

Female-Asymmetric Hybrid Animation: Why Eve is Called “Mother of All Living”

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Abstract. In 1995, Francisco Ayala considered biblical Eve a myth, because a relatively recent single-pair bottleneck is unable to sustain the observed polymorphism of the human immune system. In 2011, Kenneth Kemp showed that Ayala’s conclusion depends on an implicit condition, to wit, that God animates all and only progeny of two animated parents. Here we show that both biology (the polymorphism) and scripture (Eve’s historical existence) are equally saved, upon assuming that God animates *all and only progeny of animated mothers*. We present three reasons in favor this *prima facie* rather odd restriction: (i) it solves two long-standing biological riddles; (ii) it explains Eve’s scriptural title of “mother of all living”; and (iii) it fully respects the theology of Christ’s perfect humanity (for His lacking a biological father).

Keywords: monogenism, animation, inanimate *Homo sapiens*, dualism, hybrid progeny.

Introduction

In 1987, Rebecca Cann and coworkers discovered that the female source of all extant human mitochondria is surprisingly recent: approximate-

ly 150 thousand years (Cann 1987).¹ Cann’s finding – initially heavily contested – was corroborated by subsequent genetic studies.² Scientific commentators nicknamed the mitochondrial source “mitochondrial Eve” from the very outset (Wainscoat 1987). Although the popular literature was quick to dismiss mitochondrial Eve as a mere “genetic marker”, there is no biological doubt that mitochondrial Eve represents a well-defined historical person.

The Y-chromosomal MRCA (acronym for “most recent common ancestor”) is estimated at 275 thousand years (Mendez 2016). This MRCA must not be mistaken for Eve’s male counterpart, the historical male MRCA of the extant human population: For the male MRCA must predate the Neanderthal speciation (800 thousand years ago), given the well-documented Neanderthal admixture of the human gene pool (Green 2010, Reich 2010, Sankararaman 2012, Meyer 2012, Fu 2014). Clearly, Adam is neither Y-MRCA, nor male MRCA.

Eve’s mitochondrial MRCA-status implies that all female progeny of all of Eve’s female contemporaries (estimated to be several thousands) went extinct. This is a fantastic biological mind-boggler. All hitherto formulated attempts are unconvincing, to say the least. One wonders whether a satisfactory answer can be found within the field of molecular genetics.

In 1995, Francisco Ayala argued that the genetic diversity of the present-day human immune system is incompatible with a relatively recent (150 thousand years) one-pair (Adam and Eve) human bottleneck. Provocatively, he claimed that biblical Eve was a myth (Ayala 1995). A prolonged discussion followed, and was recently revived by Dennis Venema (2017). Several creationist authors rebutted the Ayala-Venema claim, among whom Joshua Swamidass (2019) and Ann Gauger (2019). They

¹ The mitochondrial genome is inherited maternally, as mitochondria do not reside inside the (egg) cell’s nucleus. Although male mitochondrial inheritance has been documented (e.g. Schwartz 2002), it is much too rare to bear on the conclusions presented in this article.

² The literature is too vast to quote here. For an elaborate discussion of the literature, see e.g. Schins 2022. An important observation confirming the young age of mitochondrial Eve, is that the genetic spread in human mitochondria is more than an order of magnitude smaller than that in chimpanzee mitochondria.

showed that the biological data do allow for a single-pair population bottleneck, provided that pair lived about 500 thousand years ago.

The creationist rebuttal is, in our view, unsatisfactory. First, their single-pair bottleneck must have occurred at least 800 thousand years ago, given the above-mentioned age of the human male MRCA. Yet, even if one sticks to those 800 thousand years, a mere theoretical possibility does not therefore render a scenario biologically *probable*. Second, the scenario is actually highly *improbable* – with an improbability generally characteristic of creationist proposals – because a pre-Neanderthal age of Adam and Eve should include Neanderthals among their animated descent; and as we shall see in section 5, the archeological evidence strongly suggests that Neanderthals were not animated. Creationism cannot eat its cake (Eve lived 500 thousand years ago, which is after completion of Neanderthal speciation) and have it (the human genome shows Neanderthal admixture, which demands that Eve lived before completion of Neanderthal speciation).

Recently, Kenneth Kemp offered a scientifically much more probable rebuttal of the Ayala-Venema denial of Eve’s historical existence (Kemp 2011). He showed that Ayala’s denial rests on an implicit creationist assumption, to wit, that God only animates progeny of two animated parents.

Kemp relaxed Ayala’s creationist assumption, and assumed that God also animates *hybrid progeny*, that is, progeny of one animated parent and one inanimate parent. Clearly, Kemp’s relaxed assumption saves both the traditional interpretation of dogma (for all humans count Adam and Eve among their ancestors) and the polymorphism of the human immune system (because there never was a single-pair bottleneck in the human population).

In this contribution, we show that a less relaxed animation policy saves dogma and polymorphism, too, with three important advantages with respect to Ayala’s creationist scheme:

- It explains two intriguing, hitherto unexplained biological observations: the gender-asymmetry in the gene flow from late Neanderthals (exclusively males) to anatomically modern humans (ex-

- clusively females); and the spectacular discontinuity of the fertility rate of the human population, some 150 thousand years ago;
- on the scriptural level, it explains that Adam and Eve are not called the “parents of all living”, but Eve alone is called the *mother of all living*;
 - on the theological level, it affirms Christ’s perfect humanity, for Christ had no animated father.

1. Animation

Throughout this paper, we adopt the metaphysical stance that animation is a purely metaphysical event, in which God merges two substances capable of independent existence (a material body of the species *Homo sapiens* on one hand, and a spiritual human soul on the other) into a single substance (the fully constituted human person), which is incapable of division: For the division necessarily implies the “theological death” of the human person.³ We characterize animation and death as purely metaphysical events, because their occurrence is not spatio-temporal.⁴ These events therefore have no physical appearance, and cannot be observed scientifically. Their existence can nevertheless be inferred scientifically, from the modified behavior of animated beings with respect to that of their inanimate fellows.

Accordingly, we assume that, some 150 thousand years ago, a homogeneous human population existed, of which only two individuals (Adam

³ The exact moment of “theological death” cannot be ascertained. Quite reasonably, it occurs within the time span characterizing physiological death. This time span may be relatively short in the case of a violent death, and relatively long in the case of coma-preceded death.

⁴ Spatio-temporal events propagate through space and time according to underlying physical laws, like relativity theory or quantum mechanics, depending on the phenomena at hand. Roughly speaking, physiological phenomena obey the laws of quantum mechanics. The process of animation escapes physical description. All physiological processes that can occur in a human brain, can equally occur in a chimpanzee brain. Obviously, a professional mathematician uses the calculating brain spots more often than ordinary people, and ordinary people more often than chimpanzees. Yet again, in predicting the behavior of individual people, quantum statistics are utterly useless, in much the same way that they are utterly useless in predicting whether the next photon incident on an interface will be transmitted or reflected.

and Eve) were animated, and all others (several tens of thousands) inanimate. Adam and Eve's contemporaries were human in the genetic sense only (because their bodies belong to the species *Homo sapiens*): Not in the theological sense (because they lack a human soul).

Our account is sometimes dismissed as dualistic. Erroneously so: For it considers man as a single, self-subsistent entity, in whom the composition of body and soul is as metaphysical as is that other composition, of essence and being. Our metaphysical account is however eminently *dual*, in the sense that it acknowledges the radical ontological difference between the realms of matter and spirit. A full-fledged theory of animation is beyond the scope of this article. Consequently, we consider our own conclusions conditional, in the sense that they depend on the validity of our metaphysical model.

2. Natural generation

Given the sexual nature of man, we conceive of four possible divine animation policies:

- Exclusive-symmetric: God chooses to animate only and all progeny of two animated parents;
- Inclusive-symmetric: God chooses to animate all progeny of at least one animated parent;
- Female-asymmetric: God chooses to animate only and all progeny of animated human females;
- Male-asymmetric: God chooses to animate only and all progeny of animated human males.

The first, exclusive-symmetric animation policy is typically held by creationism, which shuns the historical co-existence of animated and inanimate humans. The second, inclusive-symmetric policy corresponds to the proposal by Kenneth Kemp (2011). The fourth animation policy is the male counterpart of the third, which we here defend. To our best knowledge, gender-asymmetric animations policies have not yet been proposed in the literature.

The female-asymmetric animation policy suggests a new theological concept of “natural generation” of animated human life: we here propose to define it as *the fertilization of an egg cell produced by an animated mother*. From this definition, it follows that all presently conceived human beings are generated naturally, independently of whether fertilization occurs by coition or in the laboratory.

3. Monogenism

Theological monogenism encompasses the following four elements:

- In some colony of animals, at some moment in the past, God animated two adult individuals;
- These individuals (Adam and Eve) did not conceive with other humans, neither animated (their children) nor inanimate (other tribe members);
- God grants animation to all and only those individuals who descend from (Adam and) Eve by natural generation, in the female-asymmetric sense;
- all present-day *Homo sapiens* are theological human beings, whence descendants from (Adam and) Eve.

We use the terms “animated human” and “theological human” fully interchangeably. The second ingredient stipulates that Adam had no children from other women but Eve, and conversely, that Eve had no children from other men but Adam, as is required by the dogma of original sin.

4. Polygenism

In his 1950 Encyclical *Humani generis*, Pius XII condemned theological polygenism in either of the following acceptations (Pius XII 1950):

1. Alongside the descendants of Adam, there existed animated humans (‘true men’) who did not descend from Adam;
2. Adam stands for a collectivity of ancestors, rather than for an individual.

Biological polygenism is not as clearly defined as theological polygenism. The 18th century concept of biological polygenism was, judged by present-day standards, overtly racist, until deep in the 19th century. Scientists daring to speak out against scientific racism were a small minority, of which Charles Darwin happened to be a prominent exponent. The 19th century concept of polygenism roughly coincides with what is now called polyphyletism: the separate origin of species. During the 20th century, the concept of polygenism gradually expanded, and today includes monophyletic speciation for large transitional populations. An example of the latter is the speciation of *Homo* and *Pan* from their common ancestor: It began 12 million years ago (Moorjani 2016), and took 6 million years to complete, with homogeneously interbreeding populations always exceeding thousand individuals (Patterson 2006).

For the record: Female-asymmetric animation transgresses neither condemnation of Pius’ *Humani generis*.

5. The scientific data

In the introduction, we mentioned the creationist rebuttal of the Ayla-Venema claim. Richard Buggs stresses that human sole ancestry, although theoretically *possible*, is not for that reason *probable* (Buggs 2020). The assessment of the scientific likeness of a given theological scenario requires a careful study of all biological elements that such a scenario should respect. These elements do not constitute a biological unity of some kind, for they are selected on exclusively theological criteria. Summarily presented, they are the following:

- The ages of mitochondrial Eve and Y-Chromosomal MRCA are 150 and 275 thousand years, respectively (Cann 1995, Mendez 2016);
- from the six documented autosomal gene flow events between the archaic and anatomically modern human subspecies, two recent ones affected *Homo sapiens sapiens*: one occurred about 100 thousand years ago, from late Neanderthals to the source of all non-African human races (Mendez 2016), and another about 30 thousand

- years ago, from Denisovans to the source of all Oceanian human races (Green 2010, Sankararaman 2012, Fu 2014);
- there are no traces of Neanderthal or Denisovan mitochondrial DNA in the extant human population (Kuhlwilm 2016);
 - Neanderthals split off anatomically modern humans between 600 and 900 thousand years ago; late Neanderthals differ from archaic Neanderthals in that they all descend from anatomically modern human females who lived around 410 thousand years ago (Post 2017);
 - mitochondrial Eve lived in the horn of Africa;
 - Out-of-Africa II (the migration of *Homo sapiens sapiens* off the African continent into the Middle East) occurred about 55 thousand years ago; all non-African human races derive from those migrants (Karmin 2015, Post 2016, Rito 2019, Haber 2019);
 - in spite of recurrent claims to the contrary (Hoffmann 2018), there is no solid evidence of Neanderthal art (White 2020);
 - from mortuary practices, nothing suggests the belief of Neanderthals in afterlife (Larsen 1997, Klein 2009, Pettitt 2011); evidence of Neanderthal cannibalism is rule rather than exception (Defleur 1999, Rosas 2006, Rougier 2016);
 - hominins are particularly unfit in the evolutionary sense, as is patent from mass extinctions of hominin species (appendix 1) on one hand, and from persistently small population sizes (appendix 2) on the other – the latter sometimes leading to high levels of inbreeding, e.g. among late Neanderthals (Sullivan 2017);
 - for an average fertility rate of 2.0046 fertile children per mother (typical of hunter-gatherer societies, see appendix 3), the estimated global population size in the Neolithic (4 million in 10,000 BC) implies that exponential growth of our species initiated about 168 thousand years ago (appendix 3); such sustained exponential growth is unique in the history of species.

From this somewhat disparate list of scientific data, two points are of particular importance for our investigation.

1. Although there is solid evidence of gene flow from late Neanderthals to anatomically modern humans, all these events involve Neanderthal males and *sapiens* females, never the other way around. Biologists have as yet been unable to explain this curious gender asymmetry.⁵ Conversely, gene flow events from humans to Neanderthals are always gender-symmetric: both male and female anatomically modern humans contributed to the Neanderthal genome.
2. As the anthropological data provide no indication that Neanderthals were animated, it is reasonable to assume that biblical Eve was younger than their divergence from modern humans. This divergence initiated 950 million years ago and completed 650 million years ago. On the other hand, for the biblical Eve to have mothered all African races, she must be significantly older than Out-of-Africa II (55 thousand years ago).

Apparently, the upper bound of the age of the biblical Eve (650 million years) exceeds the lower bound (55 thousand years) by four orders of magnitude. That gives quite some maneuvering space. Two totally independent ages are contained within this extended interval: That of the begin of the exponential growth of the human population (168 thousand years), and that of mitochondrial Eve (150 thousand years). We therefore fully respect the scientific data, upon tentatively identifying three historical events: biblical Eve, mitochondrial Eve, and the beginning of the human population explosion. In the remaining two sections, we shall give a scriptural and a theological argument in favor of this threefold identification.

⁵ Yet its explanation is quite obvious. Animated human females, realizing their dignity as free spiritual beings, would have shunned sexual contact with inanimate male humans of their subspecies, and with the more reason, of other subspecies, like Neanderthals or Denisovans. In the case of rape by the latter, some fraction of animated human females would choose to raise their animated children, thereby introducing Neanderthal genes into the human pool. Within the assumption of a female-asymmetrical animation policy, the converse does not happen: The hybrid progeny of animated males and Neanderthal females, if raised, would not contribute to the extant human gene pool, for not being animated.

6. Holy Scripture

According to Genesis 3:20, Adam called Eve the mother of all living, while nothing of the kind is said of Adam. This is the more remarkable, as the Jewish Sacred Scripture transpires all the prejudices typical of a thoroughly patriarchal society – prejudices which Jesus denounced: To the point of correcting errors in the transmission of Moses’ law, and even to the point of correcting Moses himself (e.g. Matt 19:8). Consequently, if Adam was father of all living in the same sense as Eve mother of all living, the Sacred Scripture would either have mentioned this of Adam alone, or of both Adam and Eve. Hence, we tentatively interpret the Sacred Scripture as establishing Eve’s motherhood of “all living” in a sense essentially superior to Adam’s fatherhood.

7. Theology

The Holy Scripture is adamant, both in denying a biological father of Christ, and in confirming Christ’s perfect humanity. Due to our view on the nature of matter and spirit, summarily presented in section 1, we hold that the concept of human nature allows for two different meanings: In a restricted sense, it signifies the nature of a biological body of the species *Homo sapiens*: This is what one might call the “material human nature”: It is exclusively and completely determined by the genome characterizing our species. In a broad sense, human nature signifies the metaphysical composition of a material body and a human soul. Whereas the human soul cannot be other than what it is, the material body could have been anything: For even the most mutilated of bodies can support a human soul.⁶

Christ would not be perfect man, if his incarnation implied an exception to God’s animation policy. This eliminates at once the creationist

⁶ From God’s animation policy it follows, as a historical-technical corollary, that all humans share the material human nature of Eve: Yet the specific material human nature does not enter the metaphysical definition of a human person.

proposal (exclusive-symmetric), and the (never proposed) male-asymmetric animation policy. Only the inclusive-symmetric (Kemp's) and the female-asymmetric (here proposed) policies grant Christ's perfect humanity.⁷

Just like the material nature of the body enters the definition of human nature indirectly, in much the same way do the spiritual characteristics of the soul. Specifically, it does not matter whether the soul in question is created, as is the usual case, or uncreated, as is the soul of the second divine Person. Of course, the essence of the associated soul must allow for association with matter. This excludes angelic souls, whose essence excludes that kind of association. Human free actuation does depend on matter: The soul requires an associated wake and healthy brain, in order to will; without that brain – as man is in purgatory – the human soul is conscious, but fully passive. It undergoes demonic influences without being capable of merit (for merit requires free will, and human free will requires a material brain).

One might object that, since our Savior was conceived without sin, it is theologically more fitting that he was not generated naturally (in the technical sense defined in section 2). This objection is quite understandable, as original sin (*peccatum originale originatum*) is transmitted by way of natural generation. Nevertheless, we object to it, because the mere fact that original sin is *transmitted* by natural generation does not *stain* natural generation with sin.

The Holy Scripture suggests, and dogma confirms, that Adam and Eve were created in a state of innocence, free to sin and not to sin; and that they historically did sin (*peccatum originale originans*). Given their freedom not to sin, Adam and Eve could have conceived progeny in a state of

⁷ Christ received his genome from Mary alone. In agreement with Ron Wyatt's medical examination of Christ's blood, which he discovered on the Ark of the Covenant (hidden in the caves below Gordon's Calvary), we hold that Christ had but a single set of 22 autosomes, as opposed to the usual double set. As far as the allosomes are concerned, we hold that Christ had one X and one Y-chromosome, as all normal human males have. The origin of this Y-chromosome can be no other than his mother Mary. Although we have no idea of the mechanism of transmission of that Y-chromosome, we refrain from appealing to miracles, as creationists usually do. If there are exceptions to the rule that mitochondrial DNA is inherited from one's mother, there might also be exceptions to the rule that female germ cells never contain a Y-chromosome.

innocence: This is Aquinas' famous thought experiment (Aquinas ST I). Denying this possibility is tantamount to considering

- either that Adam and Eve were predestined to sin,
- or that their genitals (the very genitals that would later occasion their shame) were purely symbolical attributes.

The second option is not feasible from the biological perspective; the first is not from a theological one. Without original sin, there is no need for redemption, nor for incarnation. The latter is not for that reason metaphysically contradictory in the context of a human state of innocence. As for Christ, incarnation identifies with human animation, Christ's incarnation is equally feasible metaphysically in a state of human innocence as in a state of original sin. Consequently, natural generation itself is not *affected* by sin: it is a mere vehicle for *ordinarily* transmitting the human state.

Conclusion

Biology is unable to explain why all female descent of Eve's female competition (estimated to be several thousand inanimate females of the species *Homo sapiens sapiens*) went extinct, nor why the multiple gene flow events from late Neanderthals to anatomically modern humans were gender-asymmetric (the genetic influx being due to Neanderthal males only), nor why the human population started to grow exponentially. Materialist geneticists limit their efforts to identifying possible beneficial mutations in the DNA of mitochondrial Eve, in much the same way as they invoke deleterious mutations as an explanation of Neanderthal extinctions (Ríos 2019). Such materialist proposals are as miraculous and ad-hoc as those of creationists.

The fossil record shows unambiguously that all hominin species were poorly adapted, and barely managed to survive. For that reason, the quest for an explanation of the Neanderthal extinction is scientifically ill-posed: It is perfectly in line with all other hominin extinctions. The valid scientific interrogative is rather why *Homo sapiens* represents an exception in the panorama of mass extinctions. We here propose that our

own species escaped extinction, only because God decided to animate two individuals and their descent. This at once explains why our so poorly adapted species could start growing exponentially.

Our hypothesis of a female-asymmetric animation policy explains the gender-asymmetry in the gene flow between late Neanderthals and anatomically modern humans, and it is compatible with the polymorphism of the human immune system, in spite of a one-female bottleneck 150 thousand years ago.

It seems that, once again, Catholic dogma comes to the rescue of science. The best known example of such a rescue is from cosmology. When Georges Lemaître first presented his ‘primeval atom’ solution of the general relativity equations to Albert Einstein, Einstein objected strongly against it, probably because he considered Lemaître’s singularity too explicitly “confessional”. Compelled to by the accumulating astronomical data, Einstein later changed his mind, and the large majority of cosmologists with him.⁸

Rebecca Cann can rightfully be considered a biological pendant to Lemaître, for she first unveiled, amidst fierce opposition by materialist scientists, the mitochondrial genome of Eve, mother of all living.

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Appendix 1. Extinctions among *Hominina*

After the great apes or *Hominidae* split into *Ponginae* (orangutans) and *Homininae*, the latter gave rise to the *Dryopithecini*, *Gorillini*, and *Hominini*. All 16 species of the *Dryopithecini* (e.g., *Udabnopithecus*, *Samburupithecus*, and *Nakalipithecus*) extinguished between 8 and 10 million years

⁸ A famous exception is Fred Hoyle (inventor of the disparaging nickname ‘Big Bang’ for the theory of Lemaître), who on his deathbed still swore by a steady state model, long abandoned by all his colleagues.

ago (Hara 2012). *Gorillini* split into Gorillas and the extinct *Chororapithecus*. *Hominini* split into *Hominina* (not to be confused with *Homininae*) and *Panina* (chimpanzees and bonobos) 6.5 million years ago. All known species of *Panina* survived, which implies that it represents a group of particularly fit and stable subspecies. That is not the case for the *Hominina*. Of nine *Hominina* subspecies, only *Homo* survived. The other eight hominins (*Graecopithecus*, *Sahelanthropus*, *Orrorin*, *Ardipithecus*, *Kenyanthropus*, *Praeanthropus*, *Paranthropus*, and *Australopithecus*) extinguished between 4 and 7 million years ago. The history repeats itself with the *Homo* subspecies. Of the fourteen subspecies, again but one survived: *Homo sapiens*. The other thirteen (*Homo gautengensis*, *rudolfensis*, *habilis*, *bodoensis*, *floresiensis*, *erectus*, *ergaster*, *antecessor*, *heidelbergensis*, *cepranensis*, *denisovanis*, *neanderthalensis*, and *rhodesiensis*) all extinguished less than 7 million years ago, the last of which (*neanderthalensis*, *denisovanis*, *bodoensis*, and *floresiensis*) some 40 thousand years ago. Of the four subspecies of *Homo sapiens*, only *Homo sapiens sapiens* survived to this day. The other three (Idaltu, Cro-magnon, and Red Deer Cave) extinguished less than 100 thousand years ago.

This evolutionary history indicates that, as a species, *Homo* is particularly unfit. That is hardly surprising, given the long time required for a human newborn to hunt (12 years), as compared to other mammals (12 months), on one hand, and given the difficulty of human birth, on the other (for human mothers it is hardly possible to give birth without assistance, and even with assistance, complications arise frequently).

Appendix 2. Population sizes

At the moment of their divergence from the chimpanzees (6.5 million years ago), the effective population size of *Hominina* was around 25 thousand, a number which hardly changed over the following 6 million years (Prado-Martínez 2013). The population ratio of *Hominina* with respect to all other great apes has roughly been constant (8%). Towards the Neolithic the great ape populations stabilized at 500 thousand (200 thousand chimpanzees, 200 thousand gorillas, 50 thousand bonobos, and

50 thousand orangutans). The estimated number of inanimate Hominina at the moment of the creation of Adam and Eve is therefore 40 thousand. It is not feasible, in our view, to hold (Suárez 2015) that the first animated humans were created in the neolithic, when the population size had reached several million (McEvedy and Jones 1978): simply because inanimate Homo sapiens is not fit enough to sustain population sizes beyond 40 thousand.

Appendix 3. Fertility rate

A physical quantity of prime interest is the fertility rate, which we define as the average number of successfully reproducing children per adult female. With this definition, a population is stable for a fertility rate of 2. We shall call the deviation from this value the 'differential fertility rate', and design it by the Greek letter η , such that the fertility rate $R = 2 + \eta$. For a positive differential fertility rate $\eta > 0$ a population increases exponentially, and for a negative one $\eta < 0$ it decreases exponentially. The population multiplication factor Q therefore depends on the differential fertility rate η and the number of generations N as

$$Q = (1 + \frac{1}{2}\eta)^N$$

We shall now apply this relation to some specific cases.

The human world population is estimated to have been about 4 million in 10000 BC, and 7 million in 4000 BC (Durand 1974, McEvedy 1978, Haub 1995). Using a generation time of 25 years, 6000 years imply $N = 240$ generations, and a population increase from 4 to 7 million implies $Q = 7/4$. From

$$\frac{7}{4} = (1 + \frac{1}{2}\eta_{nhg})^{240}$$

one obtains $\eta_{nhg} \approx 0.46\%$. The suffix letters 'nhg' stand for 'nomadic hunter-gatherer' societies.

In a second application of the growth equation, we consider the population evolution between an unknown moment there existed only two animated people, and 10 thousand years ago. Now $Q = 4$ million/2 and $\eta_{nhg} \approx 0.46\%$ are fixed, and we solve for N :

$$\frac{4.000.000}{2} = (1 + \frac{1}{2}\eta_{nhg})^N$$

The result is $N = 6315$. This number of generations corresponds to 158 thousand years, which implies that the population explosion occurred 168 thousand years ago. This number is surprisingly close to Rebecca Cann’s estimated age of mitochondrial Eve.

One may be startled by the small numerical value of η_{nhg} : Indeed, it means that out of every 200 households raising two fertile children, only one manages to raise a third.

The year 10000 BC is pivotal, as it marks the discovery of agriculture, which caused the so-called ‘Neolithic revolution’. It took humanity a formidable 6000 years, before settled agricultural societies were organized enough, in the political-military sense, to defend themselves and their crops efficiently from raids of hunter-gatherers. Between the years 4000 BC and 1500 BC (2500 years, corresponding to $N = 100$ generations), the world population grew steadily, from 7 to 50 million, implying $Q = 50/7$. Inserting these values into the growth equation leads to

$$\frac{50}{7} = (1 + \frac{1}{2}\eta_{apm})^{100}$$

with the solution $\eta_{apm} \approx 4\%$: Here, the suffix ‘apm’ stands for agricultural-political-military societies. This fertility rate means that, out of 25 households raising two fertile children, one raises a third. The rate is still numerically low, but nonetheless an order of magnitude higher than that of hunter-gatherer societies.

From 1500 to 0 BC, the fertility rate is somewhat higher than η_{apm} , due to the stability of well-run empires.

Between the years AD 0 and 1800, the average fertility rate is but slightly lower than η_{apm} , due to poor hygiene. Not until hospitals allowed people like Ignaz Semmelweis and Louis Pasteur to do their jobs, did life expectancy cease to limit fertility rates.

This historical demographic account is quantitatively consistent. For the young-creationist claim to hold (that humanity counts 76 generations from Adam to Jesus), the average differential fertility rate of must have been $\eta_{\text{yec}} \approx 54\%$, which is an order of magnitude higher than η_{apm} , and two orders of magnitude higher than η_{nhg} . Such a value is impossible to achieve without a highly industrialized society.

Finally, we apply the population equation to the number of anatomically modern humans living in Africa at the time that Asia was colonized in Out-of-Africa II. The number of generations is given by $N = (168000 - 55000)/25 = 4520$, whence

$$Q = (1 + \frac{1}{2}\eta_{\text{nhg}})^{4520}$$

yielding a population size on the African continent, 55 thousand years ago, of $Q \approx 65$ thousand. Clearly, Out-of-Africa II was not caused by demographic pressure.

A simple thought experiment might help understanding the sheer magnitude of the numbers involved. Counting back in time, an individual's number of grandparents doubles every generation. It takes a mere 20 generations to reach the fabulous theoretical number of one million grandparents. Given that Eve lived abundantly more than 20 generations back in time (we believe 6000), it should come as no surprise that all then living males are universal ancestors of all of us.⁹ It also illustrates how re-

⁹ Universal ancestry refers to the fact that all individuals are ancestors of all individuals of a posterior reference generation. For a homogeneously interbreeding population, the number of generations separating the reference generation from its youngest universal ancestral generation scales with the logarithm of the size of that population. E.g.: For an effective population size of 100, it takes 7 generations to achieve universal ancestry. For an effective population size of 10.000 (100 squared), it takes 14 generations (twice 7).

markable it is that *not a single one of Eve's female inanimate contemporaries (estimated to have been several tens of thousands) was ancestor to any of us.*

Appendix 4. Mitochondrial variation

The mutation rate of human mitochondrial DNA is estimated at 1.5 per base-pair per million years (Schneider 1999), which is three orders of magnitude faster than that of nuclear DNA. As the entire mitochondrial genome includes 16,569 base pairs (Anderson 1981), it mutates with a rate of 23 per thousand years. Due to selection, the effective rate decreases to below 0.2 per thousand years in the longer term. Two examples confirm this rate. First, the mt-DNA of chimpanzees differs at some 1500 locations from ours, with an assumed divergence time of 7 million years (Green 2008). Second, the mt-DNA of Neanderthals differs at some 200 locations from ours, with a divergence time of 800 thousand years.

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