If they infect *reproductive* cells, they may be transmitted to future generations. Inherited retroviruses are said to be *endogenous*. Retrovirus genomes contain sequence motifs that direct the activity of viral genes—part of the mecha-

nism of viral reproduction. But when retroviruses are stably transmitted as endogenous retroviruses (ERVs), these same motifs can be recruited to direct the activity of cellular genes. The virus machinery becomes domesticated to serve the host organism.

Scientists have studied a class of ERV that has gene-activating (enhancer) activity in cells, in order to learn how that activity develops with time (Du et al. 2022, 1840). ERVs of the LTR18A/C type are frequently recruited to regulate nearby cellular genes. The insertion site of one such ERV is shown in Fig. 1. The ERV is present in every species of simian primate (ape, Old World and New World monkeys). The probability of multiple retroviruses of the same type inserting their DNA into exactly the same site of multiple species is infinitesimal. It follows that every species that

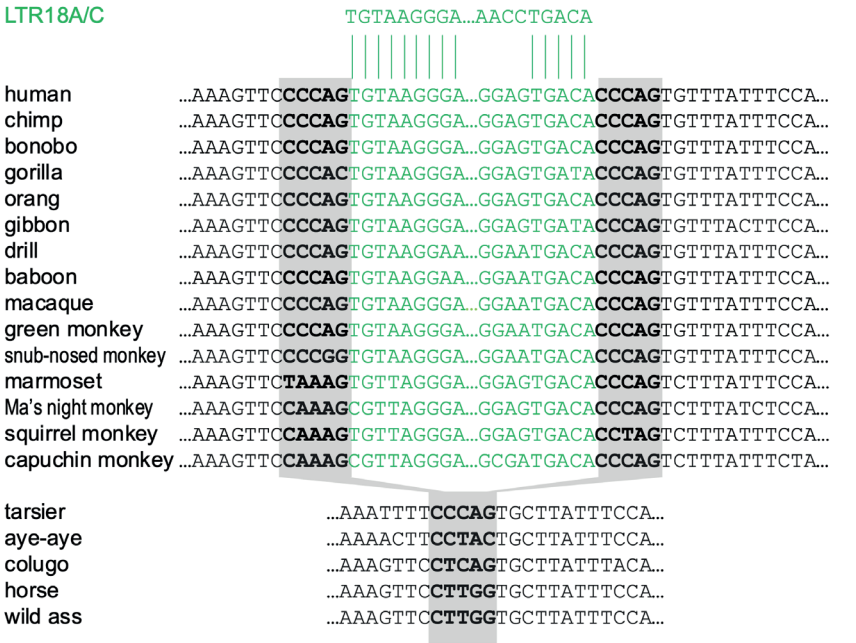

Figure 1. The insertion site of an LTR18A endogenous retrovirus

The left- and right-hand ends of the ERV sequence are shown in green type. In this and similar figures, the target site (selected by the retroviral *integrase* enzyme) is in **bold** type and shaded, and is duplicated to bracket the ERV insert. Sequences were obtained from the UCSC Browser (human), NCBI BLAST (other species), and the Dfam database (LTR18A/C). Insert identified by Du et al. 2022.

possesses the ERV inherited it from the one ancestor in which the insertion event occurred. This establishes that we and marmosets are co-descendants of the same individual. The insertion event occurred in a simian ancestor that lived 40 million years ago (Foley et al. 2023, eabl8189; Kuderna et al. 2023, 906). DNA is an amazingly stable but modifiable text.

Early in human development, multiple classes of ERV acquire the ability to recruit gene-activating proteins. Many ERVs of the LTR5B type have a sequence motif (GATAA) that recruits a gene-activating protein known as GATA6 (active in embryonic tissue called endoderm). That is, the ERV insert harbours a GATA6-dependent enhancer of gene activity. The insertion site of one such LTR5B is shown in Fig. 2 (Pontis et al. 2022, 7178).

Figure 2. The insertion site of an LTR5B endogenous retrovirus

The LTR5B sequence (green) shows GATA6-dependent gene enhancer activity (Pontis et al. 2022, 7178). Of incidental interest, a transposable element (AluS type) is present immediately to the right of the LTR5B insert (blue). Parent transposable elements in DNA generate RNA intermediates which are reverse-transcribed into daughter DNA elements (for a generalized scheme, see Fig. 4, green).

In this unique arrangement, two parasitic units of DNA are found between three versions of the target site. The originating events may be reconstructed as follows.

1. The original target site as exemplified in Old World monkeys (drill, baboon, macaque, green monkey, snub-nosed monkey) is ATAAGT.
2. An AluS transposable element inserted at this target site—a unique event, necessarily in a single cell—in an ancestor of all hominoid primates (apes).
3. The left hand target site subsequently mutated to ATAAGG.
4. In the same ancestral lineage, the LTR5B inserted into the left hand target site, which was in turn duplicated as ATAAGG.
5. This ancestor transmitted the unique genetic marker to all the descendent ape species, providing an unassailable marker of ape monophylicity (descent from the same ancestor).

The placenta is a recently evolved organ that differs greatly between mammals. One reason for this divergence is that many ERVs containing gene-regulatory sequences have been co-opted to control genes active in placental development. For example, the primate-specific MER41 family of ERVs frequently contains enhancer sequences, that possess binding sites for gene-activating proteins (GATA2 and 3) and gene-repressing proteins (MSX2) (Fig. 3, above). A MER41 insertion site demonstrating simian monophylicity is shown below. Enhancers active in trophoblastic stem cells (that give rise to placental tissue) are found within many other ERV types (Du et al. 2023, 197).

(b) Transposable elements

Transposable elements are virus-like units of DNA that enact their life cycles only in cell genomes.[3] A parent element in genomic DNA is transcribed into an RNA copy which is then inserted as a daughter element in the genome: DNA → RNA intermediate → DNA copy. An ape-specific AluS element is depicted in Fig. 2. Alu elements have reproduced to

[3] In this paper only *retrotransposons* will be discussed: DNA → RNA intermediate → DNA. Other classes of transposable element exist.

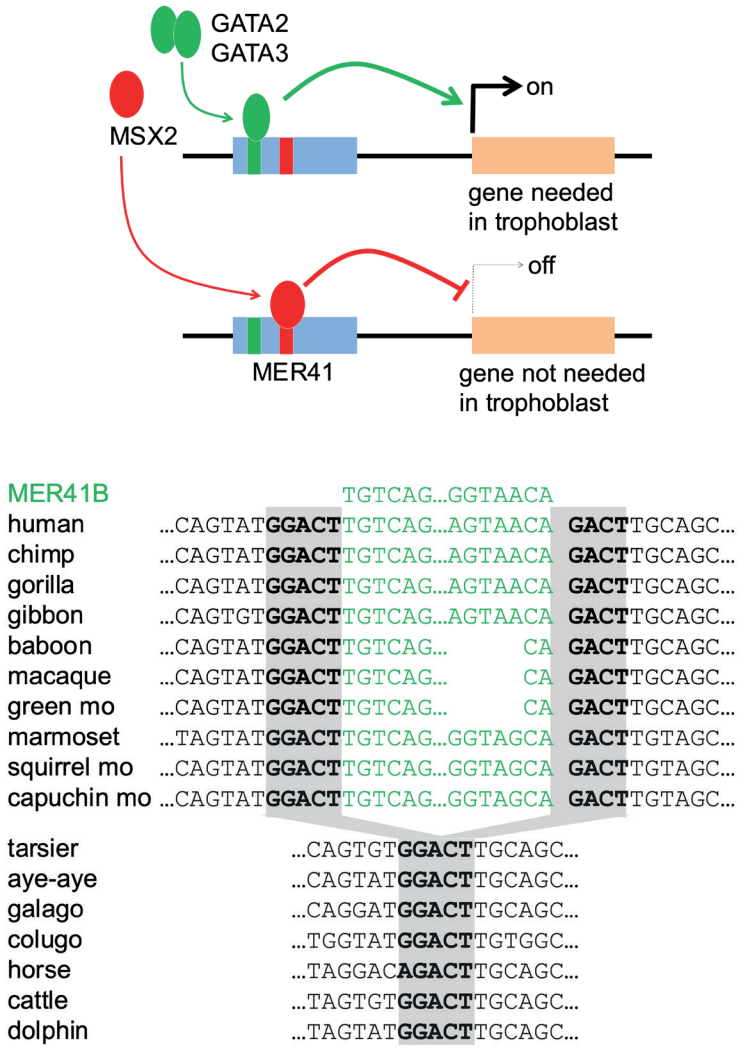

Figure 3. The insertion site of a MER41 endogenous retrovirus

Above: MER41 elements contain binding sites for proteins that both *promote* (GATA2 and GATA3, green ovals) and *suppress* (MSX2, red oval) genes required for trophoblast character.

Below: the insertion site of a MER41B element. A candidate target gene is the nearby *TINAGL1* gene (expressed in human placenta). The right-hand target site duplicate has lost a base ('GGACT' has reduced to 'GACT'), which occurred soon after the insert arose, as the deletion is apparent in all species with the insert. Old World Monkeys (mo, monkey) have a seven base deletion near the right end of the insert (Du et al. 2023).

1,100,000 copies in the genome by a copy-and-paste strategy. Transposable elements provide definitive markers of phylogenetic relationships (Nikaido et al. 2022, 989). Darwin could not have asked for more elegant and compelling markers for use in molecular systematics.

Transposable element activity is haphazard. Their enzymes may promiscuously attach themselves to RNA molecules derived from cellular genes and splice them back into genomes to generate copies of the original gene: cellular gene (in DNA) → RNA → reverse-transcribed gene copy (in DNA). The process is depicted in Fig. 4. Our genome contains thousands of copied *retrogenes*.

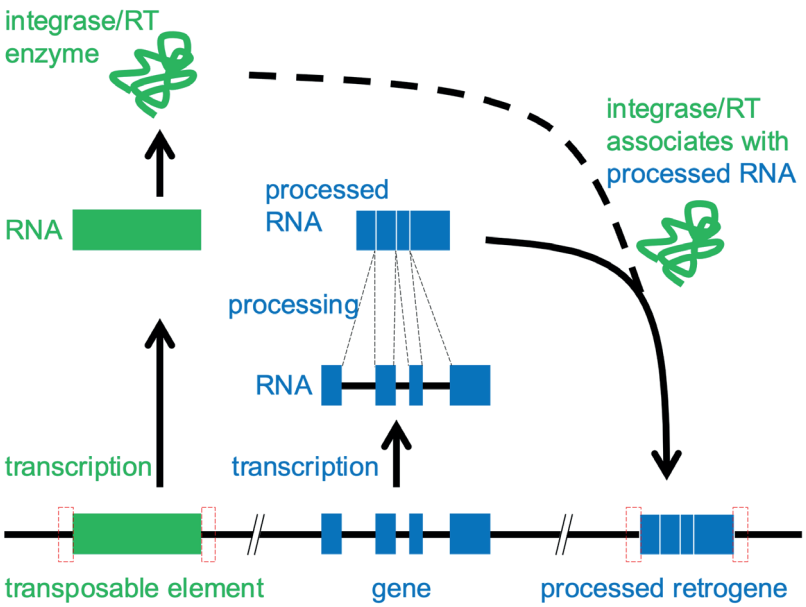

Figure 4. How transposable elements duplicate genes

Certain transposable elements generate RNA molecules which direct the production of proteins (including an integrase/reverse transcriptase enzyme) (green) which typically associate with the elements' RNA molecules and splice them back into the genome as a daughter element. However, on occasion, the element enzymes may associate, wholly serendipitously, with an RNA molecule generated from a cellular gene, and splice that RNA molecule (or part thereof) back into the genome (blue). The *retrogene* is recognisable as it arose from a *processed* RNA molecule, and is bracketed by target site duplications. It may degrade as a relic, or retain coding function that diverges to provide novel functionality.

A new gene copy may simply degenerate. If it happens to be located near appropriate control sequences, it may be transcribed into a functional RNA molecule and even direct the production of a protein. It may accumulate mutations that confer upon it novel functions. One cannot predict which of these options will pertain to any one retrogene. The whole process giving rise to novel genes involves sequential random events. Three examples follow.

Ribosomes[4] are partially structured by RNA molecules that are generated from 5S rRNA genes. Many retrogenes derived from 5S rRNA genes have been produced by courtesy of transposable element-derived enzymes. One such retrocopied gene (*RNA5SP141*) operates in our cells to protect us from infections by Herpes Simplex virus type 1 (HSV-1; causes cold sores).

When cells are infected with HSV-1, the *RNA5SP141* retrogene is copied into a 5S RNA molecule, activating a protein called RIG-1, which in turn induces production of the antiviral cytokine interferon IFN-1 (Fig. 5, above). TFIIIA is a protein required for transcription from the *RNA5SP141* gene. Some people lack TFIIIA and this mechanism will fail. In such people, HSP-1 infections (trivial in most people) may be catastrophic (Naesens et al. 2022, eabq4531). A random gene duplication protects us from HSV-1 infections.

But when did the retrogene arise? Multi-genome comparison shows that the retrogene is present only in humans (Fig. 5, below). It was generated after the human lineage diverged from that of other primates. The original target site remains undisturbed in other primates and in the colugo.

Ku70p is a protein that helps repair DNA breaks. In primates, the gene that encodes this vital protein, *KU70*, has been copied-and-pasted by transposable element-derived enzymes on numerous occasions. The human genome contains five *NUKU* retrogenes, of which *NUKU2* and *NUKU5* (both inserted into the X chromosome) show tantalising clues as to current activity. The *NUKU2* retrocopy, present in apes and Old World

[4] Ribosomes are bodies composed of RNA and proteins, upon which cells synthesise proteins.

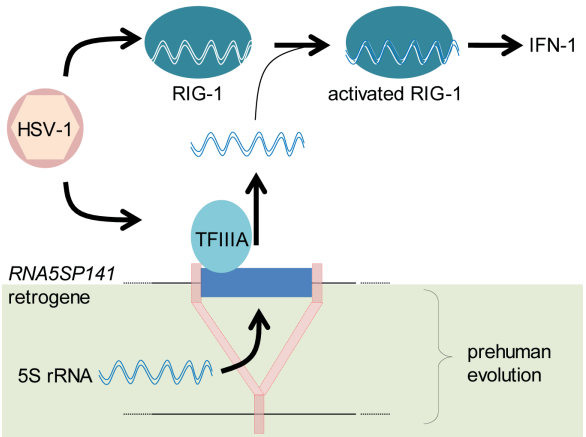

Figure 5. A 5S rRNA molecule, generated from a retrogene, stimulates antiviral responses

Above: Role of a 5S rRNA retrogene in providing immunity against Herpes Simplex-1 virus (Naesens et al. 2022, eabq4531).
Below: The insertion site of the 5S rRNA retrogene. In this and the next two figures, the first and last few bases of the retrogene are shown in blue type. 5S rRNA sequence identified by BLAST.

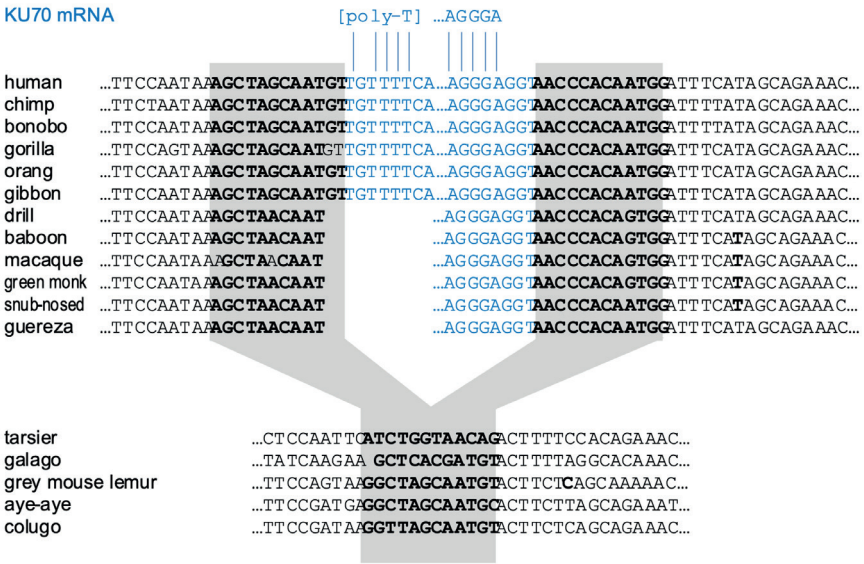

Figure 6. The insertion site of the *NUKU2* retrogene

The *NUKU2* retrogene is present but degenerated in New World monkeys (Rowley et al. 2021, jkab163).

monkeys (Fig. 6), retains protein-coding potentiality. It has undergone changes that might provide new functions; although no protein has been demonstrated. The sequence of *NUKU5* appears to have undergone random genetic drift[5] but may produce a protein (Rowley et al. 2021, jkab163). Only further experimentation will establish whether functionality has been acquired. Such uncertainties emphasise the contingency of mutational effects and of evolutionary change.

The *HAPSTR2* retrogene, copied from the parent *HAPSTR1* gene, also provides functionality in human cells. The protein specified by the *HAPSTR2* retrogene binds to that made by the parent gene and promotes the

[5] Base changes that change amino acids are as frequent as those that don't.

stability of the latter. The overall effect is to augment the ability of cells to cope with stressful conditions (Amici et al. 2023, 152).

Remarkably, the *HAPSTR2* retrogene arose in an ancestor of all extant placental mammals but retains recognisable target site duplications in species as distantly related as humans, elephants and armadillos (Fig. 7). Normally target site duplications originating in such deep time would have degenerated beyond recognition. The retrogene preserves the signature of a random molecular event that occurred in one reproductive cell over 80 million years ago (Foley et al. 2023, eabl8189).

Figure 7. The insertion site of the *HAPSTR2* retrogene

The left-hand target site duplicate has one fewer base than the right-hand one. In the absence of a known pre-insertion site, it is not clear whether the former reflects a deletion, or the latter an insertion of this (T) base.
The pre-insertion site is not recognisable in non-eutherian mammals. A hypothetical pre-insertion sequence may be reconstructed (Amici et al. 2023, 152).

Who would have anticipated, even in the 1980s, that the DNA sequestered in every nucleated cell of our bodies possesses ancient information that outlines our genealogy? We are descended from ancestors we share with all other humans beings (Fig. 5), with all other apes (Fig. 2), with all other simian (anthropoid) primates (Fig. 1, 3 and 6), and with all other fully placental (eutherian) mammals (Fig. 7). And genetic agents that mutate genomes have reorganised regulatory circuits (ERVs) and provided new genes (transposable elements) that contribute to our current capacities.

3. Biology is historical

Reality at all scales is historical. Time is factored into measurements of cosmic distances (light-years). "When we look out into space we always see its past" (Falcke 2021, 14). Geological strata define Earth's historical epochs (Rudwick 2014). The genome is not a single-edition instruction book, but also provides a cumulative record of its own formation (Figs. 1–3, 5–7 each describes a past event; Collins 2006, 123). The genome documents history in all its contingency.

"Creation as a whole is radically historical: history is not just a function of human culture" (Osborn 1993, 115). As Polkinghorne (2004, 104) has said, "we are forced to take the temporal dimension of reality extremely seriously. For us, time is no longer just the index of historical events; evolutionary insight implies that it has played an essential formative role in the constitution of the present." Genomically encoded evolutionary history provides a wealth of information as to how we came to be what we now are.

For those who embrace a biblical world view, this scientific conclusion encourages theological interpretation. Polkinghorne (2004, 158) has reflected on "what science can tell us about the history of this creation" and posits that "it is surely that God is patient and subtle, content to work through unfolding process." Implicit in this understanding is the claim that God works immanently in the unfolding (evolving) course of crea-

tion. So it is that "the God of the Bible is portrayed as one who continually engages with unfolding history, and this is something that can be fittingly supposed of the Creator of a world of unfolding fruitfulness" (in Alexander 2019, 12).

The discovery that the genome embodies a historical record should be familiar and welcome territory for Christian believers, for whom the Scriptures are a historical record of God's dealings with humanity. Christian theology is an interpretation of historical reality: Wright and Bird (2019, 80) observe that New Testament studies require both the approaches of doing history (the descriptive part) and theology (the prescriptive part). Neither the study of early church history nor the study of New Testament theology is self-sufficient. "They are in fact mutually dependent." When historical data are "properly interpreted" and "responsibly appropriated and applied, they carry prescriptive force for what the followers of Jesus believe and the task to which they are called." History and theology need each other (Wright and Bird 2019, 81) and this is as true of biological history as it is of early church history.

The genome informs its readers about aspects of *creation* history. It is the prequel, the backstory, to the biblical record which describes *new creation* history. Genomic history should elicit worship from people whose minds have been formed by biblical history.

4. Comparative genomics reveal evolution's elegant mechanisms

The vignettes presented above show the surprising elegance in genome evolution. It might seem strange that parasitic and disruptive ERVs and transposable elements are tolerated in genomes. Perhaps they are tolerated because of their capacity to generate essential selectable information. As they multiply, they scatter across genomes embedded sequence motifs that possess potential regulatory function. Genetic regulatory networks can be concertedly and efficiently rewired.

New enhancer motifs (Figs. 1–3) demonstrate how the random accumulation of ERVs and transposable elements has reorganised the genetic

instructions underlying the developmental uniqueness of species. Myriad such enhancers operative from our inception have had a major impact on the human body plan and on those of other species (Pontis et al. 2022, 7178). Placenta and mammary gland are recently developed organs, in which genes have been repurposed by ERVs and transposable elements. ERVs contribute to specification of (placental) trophoblastic cells by donating DNA motifs that bind fate-determining proteins GATA2, GATA3 and MSX2 (Fig. 3).

Transposable element-encoded enzymes act promiscuously. They can hop facilely from one RNA template to another (Fig. 4), generating new gene copies and distributing them through the genome. As redundant copies, they can undergo mutational change at no cost to the host organism, and can generate novel functionality. There is a continual arms race between pathogenic viruses and immunity. One 5S rRNA retrocopy acts to protect cells from HSV-1 (Fig. 5), and loss of this serendipitously acquired function can lead to devastating Herpes Simplex encephalitis (Naesens et al. 2022, eabq4531).

Francis Collins, former Director of the Human Genome Project, has said that: "The God of the Bible is also the God of the genome. He can be worshiped in the cathedral or in the laboratory. His creation is majestic, awesome, intricate, and beautiful" (Collins 2006, 211). To Collins, the human genome is "written in the DNA language by which God spoke life into being." He confessed to feeling "an overwhelming sense of awe in surveying this most significant of all biological texts" (2006, 123–124). Physicists who are Christian believers concur with Collins in their "awe at the intricacy of the genome, and the sorts of physical processes that worked together in its evolution" (Briggs et al. 2018, 164).

5. Worship for the potentiality inherent in creation

The science of comparative genomics has shown how natural molecular process has driven evolutionary development—including ours. The polymath Leibniz observed that God "would build things to realize his ends without ever having to step in to make adjustments […] one who trusts

in God should expect to find no gaps in nature" (Briggs et al. 2018, 161). Over a century later, the Rev Charles Kingsley manifested this confidence when he welcomed Darwin's evolutionary hypothesis. God was not an interfering God. A more appropriate conception of God's creative work is that "he can make all things make themselves" (in Brooke 1991, 293–294; Alexander 2019, 9).

We take this expression as a metaphor for the insight that creation has been so constituted that natural historical process can realise the potential intrinsic to it. Reality is so sustained by God that it can generate wonderful novelties that are latent and inherent in its constitution. In this understanding we can wonder at creation's capacity to realise its given potential (Ashby et al. 2018, 215, 216, 265). Or as Polkinghorne has said, "The scientist-theologians believe that, as part of the divine kenosis involved in the act of bringing into being the created other, allowed to be itself and to make itself, God has freely embraced temporality in addition to divine eternity" (Polkinghorne 2004, 54; also 72, 85, 96, 149). God's "purposes are being worked out through the unfolding improvisations of open historical process" (Polkinghorne 2004, 55).

Tom Wright (2014, 19) uses the same metaphor is his discussion of God's creative work. In the Genesis account, "God is said to have made a world *that will then make itself*." Trees and plants perpetuate themselves by bearing fruit; animals produce their young. We can readily extend this as a theological affirmation of the vigorous self-perpetuation and self-elaboration of life manifested through phylogenetic history.

Holmes Rolston (1999, 12) has observed that "the earth produces of itself" (αὐτομάτη, automatically; Mk 4:28). He indicates that this term denotes an "innate principle of the spontaneous origination of order, that is, of genesis." Organisms, species and ecosystems share this self-organising property.[6] A delightful term used to describe the exuberant capacity of life to perpetuate itself and to develop new capacities is *autopoiesis* (Rolston 1999, 12, 52, 298, 353, 359). To Christian theology, this innate urge to increase in diversity and complexity is a property granted to mat-

[6] We could call these biogenesis, phylogenesis and ecogenesis. For the latter neologism, see https://news.mit.edu/2023/greg-fournier-searching-across-deep-time-ecogenesis-0407.

ter by its loving Creator. We are entitled to review the evolutionary narrative as "very good" and to rejoice in what we read (Rolston 1999, 53)—an attitude that must be an inducement to worship.

6. Evolution discovers the personal dimension

The mechanisms of evolution produce startling new capacities, the genetic basis of which is being disclosed at molecular resolution (Figs. 1–3, 5–7). Hidden in our typically hominoid genome is the potential[7] for humans to apprehend a world of value, morality and destiny. Science knows nothing of *personhood*, whether God's or our own. It cannot be detected by instruments. But we have insider knowledge, unmediated access to its reality.

A wonder of evolutionary history is the advent of at least one creature, with the capacity of reflective thought, that can engage the invisible dimension of the personal. We observe the dawning of rational self-consciousness, in which the universe began to come to know itself (Polkinghorne 2004, 13). This understanding extends Pascal's description of human beings: "frail reeds though they appear to be on the cosmic scale, nevertheless they are greater than all the stars, for we know them and ourselves and they know nothing" (in Polkinghorne 2004, 173).

Palaeobiologist Simon Conway Morris (2015, 7–8) has asked whether, as an outcome of evolution, "rationality is not so much a question of emergence but one of discovery." He continues: "But suppose—and this is by no means a novel idea—mind is not so much self-realized as brains increase in size and complexity but rather the brain serves as conduit. In this way it encounters the abstract realms of mathematics, music, and language, all of infinite potentiality."

Physicist Andrew Steane has noted (2014, 1) that "reality is deeply personal" and moreover "this deeper reality cannot be broken down by critical analysis but can be known, and knows us in return, so we are driven to talk about God in personal terms." It follows that God cannot be deduced,

---

[7] Nothing more than the *potential* – personhood is *actualised* by relationship with those who were persons before us. Perhaps we can say, "I am known, therefore I am" [*Notus sum ergo sum*].

only known (2014, 103); that "humans did not invent good but became aware of it" (2014, 126); and that we do not invent love but it is a truth we may seek to manifest (2014, 157). So it is with personhood: natural selection discovered it but did not cause it. Just as 2 + 3 = 5 was always true before organisms had the capacity to know it,

> our brains give us access to things such as justice and friendship, but biological genetics does not nor cannot influence, even by one iota, what such things really are. Our biology can only furnish our ability to be aware of and responsive to these realities. To repeat, the innate nature of friendship is not caused by anything in biology. All that biology can do is influence the ability of biological forms to embody friendship. And similar things can be said about much else that is significant about human identity (Briggs et al. 2018, 188–189).

Evolution has enabled biological creatures to discover the personal world. Genetic processes exemplified in this paper have led to a creature who can be addressed by, and respond to, God. Humans are the ape that can know God (Mt 11:27; Lk 10:22; Jn 17:3)—and so wonder and worship the God who has ordained a world of such fruitfulness.

7. Order emerges from randomness

Mutations such as the genomic remodelling effected by ERVs and transposable elements are unscheduled random events occurring within the consistent lawful constraints of physical reality. The properties of stochastic activity and the prescribed limits within which it occurs are fundamental features of the cosmos. They constitute a richly generative mix. This paper provides molecular genetic backup for McLeish's proposal (2014, 101) that, in evolution as elsewhere, beauty and order arise from the chaotic world underneath them.

The emergence of novelty depends on states that are "at the edge of chaos." That is, openness and regularity, disorder and order must be present in a subtle balance. To achieve biological potentiality, evolutionary exploration (chance) required that the universe should possess lawful regularity (necessity) of very specific character. If mutations were either too

frequent or too infrequent, life could not have developed (Polkinghorne in Alexander 2019, 106–107). Indeed, Erwin Schrodinger recognised that the matter of heredity must be incredibly stable, but must manifest just sufficient instability for change to accumulate (Phillips 2021, 465).

Hutchings and McLeish (2017, 124–125) have described how "biological processes depend on the wild frenzy of particle collisions. As the particles wheel around crazily, they are effectively 'exploring' every possible shape or material combination [...] It is from within all the chaos that overall order is formed—and life exists." So it is that if natural process "was entirely random or entirely predictable, life as we know it would not be possible." McLeish (2020, 49) continues, life "requires the substrate of random molecular motion." In the same way, the "evolution of life itself" falls "into the category of ordered large-scale structure emergent from random small-scale dynamics [...] at the level of the coding molecule of DNA." The "small-scale dynamics" refer in particular to the random genetic mutations which give rise, in the context of environmental winnowing, to the macroscopic material properties of integrated organisms.

We should look on the freedom of cosmic history as the evolutionary exploration of potentiality (Polkinghorne 2004, 13, 21). And yet happenstance in evolution is channelled in its trajectories. For example, "life is destined to come as part of the narrative story, although the exact routes it will take are open and subject to historical vicissitudes" (Rolston 1999, 360). "God can bring about determinate ends through contingent paths" (Polkinghorne 2004, 108). The ubiquity of convergence shows that "biology travels through history but ends up at much the same destination" (Conway Morris 2015, 6). "Although individual steps in evolution may be random, the overall direction is constrained by the way the world is" (Briggs et al. 2018, 63).

This leads us to reflect on a theology of evolution as directed by physical reality. The world which is so hospitable to life is "not an arbitrary chaos or a static cosmos but a world with the potential to respond to the divine call" (Osborn 1993, 127). "Modern science discerns a world that is dynamically open and evolving and not statically mechanical and deterministic. The theological counterpart to these ideas is the conception

of cosmic history as an unfolding creative improvisation rather than the performance of a divinely pre-ordained score" (Polkinghorne 2004, 54).

The creative tension between chaos and order is a biblical theme (McLeish 2014, 101). "God has made a world in which uncertainty and chance—from our point of view—operate at local level in order to produce a functioning habitable world overall" (Hutchings and McLeish 2017, 123–4). The biblical figure of Job raises the question as to whether "randomness and overall divine care" are compatible. It was Job's experience that the "apparent randomness on the smaller scale is combining to form the order which emerges for creation as a whole" (Hutchings and McLeish 2017, 122–123).

Biblically, "When apparent randomness threatens to *destroy man's hope*, it calls us to hold on in the belief that God is painting a better big picture … [God] is found in both the chaos of the storm and the certainty of his love … [God] calls [his people] to believe that he is able to bring about, in their lives, what we have learned he brings about in nature: order from chaos" (Hutchings and McLeish 2017, 124–126). Randomness in evolution does in truth unwrap the gift of freedom (McLeish, 2020), but the biblical theme that God brings order and newness from contingency should elicit hope and worship even in the chaos of our lives.

8. Suffering and a transcendent resolution

The outcomes of natural history are ambiguous (McLeish 2020, 47). There is beauty and horror; delight and suffering. Our knowledge of evolution may have made such ambiguity more disturbingly obvious, but it is not a new observation. The Gospel offers hope in the face of this intensified awareness of suffering in nature. It provides an answer that has been latent for two thousand years, albeit still surprising.

In the long term, infectious retroviruses and transposable elements may be constructive, as illustrated above. In the short term they may be pathogenic (Rodriguez-Martin et al. 2020, 306). It seems clear that the "engine that has driven the fruitful history of life on Earth has been genetic mutation. Yet, if [germ] cells are to mutate and produce new forms

of life, some somatic cells will also be able to mutate and become malignant. The anguishing fact of cancer is not gratuitous … It is the inescapable shadow side of evolving fruitfulness" (Polkinghorne in Alexander 2019, 9–10).

Geophysicist Robert White (2022) has described how natural disasters (earthquakes, volcanos, floods) sustain the vitality of the biosphere by redistributing nutrients—even as their effects can be disastrous, especially for the marginalised, most vulnerable of people (White and Jonathan Clarke in Ashby et al. 2018, 91 and 88). The greenhouse effect sustains the biosphere, but the runaway accumulation of greenhouse gases would be catastrophic (John Houghton in Alexander 2019, 241). Polkinghorne concludes: "A world in which creatures make themselves is a great good, but it has a necessary cost. The shuffling explorations of potentiality (which is what 'chance' means in an evolutionary context) will inevitably sometimes have ragged edges and lead into blind alleys" (in Alexander 2019, 9).

Our physics professors have said that "pain and physical death are part of the God-given pattern of life on earth, whereas spiritual death is a breakdown of that pattern […] God bears a heavy responsibility for having brought into being, and sustained in being, a world in which life-shattering processes go on for no fault of the creatures […] God bears the responsibility in a way that can, ultimately, merit our faith in him, and this includes a bearing of pain, a fellowship with the insulted and humiliated" (Briggs et al. 2018, 209). Christians believe that God purposes to take creation forward to a new creation, a project that will be "enormously costly for God." Because of God's gift of freedom to the world, God remains committed to working within the world, paradigmatically in the suffering, death and resurrection of his Servant (Wright 2014, 118–120).

As Polkinghorne (2004, 72–73) expressed it, the haunting problem posed by suffering "is only adequately met in Christian thinking by a Trinitarian understanding of the cross of Christ, seen as the event in which the incarnate God truly shares to the uttermost in the travail of creation". To Jürgen Moltmann, "the Father suffers the loss of the Son on the cross, marking the most terrible and incomprehensible rent in the

perfect union of the persons of the Trinity" as revealed in the haunting cry "My God Why have you forsaken me?" (in Ashby et al 2018, 329).

The Christian gospel indicates that God's means of extirpating suffering from the world was Christ's death on the cross, a remedy for the natural world as well as for the morally defective biped we call humankind (Eph 1:9–10; Col 1:20; Berry in Alexander 2019, 87). If human beings are loved by their Creator, they must have a destiny beyond their deaths, may hope to experience the healing of their hurts, and participate in the fulfilment of the divine purpose (Polkinghorne 2004, 149). We may rejoice that suffering and death are not the last word. In the meantime, our response to the suffering of others—whether human or nonhuman—is to share their pain and to do our utmost to overcome it (Briggs et al. 2018, 211).

References

Alexander, Denis, ed. 2019. *Has Science Killed God?* London: SPCK.

Alvarez-Carretero, Sandra, Asif U. Tamuri, Matteo Battini et al. 2022. "A species-level timeline of mammal evolution integrating phylogenomic data." *Nature* 602: 263–67. https://doi.org/10.1038/s41586-021-04341-1.

Amici, David R., Harun Cingoz, Milad J. Alasady et al. 2023. "The HAPSTR2 retrogene buffers stress signaling and resilience in mammals." *Nature Communications* 14: article 152. https://doi.org/10.1038/s41467-022-35697-1.

Ashby, Roland, Chris Mulherin, John Pilbrow, and Stephen Ames, eds. 2018. *A Reckless God? Currents and Challenges in the Christian Conversation with Science*. Reservoir Victoria: ISCAST Nexus.

Briggs, Andrew, Hans Halvorson, and Andrew Steane. 2018. *It Keeps Me Seeking*. Oxford: Oxford University Press.

Brooke, John Hedley. 1991. *Science and Religion*. Cambridge: Cambridge University Press.

Brueggemann, Walter, 1997. *Theology of the Old Testament*. Minneapolis: Augsburg.

Collins, Francis S. 2006. *The Language of God*. New York: Free Press.

Conway Morris, Simon. 2015. *The Runes of Evolution*. Conshohocken: Templeton.

Du, Alan Y., Xiaoyu Zhuo, Vasavi Sundaram et al. 2022. "Functional characterization of enhancer activity during a long terminal repeat's evolution." *Genome Research* 32: 1840–51. https://doi.org/10.1101/gr.276863.122.

Du, Cui, Jing Jiang, Yuzhuo Li et al. 2023. "Regulation of endogenous retrovirus–derived regulatory elements by GATA2/3 and MSX2 in human trophoblast stem cells." *Genome Research* 33: 197–207. https://doi.org/10.1101/gr.277150.122.

Falcke, Heino, 2021. *Light in the Darkness*. London: Wildfire.

Finlay, Graeme. 2022. *God's Gift of Science*. Eugene, OR: Wipf and Stock.

Foley, Nicole M., Victor C. Mason, Andrew J. Harris et al. 2023. "A genomic timescale for placental mammal evolution." *Science* 380: eabl8189. https://doi.org/10.1126/science.abl8189.

Hanes, Jonathan M. 2021. *Review of "The Bible & Ancient Science: Principles of Interpretation" by Denis O. Lamoureux*, https://iscast.org/reviews/review-of-the-bible-ancient-science-principles-of-interpretation-by-denis-o-lamoureux/.

Harrison, Peter. 2021. "Religion and the rise of science." https://www.faraday.cam.ac.uk/wp-content/uploads/2021/03/Faraday-Paper-21-Harrison-web.pdf.

Hutchings, David, and Tom McLeish. 2017. *Let there be Science*. Oxford: Lion.

Jeeves, Malcolm, ed. 2011. *Rethinking Human Nature*. Grand Rapids: William B. Eerdmans.

Kuderna, Lukas F.K., Hong Gao, Mareike C. Janiak et al. 2023. "A global catalog of whole-genome diversity from 233 primate species." *Science* 380: 906–13. https://doi.org/10.1126/science.abn7829.

McLeish, Tom. 2014. *Faith and Wisdom in Science*. Oxford: Oxford University Press.

McLeish, Tom, 2020. "Evolution as an unwrapping of the gift of freedom." *Scientia et Fides* 8, no. 2: 43–64. https://doi.org/10.12775/SetF.2020.014.

Naesens, Leslie, Santoshi Muppala, Dhiraj Acharya et al. 2022. "*GTF3A* mutations predispose to Herpes Simplex encephalitis by disrupting biogenesis of the host-derived RIG-I ligand *RNA5SP141*," *Science Immunology* 7: eabq4531. https://doi.org/10.1126/sciimmunol.abq4531.

Nikaido, Masato, Hidenori Nishihara and Norihiro Okada. 2022. "SINEs as credible signs to prove common ancestry in the tree of life: a brief review of pioneering case studies in retroposon systematics." *Genes* 13: 989. https://doi.org/10.3390/genes13060989.

Osborn, Lawrence. 1993. *Guardians of Creation*. Leicester: Apollos.

Phillips, Rob. 2021. "Schrodinger's *What is Life?* at 75." *Cell Systems* 12: 465–76.

Polkinghorne, John. 2004. *Science and the Trinity*. Oxford: Oxford University Press.

Pontis, Julien, Cyril Pulver, Christopher J. Playfoot et al. 2022. "Primate-specific transposable elements shape transcriptional networks during human development." *Nature Communications* 13: 7178. https://doi.org/10.1038/s41467-022-34800-w.

Rodriguez-Martin, Bernando, Eva G. Alvarez, Adrian Baez-Ortega et al. 2020. "Pan-cancer analysis of whole genomes identifies driver rearrangements promoted by LINE-1 retrotransposition," *Nature Genetics* 52: 306–19. https://doi.org/10.1038/s41588-019-0562-0.

Rolston, Holmes IIII. 1999. *Genes, Genesis and God*. Cambridge: Cambridge University Press.

Rowley, Paul A., Aisha Ellahi, Kyudong Han et al. 2021. "Nuku, a family of primate retrocopies derived from KU70." *G3: Genes, Genomes, Genetics* 11: jkab163. https://doi.org/10.1093/g3journal/jkab163.

Rudwick, Martin J.S. 2014. *Earth's Deep History*. Chicago: University of Chicago Press.

Steane, Andrew. 2014. *Faithful to Science*. Oxford: Oxford University Press.

Wagner, Roger and Andrew Briggs. 2016. *The Penultimate Curiosity*. Oxford: Oxford University Press.

White, Robert S. 2022. *Natural Disasters and Human Responsibility*, https://www.faraday.cam.ac.uk/wp-content/uploads/2022/02/Faraday-Paper-25-White-v4.pdf.

Wright, N.T. 2014. *Surprised by Scripture*. London: SPCK.

Wright, N.T. and Michael F. Bird. 2019. *The New Testament in its World*. London: SPCK.