Anthropic measure of hominid (and other) terrestrials.

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Abstract. According to the (weak) anthropic principle, the *a priori* probability per unit time of finding oneself to be a member of a particular population is proportional to the number of individuals in that population, multiplied by an anthropic quotient that is normalised to unity in the ordinary (average adult) human case. This quotient might exceed unity for conceivable superhuman extraterrestrials, but it should presumably be smaller for our terrestrial anthropoid relations, such as chimpanzees now and our pre-Neanderthal ancestors in the past. The (ethically relevant) question of how much smaller can be addressed by invoking the anthropic finitude argument, using Bayesian reasonning, whereby it is implausible *a posteriori* that the total anthropic measure should greatly exceed the measure of the privileged subset to which we happen to belong, as members of a global civilisation that has (recently) entered a climactic phase with a timescale of demographic expansion and technical development short compared with a breeding generation. As well as "economist's dream" scenarios with continual growth, this finitude argument also excludes "ecologist's dream" scenarios with long term stabilisation at some permanently sustainable level, but it it does not imply the inevitability of a sudden "doomsday" cut-off. A less catastrophic likelihood is for the population to decline gradually, after passing smoothly through a peak value that is accounted for here as roughly the information content $\approx 10^{10}$ of our genome. The finitude requirement limits not just the future but also the past, of which the most recent phase – characterised by memetic rather than genetic evolution – obeyed the Foerster law of hyperbolic population growth. The coefficient governing this growth is derivable from a simple neo-Darwinian model of evolution in the preceding phase, which was characterised by growth not of the population but of the hominid brain. It is found that the finitude argument downgrades the plausibility of attributing a substantial anthropic quotient to non-hominid animals, and also by analogy, to infant members of our own species.

1. Introduction

Continuing an approach presented in an earlier article on the biological implications of the anthropic principle [1], the present work zooms down to shorter timescales – hundreds of thousands rather than thousands of millions of years. This line of investigation is concerned with the emergence in the universe, and more particularly on Earth – the only example we have discovered so far – of what are qualifiable as "sentient" beings, in the sense implied by Bentham's much quoted words [2] "The question is not, Can they reason? nor, Can they talk? but, Can they suffer? ". Expressions such as "intelligent" or "conscious" observers are often used with this connotation, but have the disadvantage of being alternatively interpretable as excluding those who may be sensitive but stupid, while including clever but unfeeling (quasi psychopathic) computer controlled robots that may be capable of switching from an energetically economical "dormant" state, lacking environmental awareness, to a "conscious" state receptive to signals from outside.

This theme is subject to the well known difficulty that such "sentience" is not directly measurable, but is known only by analogy with ourselves. As an example of the issues that arise, it has been remarked by Dawkins [3] that the legal acceptability of boiling lobsters alive is based on the questionable but traditional notion that their analogy with mammals such as ourselves is sufficiently remote to justify their classification as automats rather than sentient beings. Their degree of genetic relationship to ourselves is now quantitatively measurable by DNA analysis (and turns out to be moderately high) but that is not much help for settling the question, because there is no obvious correspondence between such a genetic measure and any meaningful quantification of "sentience".

The innovation in the present approach is to exploit the idea that an appropriate measure of "sentience" should be the same as the measure involved in the application of the anthropic principle, which specifies the *a priori* probability ansatz for finding oneself in any particular sentient state.(According to what I called the "strong" anthropic principle, [4] such an ansatz was to be used for fundamental physical applications in conjunction with the hypothesis of a "world ensemble" – meaning what is now more commonly known as a "multiverse" – but such a hypothesis is not needed for the biological rather than physical applications considered here.) In the original primitive version [4, 1] of the anthropic principle, as discussed by Leslie [5] and Bostrom[6], the proposed ansatz consisted merely of the rather obviously natural (but by no

means tautological) affirmation that the *a priori* probability should be non-zero only where "observers" are present, and that it should be distributed uniformly over observers comparable to ourselves.

That rather vague formulation was sufficient for many purposes, not only in cosmology [7], where the qualification "comparable" can be given a rather broad interpretation, but also concerning the question of the "hard steps" in the evolution of our biological ancestors on planet Earth[1, 8, 9]. Nevertheless it is evidently necessary to seek more refined versions [10] of the anthropic principle, not just for application to conceivable extraterrestrials that might be far from comparable with ourslves, but more specificly for application to the measurably intelligent but not so clearly sentient animals of the various kinds (including lobsters) that we know about on Earth.

A more basic issue than the quantitative evaluation of comparability is the qualitative question of the meaning of the term "observers", which I use in this context to mean "sentient beings" in the Benthamite sense. Although correlated with "intelligence" of the kind that may be possessed by an automat and measured by an I.Q. test, the "sentience" in question is something different, which pertains to incoherent reverie as well as to wakefull cleverness and self-awareness. In addition to being distinguished from "intelligence", such "sentience" must also be distinguished from "consciousness", as the likelihood that subconscious thought may also be "sentient" is suggested by evidence such as clinical experience with split brain patients.

My reason for assuming that the allocation of Bayesian *a priori* probability must be based on such "sentience" is that – as remarked in the seventeent century by Descartes – the reality of its physical (not just Platonic mathematical) existence is known to us directly, whereas – as remarked in the eighteenth century by Berkeley – we do not have direct knowledge of any other kinds of physical (not to mention theological) "reality". It took time before that point sunk in. Even at the end of the nineteenth century obstinate positivists continued to believe in the material reality of entities such as electromagnetic fields, whereas their status could already be seen to be merely that of mathematical abstractions in a model whose predictions can be just as well be obtained from a reformulation (via Green functions) in terms of action at a distance. Berkeley's recognition that the material world is merely an illusory theoretical construct remained a subject of mockery by positivists until their certainties were irreparably shattered by the advent of quantum theory, when Johnson's famous stone was trumped by Schroedinger's notorious cat.

Although (unlike anything else) its reality can not be doubted, the nature of "sentience" remains mysterious, and the way it should be evaluated remains obscure, so as an ansatz for allocation of *a priori* probability measure it is far from unambiguous. In pragmatic practice, the best one can ultimatedly do is, as Linde put it [7] "to consider the probability measure as a part of the theory, and to compare its predictions with observations".

It has been plausibly proposed by Dyson [11] that the feelings of sentient beings should be quantifiable in terms of of the information content of the perceptions involved. Persuing this idea – which is essential for what I consider to be the correct way of construing the Everett interpretation of quantum mechanics – my concept of the anthropic principle [10] is that the a priori probability for one to find oneself having any such perception should be proportional to the corresponding information content. However, to apply this concept of anthropic probability measure, one needs to have some idea of how much information actually is involved.

For the only case we know of first hand, that of ordinary humans, Dyson suggested [11] that the information content of a typical perception, with duration of about a second, would be in the vicinity of the Avogadro number, of the order of 10^{23}, because that is the amount of entropy dissipated by the human brain during the time of such a perception. However Dyson's estimate – adding up to something like 10^{30} bits in a complete human life – can be considered only as an extreme upper limit, because most of that entropy is generated by the processes involved in keeping the all the necessary brain cells alive, not just in the collective neural activity responsible for the perceived feelings themselves. Entropy is generated at a comparable rate even by a brain in a state of coma, during which it would seem (though it is hard to be sure) that all perception of feelings is switched off, and anyway entropy is similarly generated by plants, such as trees, which never show any signs of having any sentient perceptions at all.

In a more recent discussion of such questions by Merkle [12] it was recalled that there is a more stringent upper limit due to Von Neuman, based on the observation that neural processes are characterised by a time step of about a tenth of a second, within which the amount of information that is processed will be restricted by the number of neural synapses involved, so that its magnitude will not greatly exceed the square root of the Avagadro number. There will also be a lower limit, provided by Landauer's observation [13] that within such a timestep we are capable of retaining at least a few bits of consciously memorised information. In view of the consideration

that most mental activity is of the presumably non-sentient kind categorised as "subconscious", because it does not leave a conscious memory, it seems plausible that the amount of information characterising sentient perception should be nearer to Landauer's lower limit of about 10^{10} bits in a human lifetime, than to von Neumann's upper limit of about 10^{20} bits in a human lifetime.

In view of the discrete nature of information, a more precise evaluation of the absolute value of the lifetime total – somewhere in the range $10^{15\pm5}$ – would be of interest in relation to the difficult problem of identifying the first moment – beyond the range of conscious adult (or even primary school child) memory – at which sentient perception first occurs, at some early infant or embryonic stage of life. (The identification of the last moment – identifiable as the instant of death – will in most cases be much easier.) However comparitive values are all that is needed for most practical applications of the anthropic principle, which need a measure, not of absolute probability, but just of relative *a priori* probability. I have occasionally regretted choosing the term "anthropic" for the *a priori* probability principle in question, since, from the outset [4, 1], it was always intended for application, not just to humanity and related anthropoids, but also to conceivable – as yet undiscovered – extraterrestrials. Nevertheless, the term "anthropic" is fully justified with reference to the relative probability measure of the particular kind to be considered here, since it will be specifically calibrated with respect to the only case we know about directly so far, namely our anthropic selves

After starting by consideration of the relatively recent past – that of our own homo sapiens species – about which we know quite a lot, the plan of this article is firstly to discuss implications for the near future, and then to move on to the main objective of this work, which is an attempt to throw some light on the mystery of what happened in the rather more distant past – that of our pre-Neanderthal hominid ancestors.

2. The concept of anthropic measure and quotient

It would be possible in principle (and for many astrophysical or cosmological applications adequate in practice) to work with a relative probability measure specified in dimensionless human life units, corresponding to an as yet unknown amount of sentiently perceived information, somewhere in the range between 10^{10} and 10^{20} bits. However in view of the fact that the duration of an average human lifetime is highly sensitive to historical circumstances, it is more convenient for the purpose of precision to evaluate

5

anthropic probability in terms of what Dyson [11] called "subjective time". This means using a relative probability measure, $\mathcal{A}$ say, that is specified in time units, such as human centuries (which would again correspond to units of information somewhere in the range $10^{15\pm5}$) or human seconds (for which the corresponding units of information would be somewhere in the range $10^{5\pm5}$). The idea is that such units would be calibrated with respect to an average (adult) human value, on the understanding that the specification of the averaging process should require it to be taken over both awake and sleeping states, of which the latter would include allowance for the sentient perceptions in dreams.

The rate of progress of such "subjective time", $\mathcal{A}_i$ say, for an individual labelled by an index i will be given with respect to the progress of ordinary time t by an expression of the form

$$\mathrm{d}\mathcal{A}_i = \mathfrak{q}_i \, \mathrm{d}t \,, \tag{1}$$

in which $\mathfrak{q}_i$ is a dimensionless coefficient that I shall refer to as the *anthropic quotient* of the individual concerned at the time under consideration. This quantity $\mathfrak{q}_i$ will presumably be subject to diurnal variation, with a maximum when the individual concerned is awake, and with an average $\bar{\mathfrak{q}}_i$ that is by definition unity for a typical human adult. It is however to be expected that the diurnal average will itself depend on the state of health of the individual concerned, for example it might be higher for an insomniac than for someone who sleeps too well. Rather generally one would expect that the diurnal average $\bar{\mathfrak{q}}_i$ would be a function of age: it is commonly recognised that older people tend to think more slowly, which implies that a very old person will normally have an anthropic coefficient that is lower than than the relevant average $\bar{\mathfrak{q}}$ over the whole population, which, by definition, in the ordinary human case, is unity: $\bar{\mathfrak{q}} = 1$.

It should not be too difficult (and might be useful for clinical and sociological purposes) to follow the example [13] of Landauer's empirical work, by developing tests for measuring the slowdown of mental processes – and by implication the concomitant reduction of the anthropic quotient $\bar{\mathfrak{q}}_i$ – in aging subjects. A more difficult but academically more interesting challenge would be to try to make analogous measurements of the rise of the average anthropic quotient as a function of age in infancy and early childhood. The reason why this would not be so easy is that, although it may be performed at a lower speed, the mental activity of older people is qualitatively similar to

that of younger adults, whereas the mental activity of infants is of a quite different nature. Thus it is hard to see how infantile rates of performance should be calibrated with respect to the rates of performance of the very different mental activities of older children and adults. (This difficulty illustrates the contrast between the concept of the anthropic quotient, as formulated here in terms of rates of performance, and the well known concept of the intelligence quotient, as formulated in terms not of rates but of absolute levels of performance, for which the traditional calibration is based on the evaluation of "mental age", a notion that is more directly meaningful for young children than for adults.)

3. The anthropic finitude argument

The problem of the emergence of sentient perception in human infancy is part of the more general problem of its emergence in other creatures, and more particularly in our hominid ancestors, of the genus anthropithicus and finally the genus homo, for which the mean anthropic quotient $\bar{q}$ – as averaged over the whole population – would have risen to a value $\bar{q} \lesssim 1$, comparable with unity but – at least until the arrival of the Neanderthals – still presumably less than that of our modern human population.This issue is of relevance for ethical purposes such as the evaluation [3] – with a view to prevention – of avoidable suffering in animals. A conventional – reasonable but unsubstantiated – supposition would have it that members of our own phylum, that of the vertebrates, including fishes, do have real feelings like our own, while others, including arthropods and molluscs do not: in effect their anthropic quotients are deemed to be zero. According to the anthropic principle, as formulated above, that conventional supposition would imply that, compared with the probability of finding oneself to be human, there was, *a priori*, a finite relative probability for finding oneself to have the feelings of a fish, but not of an arthropod such as a lobster, or nor a mollusc such as a squid.

One of the main aims of the present article is to show that some light can be thrown on this issue by application of the kind of anthropic finitude argument that has already been used [5] to predict that the human population must drop after passing through a peak in the not too distant future. This prophesy has been referred to [6] as the "doomsday argument", because it might be fulfilled via a sudden extermination such as could result from a nuclear war, but I prefer the term "finitude", because it might just as well be fullfilled in a less drastically catastrophic manner by a continuous decline

of the population.

The reasonning behind this finitude prediction is simply an ordinary Bayesian argument to the effect that for a scenario to be plausible our observed situation within it should not be too blatently exceptional, with respect to the relevant *a priori* probability measure, $\mathcal{A}$. For an entire population of N individuals, this anthropic measure will simply be $\mathcal{A} = \sum_i \mathcal{A}_i$, which means that its time variation will be given in terms of the averaged anthropic quotient, $\bar{\mathfrak{q}} = \sum_i \mathfrak{q}_i / N$, by

$$\mathrm{d}\mathcal{A} = \bar{\mathfrak{q}}\,\mathrm{d}\mathcal{T}\,. \tag{2}$$

where, as discussed in my preceding article [14], $\mathcal{T}$ is the total time lived by the population under consideration – namely what Wells [15] calls the population time – as given by

$$\mathrm{d}\mathcal{T} = N\,\mathrm{d}t\,. \tag{3}$$

In its most primitive version, the finitude argument requires containment, within a finite and not too large upper limit, of the integrated anthropic measure, $\mathcal{A}_>$ say, of our human descendents in the future, which – unless our arrival is exceptionally early – must satisfy the rough order of magnitude inequality

$$\mathcal{A}_> \lesssim \mathcal{A}_<\,, \tag{4}$$

where $\mathcal{A}_<$ is the accumulated measure of our human and other hominid predecessors in the past, while similarly – unless our arrival is exceptionally late – the contribution $\mathcal{A}_<$ from the past must be subject to, a limitation of the corresponding form

$$\mathcal{A}_< \lesssim \mathcal{A}_>\,. \tag{5}$$

Taken together these conditions simply tell us that – if our arrival time is not exceptional either way – the magnitudes of the past and future anthropic measure contributions should be roughly comparable,

$$\mathcal{A}_< \approx \mathcal{A}_>\,. \tag{6}$$

More refined versions of the finitude argument [5] take account of the observation that our arrival has occurred at what is clearly a rather special

time in human history, which makes it necessary to check whether this time is so special as to be exceptional, since if it were the foregoing reasonning would not be directly applicable. The observation in question is the recognition that the accelerating development of our civilisation has recently – at a time t_2 roughly at end of the second millenium – reached a climactic phase, in which the timescale of revolutionary change at a global level has become shorter that a normal human lifetime, and comparable with the limit imposed by our reproductive breeding timescale τ_g, of the order of 20 or 30 years.

The people (including the author and foreseeable readers of this article) involved this phase transition at time t_2 are characterised by a typical lifetime of about $3\,\tau_g$ (whereas it would have been much less for most previous generations) so the anthropic measure, $\mathcal{A}_\star$ say, of the lives of the members of this privileged subset will be given in order of magnitude by

$$\mathcal{A}_\star \approx 3\,N_2\,\tau_g\,, \tag{7}$$

where N_2 is the global population at the end of the second millenium. According to official U.N. statistics, this is given fairly accurately by

$$N_2 \simeq 6 \times 10^9\,, \tag{8}$$

so the measure $\mathcal{A}_\star$ of our privileged subset world works out to be about five hundred thousand million human years.

The question that immediately arises is whether our membership of this subset makes us untypical compared with people living at other times. Unlike the uncertain future, with masure $\mathcal{A}_>$, and the obscure past during what will be classified as the first phase of hominid evolution, with measure $\mathcal{A}_1$ say, which will be investigated below, the second phase of hominid evolution, meaning the past of our own modern human species, is sufficiently well known for a reasonably reliable estimate of the order of magnitude of its measure, $\mathcal{A}_2$ say, to be already available. In order to be able to go ahead with the application of ordinary Bayesian reasonning in favour of theories in which we are not highly untypical, it must be verified that the order of magnitude of the measure $\mathcal{A}_2$ of this second phase satisfies a finitude condition of the form

$$\mathcal{A}_2 \lesssim \mathcal{A}_\star\,. \tag{9}$$

It will be shown below that this condition is indeed satisfied, within a reasonable but not enormous margin, as the evidence suggests that the required

value is given, within a factor of two or so, by the estimate

$$\mathcal{A}_2 \simeq 5\,\mathcal{A}_\star\,, \tag{10}$$

which means that although our subset with measure $\mathcal{A}_\star$ is effectively "privileged", it is not highly exceptional with respect to the part of the human race that has lived so far, of which it constitutes a significant fraction, about 20 percent. The plausible – but as yet unstested – supposition that our subset is similarly unexceptional with respect to the human race in the future leads to the prediction that – as a matter not of certainty but just of likelihood – the total measure, $\mathcal{A}_>$ say, of the future human population should not greatly excede the past contribution $\mathcal{A}_2$. If the future population were to remain near its present value until a sudden "doomsday" cut-off, then this anthropic finitude requirement

$$\mathcal{A}_> \lesssim \mathcal{A}_2\,, \tag{11}$$

would mean that the catastrophic cut-off would be likely to occur within a century or so, but the finitude requirement (11) is also compatible with scenarios in which the population declines gradually over a much longer timescale.

The main question to be considered in this article later on is what happenned further back in the past, before the time, t_1 say, when our own species, homo "sapiens" first appeared just a few hundred thousand years ago, but after the separation from the chimpanzee line of our hominid ancestors. Although some taxonomical "lumpers" have underated the importance of this separation by classifying humanity as just a third species [16] in the pan genus (of which the other extant members are the bonobo and the ordinary chimpanzee) it is generally recognised that our branch qualifies as a separate subfamily containing more than one genus (not just homo but also anthropithesus) in its own right. As discussed by Dawkins[17] (in a treatise that is commendable modulo the caveat that its treatment of the anthropic principle misses the terrestrially relevant points by getting sidetracked into far fetched cosmomogical speculations) it has been deduced, mainly from genetic evidence (as fossils are lacking, particularly on the chimpanzee side) that this crucially important bifurcation occurred at a time t_0 about 6 million years ago.

Unless our human status among hominids is exceptional, it can be seen that – like the contribution $\mathcal{A}_>$ from the future – the earlier measure contribution, $\mathcal{A}_1$ say, from hominids of the genera australopithecus and homo

during the pre-sapiens phase from t_0 to t_1, should also be subject to a corresponding anthropic finitude condition: for the the condition $\mathcal{A}_< \lesssim \mathcal{A}_2$, got from (5) and (11), to be satisfied by the total, $\mathcal{A}_< \simeq \mathcal{A}_1 + \mathcal{A}_2$, we must evidently have

$$\mathcal{A}_1 \lesssim \mathcal{A}_2 \,. \tag{12}$$

This first phase of hominid development is characterised by genetic evolution of which the salient feature in the fossil record is the cerebral growth that is presumably associated with corresponding growth of the average anthropic quotient, whereas the second phase, between t_1 and t_2, is characterised not by biological evolution but by accelerating technological progress and concomitant population growth. Whereas the finitude condition (11) on $\mathcal{A}_>$ tells us something new about the future evolution of the human population N, and the finitude condition (10) on $\mathcal{A}_2$ merely confirms what is known anyway about the human population in the phase from t_1 to t_0, the finitude condition (12) on $\mathcal{A}_1$ will be able to tell us something new about about the growth of the average anthropic quotient $\bar{\mathsf{q}}$ of our hominid predecessors in the first phase, from t_0 to t_1.

4. The controversial question of the finitude of the future

Before reverting to the more academically fascinating problem of the past – the question of how we got here, with which this essay is primarily concerned – it is worthwhile to linger on the question of the future, a subject about which it is even harder to be objective. Darwinian selection has programmed us to strive for the propagation, against the odds, of our own genes (not to mention memes) as opposed to others. We are thus innately disinclined to accept that the odds in question are (as they always have been) against success in the long run.

The ensuing tendency towards blinkered myopia applies particularly to economists, by whom the unwelcome revelation [18] that "in the long run we are all dead" is commonly blamed on Keynes, despite his utter innocence of any originality in this respect. His 1923 warning was preceded, for example, by Kipling, who preached that this "inconvenient truth" applies not just to individuals but to entire civilisations, which will ineluctably end up by becoming, as he poetically put it [19] "one with Niniveh and Tyre". Despite the precedence of such illustrious authors (and many others) the controversial banality that life can not go on for ever came to be known in science fiction [20] as the "Carter catastrophe" after I had drawn imprudent attention to

11

its relevance in the context of the anthropic principle [1]. Although widely familiar, in one form or another, since long before its official proclamation in English by King James's "authorised" version of St John's Apocalypse, the "inconvenient" but ubiquitously pertinent precept encapsulated in the proverb that "life can not go on for ever" has never been universally accepted. Its application[21] by Dicke was dismissively rejected by Dirac, and its affirmation by Islam [22] was courageously – albeit not convincingly – contested in detail by Dyson [11]. Echoing the sentiment expressed half a century before by Dirac [21] (and yeilding to the temptation that typifies theology) Dyson has reaffirmed his uncompromising inclination to conflate plausibility with (debateable) desirability by the recent declaration [23] that he would "prefer" (as if he had been offered the choice!) "to belong to a species destined for inexhaustible intellectual growth".

The issue in question – that of the future survival of humanity in general, and of our industrial civilisation in particular – has long been a subject of academic interest. In recent years it has also become a subject of widespread concern in a political context, in view of the impending exhaustion of many economically important non-renewable ressources. For the purpose of debate about what may be ethically or politically desirable it would be useful to have a clear scientific understanding of what may be possible or probable under various likely conditions. However the range of divergence of opinion within the scientific community is still very wide. Dyson [11] is not the only author who has given serious consideration to the possibility that our descendants might continue to multiply by extraterrestrial colonisation on a galactic scale, but many others have emphasised the economic, ecological, and other technical obstacles to such an open future.

The already well founded scepticism about unlimited population expansion in the future is evidently reinforced the anthropic finitude argument as presented in above, a point that I made informally about thirty years ago [1], and that has since been put forward and developed in detail by Leslie [5]. He and others [6] have referred to it as the "doomsday" argument, but that evocative decription has the disadvantage of distracting attention from the viable alternative of a prolonged decline, by focussing too much attention on the likelihood that our civilisation will terminate suddenly.

A comparable argument was developed independently by Richard Gott [24], whose "delta t" principle asserted that we should expect to find ourselve at a random temporal position in human history, and therefor probably not very near the beginning as would be the case in a scenario of the kind

envisaged by Dyson. However, as discussed by Wells [15], the force of Gott's reasonning was weakenned by its unduly exclusive emphasis not on the relevant population time $\mathcal{T}$ given by (3) but just on ordinary time t as the pertinent parameter, whereas the corresponding – purely time-weighted – probability measure would be justifiable only if the human population, N say, remained roughly steady until a sudden cut off, at a moment for which the description "doomsday" would indeed be appropriate.

For application to the actual case, in which the population is highly time dependent, the crude "delta t" argument is inadequate. The more careful reasonning developed by Leslie [5] is based on the anthropic principle [1], which – as explained above – serves to specify the *a priori* probability for finding oneself in some particular situation during some particular time interval. On this basis we should expect our position in human history to be random, not with respect to ordinary time t, as suggested by Gott[24], but with respect to anthropic measure $\mathcal{A}$, as characterised by (2), which in the ordinary human case characterised by $\bar{\mathsf{q}} = 1$ simply gives

$$\dot{\mathcal{A}} = N \,. \tag{13}$$

where N is the instantaneous value of the total population number, and a dot is used to indicate differentiation with respect to t. It follows that the measure $\mathcal{A}_2$ introduced above for the entire interval from the emergence of modern humans, at a time t_1 say, a few hundred thousand years ago, until the time t_2 of the epoque in which we find ourselves, will be expressible simply as

$$\mathcal{A}_2 = \int_{t_1}^{t_2} N \, \mathrm{d}t \,. \tag{14}$$

(It is of course to be remarked that the definition of t_1 is rather imprecise, as the emergence process was naturally continuous, but it will be seen later on that the result is insensitive to this vagueness.)

As discussed in the preceding section, and in more detail by Leslie [5] and Bostrom [6], the relevant application of the anthropic finitude argument tells us that we should not expect to find ourselves exceptionally close to the beginning of the anthropic measure of the human race, so that – in accordance with (11), but contrary to what would happen in a scenario of the kind envisaged by Dyson [11] – the future value of the anthropic measure $\mathcal{A}$, as measured from about the present time t_2, should never get to be extremely large compared with the value given by (14). More particularly, so long as

our descendents remain similar to ourselves,as ordinary humans with $\bar{\mathrm{q}} = 1$, it is unlikely that their anthropic measure will exceed a bound given within some moderate order of magitude margin by the condition

$$\int_{t_2}^{t} N \, \mathrm{d}t \lesssim \mathcal{A}_2 \,, \tag{15}$$

for which, the wider the margin, the lower its likelihood of being exceeded.

As an immediate corollary of this finitude condition, it can be seen that in so far as the ordinary human race is concerned, the population number N must finish by dropping sufficiently rapidly towards zero. Thus in the long run (as Keynes put it) we (meaning ordinary humans) shall all (including those not yet born) be dead. This "inconvenient" conclusion might of course turn out to be wrong, as it is only based on consideration of what is most likely within the framework of the anthropic principle, which is itself just a falsifiable scientific hypothesis among others. However, in the absence of contrary evidence, such a plausible principle can not reasonably be rejected (whether by economists in general, or by illustrious physicists such as Dirac and Dyson in particular) merely because its consequences are displeasing.

5. Distinction between anthropic measure and soul count

For the quantitative evaluation of the measure $\mathcal{A}_2$ in (15), and more particularly to verify that it actually does satisfy the condition (10) for our presence at this critical period of history to be unsurprising, one needs a demographic model describing the past evolution of the the global human population N.

Befor proceeding, it to be recalled that in the human case (with $\bar{\mathrm{q}} = 1$) the anthropic measure $\mathcal{A}$ in which we are interested is roughly definable, in accordance with (13) as the accumulated amount of time lived by all the people in the period under consideration. It is important to avoid confusing this measure with a related quantity that has also been the subject of discussion in the context of demographic evolution, namely what might be called a "soul count", meaning the total number, $\mathfrak{N}$ say, of humans that ever lived during the period under consideration. In terms of an average human lifetime, $\bar{\tau}$ say, at the period under consideration, the rate of increase of such a "soul count" will be given by an expression of the form $\dot{\mathfrak{N}} = N/\bar{\tau}$.

If we were concerned only with modern "developed" countries it might be realistic to take a fixed value $\bar{\tau} \simeq 3\tau_g$ where τ_g is the generation timescale

introduced above, in rough agreement with the traditional "biblical" value, $\bar{\tau} \simeq 70$ years, so that $\mathfrak{N}$ would be related to the measure $\mathcal{A}$ by a simple proportionality law of the form $\mathcal{A} \simeq 3\mathfrak{N}\tau_g$. Such a simple relationship will however be unable to provide an accurate treatment of historic and prehistoric times, for which one would need to take $\bar{\tau}$ to be a variable with, until recently, a much lower value $\bar{\tau} \leq \tau_g$, meaning an average lifetime of less than 20 years, to allow for the consideration that most people died before emerging from infancy. Due to uncertainty about prehistoric rates of birth and of infantile death, estimates of $\mathfrak{N}$ are even more unreliable than estimates of $\mathcal{A}$, to which the main contribution is from older children and adults, whose numbers are easier to evaluate. The "soul count" $\mathfrak{N}$ is something that may be of theological interest for believers in an "eternal afterlife", but for mundane scientific and practical purposes – such as estimation of corresponding rates of consumption of non-renewable ressources – the anthropic measure $\mathcal{A}$ is more generally relevant. For such purposes, and in particular for the application of the anthropic principle, it is fortunate that one does not need $\mathfrak{N}$, but only the more easily calculable quantity $\mathcal{A}$, as given by (13), which depends only on the evolution of the total population number N.

6. Foerster model of demographic expansion in the past

One of the first people to think seriously about demographic evolution was Malthus, who introduced the simplest and still most widely used kind of model for this purpose, namely that of the exponential type characterised by a fixed fractional growth rate according to a prescription of the form

$$\dot{N}/N = 1/\tau \,, \tag{16}$$

for some fixed timescale τ. This gives

$$N = N_0 \exp\{t/\tau\} \,, \tag{17}$$

where N_0 is the population at some chosen time origin when $t = 0$.

Although the secret of perpetual exponential growth is still commonly sought as an ideal "holy grail" by economists, its ecological impossibility in the long run was clearly recognised by Malthus himself. As discussed in the preceding article [14], the first and simplest "sigmoid" model allowing for the limited availability of renewable ressources was introduced by his follower, Verhults, in the middle of the nineteenth century, but it took another century before attention began to be given to the need to take analogous account of

15

for the limited availability of non-renewable ressources, for which a corresponding "peaked" model was introduced by Hubbert. Unlike the Verhults model, a Hubbert type model of future demographic evolution is compatible with the anthropic finitude condition described above, but as it starts off exponentially (like the simple Malthusian model) it badly underestimates the population in the past. The simplest realistic description of the human population in the past is provided by a model of the hyperbolic kind that was introduced for this purpose by von Foerster [25].

Despite their addiction to the idea of permanent exponential growth, one of the few things about which economists have always agreed is that the prescriptions of Malthus are wrong in one way or another. Some have considered them to be morally wrong. Others have objected for reasons of a factual rather than ethical nature, claiming that Malthus overdramatised the problem of population expansion by failure to take account of the importance of technological progress. What is now becoming clearer is that he did indeed fail to take account of the importance of technical progress, but that his error, in consequence, was not an overestimation but an underestimation of the drama of the situation.

The upshot of Foerster's denoument [25] is that the essential flaw in the line of thought developed by Malthus and his followers was indeed the lack of allowance for technical progress. As recently explained by authors such as Kremer [27] and Koratayev [28], the simplest way of allowance for technical progress is to correct the Malthusian equation (16) by insertion of an extra factor of N on the right hand side, so as to obtain what I shall refer to as the Foerster equation, which takes the form

$$\dot{N}/N = N/T_\star \,, \tag{18}$$

in terms of a timescale $\tau_\star$ that really is fixed. This means that the absolute growth rate $\dot{N}$ is in fact proportional not, as envisaged by Malthus, to the existing population N, but rather to its square N^2.

It is empirically verifiable that this very simple formula is roughly valid as a fairly good order of magnitude estimate of what is known, or can be plausibly guessed, over an enormous time range $t_1 < t < t_2$, starting when the modern human species first emerged, more than a hundred thousand years ago, and ending only very recently, about the beginning of the third millenium. This is something that I noticed independently before finding that it had been previously recognised by von Hoerner [26], and that it had

already been pointed out even earlier – back in 1960 – by von Foerster *et al* [25], whose contribution (like that of his compatriot Mendel) did not attract much attention until many years later, when new data became available to confirm it.

The required value of the parameter $T_\star$ (pronounced tea-star) is quite literally astronomical. A noteworthy coincidence is that it turns out to have the order of magnitude of the hydrogen burning lifetime of a typical small star,

$$T_\star \simeq 240 \text{ Gyr}. \tag{19}$$

This is about twenty times larger than the lifetime of a middle sized star like our Sun, which (for the anthropic reason originally pointed out by Dicke [21, 4]) is also about the age of the universe, namely about 10^{10} yr.

The preceding article [14] presented what, as far as I know, is the first attempt to obtain a theoretical derivation of the order of magnitude of this empirically observed timescale (19), but the need for the extra factor N on the right of (18) has already been plausibly – albeit not definitively – accounted for by previous authors [27, 28] as follows. Whereas most other animal species inhabit extrinsically determined ecological niches, the range of niches accessible to humans is evidently determined by their own technogical progress, of which a prototypical example is the invention, about 10^5 years ago, of cloths, which allow the exploitation of a very wide range of climate zones. The idea is simply that the sustainable population density is interpretable as a measure of the technological level, of which the relative rate of progress will be proportional to the rate of invention and introduction of new techniques, which (like the rate of occurrence of the mutations needed for genetic evolution, as discussed below) will itself be proportional to the total population (or equivalently to the local population density). The relatively slow rate of such technical progress when the process first got under way (in Africa [29, 30]) has been referred to by Renfrew [31] as the "sapient paradox". Its subsequent acceleration is illustrated by the introduction of animal powered wheeled vehicles in prehistoric times, of coal powered railway transport at the time of Malthus, and of oil powered aircraft within living memory. Moreover the rate at which we update our internet telephone equipment (ten year old hardware in good condition is already historic junk) shows that it is still accelerating even now.

Unlike the exponential growth envisaged by Malthus, for which the anthropic measure $\mathcal{A}$ is finite in the past and divergent in the future only after

17

an infinite time, the Foerster equation (18) gives what is known as hyperbolic growth, for which the anthropic measure $\mathcal{A}$ is divergent not just in the future but also in the past. Moreover it is divergent in the future not just after an infinite time but at a finite critical "doomsday" time, t_d say, in terms of which the population will be expressible simply as

$$N = \frac{T_\star}{t_d - t}\,.\tag{20}$$

What makes this alarming – more dramatic than anything imagined by Malthus – is that the required value for the time t_d of the divergence is now very soon, indeed well within the expected life of many people already adult today. My own estimate is that the best matching is obtained, as shown in Figure 1, by taking

$$t_d \simeq 2040 \text{ A.D.}\,,\tag{21}$$

which makes the Foerster model applicable until about the turn of the century, at the time

$$t_2 \simeq 2000 \text{A.D.}\tag{22}$$

when the corresponding prediction

$$N_2 = T_\star/(t_d - t_2)\,,\tag{23}$$

was still in fairly good agreement with what was reported by the United Nations, namely

$$N_2 \simeq 6 \times 19^9\,.\tag{24}$$

It is to be remarked that, on the basis of fine tuning to the demographic statistics of their own time in the short run, von Foerster [25] and von Hoerner [26] originally suggested a "doomsday" time that was even nearer, $t_d \simeq 2025$ A.D., in conjunction with a fixed timescale that was correspondingly reduced, $T_\star \simeq 200$ Gyr. However the rather longer fixed time scale (19) and the rather later divergence time (21) seem to give a better match in the long run, not just for more recent years, but also for the more distant past, through mediaeval times. For even earlier (classical, bronze age, and neolithic) times, the uncertainties are anyway so large that the differences between such alternative adjustments are not statistically significant.

Starting with the work of Cook [32] as cited by Keyfitz [33], estimates of about 100 G – meaning 10^{11} – for the "soul count" $\mathfrak{N}$ – specified as the

number of people who have ever lived – have commonly been based on the use of a rather clumsy succession of models of the exponential type (16) with different values of the characteristic timescale τ. The same approach could of course be used to obtain the anthropic weighting $\mathcal{A}$ that we are interested in here, which, as remarked above would be proportional to the number who have lived if their life expectation had remained constant. For example if, as seems likely in view of the high infantile mortality, the averaged life expectation $\bar{\tau}$ was only about 25 years during most of the relevant past, then for a soul count of about 10^{11} the correponding value $\mathfrak{N}\bar{\tau}$ of $\mathcal{A}$ would be 25×10^{11} human years, or equivalently, in more evocative terms, 25 Giga human centuries. As that is only of the same order of magnitude (within a factor of 5 or so) as the total of the expected lifetimes of all the people who are present today, which according to (7) is

$$\mathcal{A}_\star \simeq 5 \text{ Giga human centuries}, \tag{25}$$

it would transpire that our presence now is not particularly exceptional – provided that the number in the future satisfies the anthropic finitude condition that it should not be too much larger than that.

Instead of proceeding indirectly via such widely quoted but questionable estimates, it is easier – and (in view of the uncertainties about birth rates and infantile mortality) more reliable – to work directly with the simple hyperbolic model as given by (20), starting at some initial time t_1 say, at which our ancestors can be considered to have first become fully human in the modern sense. That would have been about the time of the mastery of fire, a few times 10^5 years ago, when according to (19) and (20) the global hominid population

$$N_1 = T_\star/(t_d - t_1). \tag{26}$$

would have been of the order of a million (presumably in small widely scattered tribal groups, still mainly "erectus" in Asia, but already "sapiens" in Africa [29, 30]). On that basis, the accumulated anthropic measure (14), from that time t_1 until about the present time t_2, would be given according to the Foerster ansatz (13) by

$$\mathcal{A}_2 = T_\star \ln\{N_2/N_1\}. \tag{27}$$

From the very rough order of magnitude estimate $N_2/N_1 \approx 10^4$, it can be seen that the logarithmic factor will be given approximately by

$$\ln\{N_2/N_1\} \simeq 10, \tag{28}$$

19

a result which is clearly not very sensitive to the precise value of N_1. Consistently with what was obtained less directly from the work of Cook and Keyfitz as cited above, this leads to the final rough estimate

$$\mathcal{A}_2 \approx 24 \text{ Giga human centuries}. \tag{29}$$

In conjunction with (25) this establishes the previously quoted relation (10), thus confirming that our own "privileged" situation is not too blatantly exceptional with respect to other humans that have lived so far

7. Canonical and catastrophic models for demographic future

Although the fluctuations observed so far exhibit no significant deviation from the Foerster model as shown in Figure 1, it is evident this simple behaviour can not continue much longer: it must surely breakdown before the remaining time before the divergence is too short compared with the minimum timescale of human reproduction, of the order of twenty or thirty years. This consideration suggests that to describe what may be expected we should replace the Foerster model characterised by the single timescele $T_\star$ by a model depending also on a round-off timescale τ_g of the order of twenty years or so. The simplest way of doing this is evidently to replace (20) by what I shall refer to as the canonical prescription, which takes the form

$$N = \frac{T_\star}{\sqrt{(t_c - t)^2 + \tau_g^2}}, \tag{30}$$

in which the time calibration is no longer specified with respect to a Foerster type divergence date t_d but with respect to a new critical date t_c at which the model passes smoothly through a Hubbert style peak. In terms of its value $\mathcal{A}_c$ at this critical moment of time symmetry, the corresponding anthropic measure will be given according to (13) by

$$\mathcal{A} = \mathcal{A}_c + T_\star \operatorname{arcsinh}\left\{\frac{t - t_c}{\tau_g}\right\}. \tag{31}$$

In order to obtain the best fitting, as shown in Figure 1, what I find is that the canonical round-off timescale should be taken to be
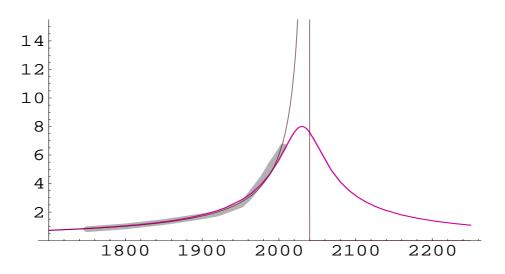
$$\tau_g = 30 \text{ yr}, \tag{32}$$

Figure 1: Plot of global population N, in units of 10^9, against date, using thick pale shaded curve for U.N. statistics from 1750 A.D. to 2000 A.D. The thin dark curve shows successful matching of past population, up to the date $t_2 \simeq 2000$ A.D., by a Foerster model, as given by (20) for $T_\star \simeq 24 \times 10^{10}$ yr, with divergence date $t_d \simeq 2040$. This simple Foerster model is realistic as a description of the past, but its divergence at the "doomsday" date, t_d, is a flagrant violation of the anthropic finitude condition, which excludes it from credibility as a description of the future. The pale firm curve shows alternative matching by the canonical demographic model (30) using smoothing timescale $\tau_g \simeq 30$ yr, with the same value $T_\star \simeq 24 \times 10^{10}$ yr as for the Foerster model (from which it is indistinguishable in the past) but with slightly earlier peak date t_c, about 2030 A.D.

21

and that the canonical critical date should be given by

$$t_c \simeq 2030 \text{ A.D.} \tag{33}$$

That is sooner than my estimate (21) of the best matching for time t_d of the divergence, but slightly later than von Foerster's original estimate for that "doomsday" date. Unlike a Hubbert type model (as characterised [14] initially by exponential growth and ultimately by exponential decay) which the anthropic measure $\mathcal{A}$ is finite, the canonical model is characterised by an anthropic measure $\mathcal{A}$ (as given by the area under the curve) that diverges (logarithmically) both towards the past and towards the future, so the anthropic finitude condition requires that its validity should be restricted to some finite time range. This will be classifiable in terms of three phases, starting with the Foerster type phase that lasts over the range $t_1 < t < t_2$ with upper bound specified by the condition

$$t_2 = t_c - \tau_g \,, \tag{34}$$

when the population reaches its present value,

$$N_2 \simeq T_\star / \tau_g \,, \tag{35}$$

which is consistent with (22) for the matching conditions (32) and (33). Following this phase, with measure $\mathcal{A}_2$ specified by (14), there is a crisis phase that is symmetric about the peak at t_c and that lasts over the range $t_2 < t < t_3$ with upper bound specified by the condition

$$t_3 = t_c + \tau_g \,, \tag{36}$$

(which for the matching conditions (32) and (33) gives $t_3 \simeq 2060$ A.D.) and for which the anthropic measure,

$$\mathcal{A}_3 = \int_{t_2}^{t_3} N \, \mathrm{d}t \,, \tag{37}$$

will have a finite value obtainable from (31) as

$$\mathcal{A}_3 = 2 \, T_\star \operatorname{arcsinh}\{1\} \simeq 2 \, T_\star \,, \tag{38}$$

which is not significantly different from the corresponding value,

$$\mathcal{A}_\star \approx 2 \, T_\star \,, \tag{39}$$

22

of the expected total time (7) lived or to be lived by the "privileged" witnesses (including the writer and anticipated readers of this article) of the phase transition at about the present time t_2. After its peaked crisis phase, the canonical model has an anti-Foerster phase of monotonic decline over a range $t_3 < t < t_4$ that, to avoid a divergence of its anthropic measure,

$$\mathcal{A}_4 = \int_{t_3}^{t_4} N \, \mathrm{d}t \,, \tag{40}$$

and more particularly to satisfy the anthropic finitude requirement

$$\mathcal{A}_4 \lesssim \mathcal{A}_2 \,, \tag{41}$$

must be terminated at some not too large cut off time t_4, to which however the measure will be very insensitive as the divergence is merely logarithmic. It will evidently suffice that the future cut off time t_4 should not be more distant that the past time limit t_2, which allows a generous margin of a hundred thousand years or so before the final extinction of our species.

It is important to emphasise that, although the canonical scenario illustrated in Figure 1 is the simplest (and in some ways the optimum) possibility consistent with the data available at the end of the 20th century, it does not follow that this kind of outcome is what is qualitatively most probable.

Another very simple possibility is that of what is describable as the symmetrised Foerster model, which exhibits what is describable as a "first order catastrophe", in the form of a sharp peak, at which the rising hyperbolic curve of the original Foerster model suddenly switches over to a symmetrically descending hyperbolic curve according to a prescription of the form

$$N = \min \left\{ \frac{T_\star}{|t - t_d|}, \ \frac{T_\star}{|t - t_d + \tau_g|} \right\} \,. \tag{42}$$

according to which the peak will occur when $t = t_d - \tau_g/2$, which – as shown on Figure 2 – is very close to Foerster's original "doomsday date", about 2025, if t_d is given by (21) and τ_g by (31).

Experience with comparable phenomena on a smaller scale shows that it is not realistic to expect such a catastrophe to be symmetric. One of many other, more or less equally likely, alternatives is sketched in Figure 2 which illustrates what is known as an "overshoot" catastrophe of the kind exemplified on a small scale by the much discussed case of the Irish potato disaster of the nineteent sentury [34].
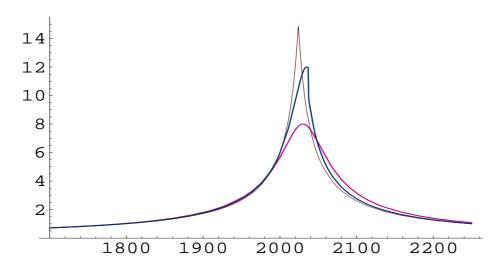
23

Figure 2: Conceivable (first order) catastrophe scenarios, compared with (smooth peaked) canonical scenario (20) plotted as in Figure 1. The symmetrised Foerster scenario (42) peaking earlier (near Foerster's original "doomsday" date, about 2025 A.D.) is shown here by a thin dark line. The firm dark line shows a more realistic example of non-symmetric "overshoot", peaking later (about 2040 A.D., the time of the divergence in Figure 1). The areas under the three (as yet observationally undistinguishable) curves will ultimately become equal, so that they have the same anthropic weighting

A more extreme possibility, classifiable as a "zero order" catastrophe, would be one in which the history of humanity comes to an abrupt end at a critical "doomsday" moment when the population is suddenly annihilated by weapons of mass destruction, as envisaged during the cold war by Nevil Shute [35]. However that particular danger seems lower, at least in the short run, since the end of the cold war.

8. Theoretical prescription for the Foerster timescale

Let us now revert our attention from the speculative future back to the more knowable past, of which the nearest and clearest part is the Foerster phase characterised by (20), which seems to have started at a vaguely defined time t_1 a hundred thousand years or so ago, when our modern homo sapiens race first emerged as a species distinguishable from other – earlier and contempory – hominids.. Having already started before the invention of clothes, this Foerster phase of hyperbolic population growth has lasted until about the present time, that of the installation of the internet.

The task of the present section will be to recapitulate the outcome of recent preceding work [14] showing how to account for the actual value of the coefficient in the growth law (18), or in other words how to explain the observed length (19) of the Foerster timescale $T_\star$. In view of the complexity of the processes involved, that might have been thought to be easier said than done, but it fortunately transpires that the most highly uncertain of the relevant parameters conveniently cancell themselves out.

Before the onset of the Foerster phase, the paleological evidence indicates that hominid evolution was of essentially (neo) Darwinian type, meaning that the main developments – in this case particularly the progressive growth of the brain and consequently of intelligence – were intrinsically genetic. In contrast with that, the more rapid evolution that has taken place since the Foerster phase got under way is describable (in terminology introduced by Dawkins [37]) as essentially memetic, the memes in question being technical developments, such as the use of string bags and clay pots. The timescale $T_\star$ in the Foerster equation (18) governing the rate of acceleration of this memetic evolution is presumably dependent on the intelligence level of the species involved: if we had been cleverer than we are, we would have been able to work through the stages of technical development more quickly, so $T_\star$ would be smaller. (As the intelligence distribution is roughly Gaussian, a modest increase in the average would have produced a disproportionate increase of the fraction clever enough to contribute significantly to progress,

and thus a correspondingly disproportionate decrease in $T_\star$.) However the Foerster phase could not have got under way until our hominid ancestors had become sufficiently intelligent for the timescale characterising progress in technical know-how, namely

$$\tau \approx T_\star/N \tag{43}$$

to become short compared with the corresponding timescale τ characterising progress by Darwinian evolution of the hominid intelligence level itself. As soon as we had reached this point, the Foerster phase (18) would have started automatically, subject to the proviso that the technical level at that stage was already sufficient to have a a proportionate multiplicative effect on the sustainable population number N. This proviso does indeed appear to have been satisfied.

In order to procede, we now need to evaluate the relevant timescale τ characterising Darwinian evolution in the first phase of hominid evolution, just before the onset of the Foerster phase at the time t_1. It is to be recalled that the rate of evolution of genetic information, as encoded at any particular locus on a DNA chain, is essentially dependent on three parameters. Two of these, namely the size N of the relevant breeding population, and of course the size s of the Darwinian selection coefficient favouring the modification in question, are highly dependent on particular circumstances of time and place. However the third parameter, namely the rate r of random mutation (meaning erroneous transcription) per generation at the site in question has the convenient property of having roughly the same order of magnitude for all large organisms. Its inverse, $N_r = 1/r$, is the number of successive generations over which one would expect the genetic information at a particular locus to be copiable without error under favorable conditions.

The probability of erroneous transcription at a particular position on the relevant DNA chain is evidently equal to the total mutation rate μ divided by the number of positions, which is just twice the total amount I of genetic information (twice because it is encoded with a four letter alphabet, so each site carries two bits of information). The ensuing formula

$$N_r \approx I/\mu \,, \tag{44}$$

leads immediately to the values of the order of magnitude that is observed [36] because the measured amount of DNA in the eukaryotic cells of multicellular organisms indicates that the quantity of genetic information is given

in order of magnitude by

$$I \approx 10^{10} \, , \tag{45}$$

(about a hundred times more than in simple bacteria) while it is to be expected that the mechanism ensuring the reliability of replication should be just sufficiently effective to ensure that μ is not too large compared with unity. (For an initially well adapted organism, most mutations will be unfavorable and many will be lethal, so a large number of mutations per generation would be incompatible with short term survival. On the other hand, reduction of the number of mutations much below this maximum tolerable rate would be unfavorable for the genetic flexibility needed for long term survival in a changing environment.)

According to the analysis in the preceding article [14], the relevant evolution timescale τ will be obtainable from (44) as a multiple of the generation timescale τ_g by the prescription

$$\tau = \tau_g \, I / \mu s N \, . \tag{46}$$

Since, as explained above, one expects μ to be a bit larger than unity, but not much, whereas the selection coefficient will be smaller than unity even in the most favorable cases, it is to be anticipated that the product of these factors will satisfy the order of magnitude inequality $\mu s \lesssim 1$, with equality in the most favorable cases, for which the preceding formula reduces to the form

$$\tau = \tau_g \, I / N \, . \tag{47}$$

This formula specifies the minimum timescale required for veritable genetic evolution a minimum that will be attained only when the Darwinian selection coefficient s is high – meaning not too small compared with unity – a condition that (for reasons that are still obscure) does indeed seem clearly to have been satisfied in the case with which we are concerned, namely that of cranial expansion by the hominid population prior to the Foerster phase.

We are now ready to apply the ansatz explained above, according to which the required value of the Foerster timescale $T_\star$ is to be obtained by equating the expression (43) with the expression (47) for τ at the time of the transition to the Foerster phase. The fact that the relevant population was not very large conveniently ensures that the result is not sensitive to the highly uncertain value of the selection parameter s, and it is now to be noticed that the prescription (47) has the remarkable feature of having the same

hyperbolic form – with timescale inversely proportional to population number – as the Foerster formula (20), which means that the other variable controling the evolution rate, namely the population number N, will also cancel out. This cancellation arises from the deep analogy between the dependence of memetic evolution on new ideas and the dependence of genetic evolution on new mutations.

The result of matching (43) and (47) thus reduces to an extremely simple prescription whereby $T_\star$ is given just as the product of a couple of fairly well known constants in the memorable form

$$T_\star \approx \tau_g \, I \tag{48}$$

The timescale τ_g is that of a reproductive generation, which, as in (31), is something like 20 or 30 years in the human case under consideration, so from the estimation (45) it can be seen that the observed value (19) of the Foerster timescale $T_\star$ does indeed agree with the this prediction (48).

Whereas the Foerster phase could not have started before we had become sufficiently intelligent for the memetic technical development timescale $T_\star/N$ to become shorter than the minimum genetic evolution timescale $\tau_g I/N$, it would automatically have started as soon as we had reached that point provided our technical level at that stage was already sufficient to have a proportionate multiplicative effect on the sustainable population number N. The coincidence (48) is thus interpretable as meaning that this is in fact what happened, which solves the problem of explaining why $T_\star$ has the particular value (19) that is observed.

9. Hominid evolution before the memetic Foerster phase.

Let us now consider the first phase of hominid evolution, on the understanding that the the term hominid is interpreted to mean species of the clade constituted by our ancestral branch after its separation, from the branch that gave rise to our nearest living relations, the chimpanzees. In other words hominids are members of the sub-family of which the main (known) constituents are the extinct genus australopithecus, and the genus homo of which the only surviving species is our own. It is thought that whereas the other apes required a forested environment, the hominid branch was distinguished by its adaptation to more open country, notably by the adoption of a standing posture, which freed the hands for throwing and other uses of sticks and stones.

28

Starting from a very small value, $\bar{q}_0 \ll 1$, at the branch-off time t_0 when this phase began, the average value $\bar{q}$ of this quotient in the various species concerned would presumably have increased in a more or less monotonic manner until it attained an approximately unit value, $\bar{q} \simeq 1$, at the time t_1, of the transition to the Foerster phase, after completion of a first phase of duration

$$\tau_1 = t_1 - t_0 \,, \tag{49}$$

which, as remarked above, has been evaluated [17] as about 6 million years.

In terms of the average value $\bar{q}$ of the anthropic quotient of our ancestors, both before and after the branch-off time t_0, it is useful to define a corresponding anthropomorphism timescale

$$\tau_A = \int_{\bar{q}=0}^{\bar{q}=1} \bar{q} \, \mathrm{d}t \,, \tag{50}$$

which is interpretable as a measure of the duration of the the anthropomorphism stage, meaning that in which $\bar{q}$ was at least comparable with unity. This timescale could have been relatively short, $\tau_A \leq \tau_1$, as the anthropomorphism stage might have been preceded by a hominid stage in which the anthropic quotient grew so slowly that it still satisfied $\bar{q} \ll 1$. It will be seen below that the anthropomorphism stage might be interpretable as the period dominated by the genus homo, while the preceding stage might be that of the australopithecines.

Although the total hominid population would no doubt have undergone substantial – occasionaly even severe – short term fluctuations, such as would have been caused by modifications of the climate, it seems reasonable to suppose that it was not systematically subject to major long term variation before the onset of the Foerster phase. (Genetic "progress" would have enabled "fitter" groups to proliferate at the expense of others, but would not yet have been sufficient to greatly expand the ecological niche available to the hominid population as a whole.) This means that an adequate evaluation of the anthropic measure

$$\mathcal{A}_1 = \int_{t_0}^{t_1} \bar{q} \, N \, \mathrm{d}t \tag{51}$$

of the whole of the first phase should be obtainable simply by taking the fixed value N_1 for N. This leads to the estimate

$$\mathcal{A}_1 \approx N_1 \tau_A \,, \tag{52}$$

29

where τ_A is the anthropomorphism timescale given by (50). In view of (27) and (28) , it follows that the anthropic finitude requirement (12) will be exressible as

$$N_1 \tau_A \lesssim 10\, T_\star \,. \tag{53}$$

This upper limit on the timescale τ_A characterising hominid evolution is to be compared with the lower limit imposed, as recapitulated in the appendix, by the maximum rate at which Darwinian evolution can take place in a population of the size N_1 under consideration. The transformation whereby $\bar{\mathsf{q}}$ increased from a near zero to near unity must have involved several substantial steps each of which would have required a time τ that would have been bounded below by the value required for the occurrence of the necessary mutations. As that minimum value will be given by the subsitution of N_1 for N in (47), the time τ_A required for many – meaning a number of the order of ten – of such steps will be subject to the condition

$$\tau_A \gtrsim 10\, \tau_g\, N_r/N_1 \,. \tag{54}$$

In view of the theoretically predicted and observationally confirmed relation (48), the reconciliation of the opposing inequalities (53) and (54) fixes that the relevant anthropomorphism timescale must be given roughly by the order of magnitude equality

$$\tau_A \approx 10\, T_\star/N_1 \,, \tag{55}$$

since for a larger value of τ_A our presence in the mimetic as opposed to genetic phase of evolution would be surprising. The implication of this rough equality (55) is that during the genetic phase the relevant Darwinian selection coefficient must have been large enough for the evolutionary increase of the anthropic coefficient $\bar{\mathsf{q}}$ to have proceeded at just about the maximum speed allowed by the genetic mutation rate.

In terms of the duration

$$\tau_2 \simeq t_2 - t_1 \,, \tag{56}$$

of the Foerster phase, which will be given according to (26) by

$$\tau_2 \approx T_\star/N_1 \,, \tag{57}$$

the relation (55) is expressible as

$$\tau_A \approx 10\, \tau_2 \,, \tag{58}$$

30

The palaeontologically observed value of this duration τ_2 – the time since the emergence of such modern humans, when the memetic phase of hyperbolic population explosion was initiated by the domestication of fire – is of the order of a few hundred thousand years. According to the Foerster formula with the calibration (19) the global population at that transition period would therefore have been getting on for a million (which is somewhat, but not much, larger than the critical value). This rough order of magnitude

$$N_1 \approx 10^6 \,, \tag{59}$$

seems to be consistent, as an upper limit, with the little that is known about population fluctuations in those times. From the point of view of potential carrying capacity, this figure is to be compared with Jane Goodall's estimate of a couple of million for the anthropoid ape population of Africa in recent historical times, before the destruction of habitat following the rise of industrial civilisation. The consideration that hominid fossils are more common than those of apes suggests that the hominid population would have been considerably larger than that, but this is likely to be due merely to the fact that the jungle environment preferred by the apes was less favorable to fossilisation. On the contrary, analysis of modern human genes suggests [17] that we have an "effective" ancestral population that was quite a bit smaller than that, only a few tens of thousands. However such low values are relevant rather as lower limits of fluctuation than as average values, and anyway they apply only to those who were our direct ancesters, including neither the Neanderthals nor the many homo sapiens tribes that (like the historical Mohicans) must presumably have been wiped out without leaving significant numbers of descendants. It therefore seems not unrealistic to suppose that the hominid population actually was within a factor of ten of the value given by (59) during most of the first phase. Combining this estimate with (19) we see that according to (58) that the duration of the Foerster phase of technological development of "homo sapiens" would have been given roughly by.

$$\tau_2 \approx 3 \times 10^5 \, \text{yr} \,. \tag{60}$$

On the basis of the foregoing theoretical and observational considerations, one thus obtains a fairly coherent picture in which, according to (53), the order of magnitude of the anthropomorphism timescale (50) (as limited below by the necessary evolution time, and limited above by the anthropic finitude

condition) can be crudely estimated as

$$\tau_A \approx 3\,\mathrm{Myr}\,. \tag{61}$$

The striking fact that this is of the same order – nearly if not quite as big – as the value

$$\tau_1 \simeq 6\,\mathrm{Myr}\,. \tag{62}$$

estimated, as remarked above[17], for the entire duration of the genetic phase of hominid evolution, suggests what I shall refer to as the hominid solitude hypothesis, to the effect that the anthropisation process – meaning the rise of $\bar{q}$ from zero to a value of order unity – took place entirely within this phase. If this hypothesis is correct, it means that as far as terrestrial animals are concerned, non-vanishing anthropic measure – and concommitent sentience – is attributable only to hominids.

10. Implications of the hominid solitude hypothesis

By providing support for the conjecture that – as a corollary of the hominid solitude hypothesis – humans may be the only non-exinct animals with a significant capability of sentient perception, the foregoing – plausible but debatable – considerations throw light from a new angle on an old but still far from settled issue, that has been a focus of ongoing philosophical controversy since the time of Aristotle. A scientifically comprehensive and up to date discussion of this issue has recently been provided in a review by Christen [38], who marshalls an impressive body of evidence in defense of the contrary idea that "les bêtes pensent", meaning that other animals think in a a manner that is not fundamentally different from our own.

Although that idea would not have been considered shocking by the ancient Greeks, it was opposed during the middle ages and even after the Renaissance by the Western philosophical establishment. The "humanist" attitude that was prevalent then (and common even today) was authoritatively expressed by Descartes, who (in a letter of 1646[38]) wrote off the idea that "les bêtes pensent" on the grounds that if animals did think like us then they would have "immortal souls" like ours. The obvious alternative provided by the ordinary non-religious (observation based) idea that souls are merely mortal – with no existence beyond that of the associated body – was not enviseaged, and nor was the Eastern (e.g. Budhist) religious notion of an immortal soul that transmigrates between mortal (human and other animal)

bodies. The reasonning of Descartes was implicitly and exclusively based on a conventional interpretation of the Western (Judaeo-Christian-Islamic) religious doctrine of a soul that is immortal in the strong sense of being able to survive in some heavenly manner without any mundane body at all.

It is to be remarked that unlike the the Eastern idea of transmigration – which is irrefutable so long as it is amnesic – the Western notion of an afterlife in heaven is a scientific theory in the sense that (like a prediction of what might happen inside a black hole) it can be tested: it would in principle be observationally confirmable by someone who experienced it, while on the other hand one can, in practice, refute the idea of an everlasting afterlife by an extension of the anthropic finitude argument. (If one doubts the anthropic principle one may believe in an infinite afterlife, or vice versa, but one can not consistently believe in both.) As more recently for Dirac [21], it was indeed logically admissible for Descartes to have (implicitly but effectively) refused to adopt the anthropic principle on which the reasonning of the present work is based. However his acceptance of the standard Western religious doctrine of the immortality of the soul was evidently based essentially on prejudice acquired from his childhood education, rather than on serious philosophical reasoning. It seems likely that Descartes was at least subconsciously aware of this weakness of his position, because (in 1649 [38]) he laboured the point by denouncing the belief that "les bêtes pensent" as the greatest of all the "préjugés de notre enfance". That sounds like an indiscriminantly pre-emptive counter-attack, to which my personal response is "touché!", as I have always felt (like Dawkins [3]) that even lobsters (and *a fortiori* domestic cats and dogs) should be given the benefit of the doubt.

Although the line of reasoning used by Descartes (and similarly prejudiced philosophers even in much more recent times) does not hold water, it does not automatically follow that his actual conclusion was wrong. Descartes had the misfortune of living too soon to have known the masterpieces of anthropomorphistic art created by Potter and Lofting, but he would have been familiar (if only via vernacular translation) with the ancient classical writing of Aesop, and he would no doubt have been correct in denying that other animals "pensent" if that merely meant thinking in the adult human manner described in such fictional work. However Descartes and the others involved in the debate were concerned with something more basic than the (anthropomorphically calibrated) maturity or intelligence level of the "thinking" in question. The nature of the thinking characterised by his famous epigram of 1637 "I think so I exist" (originally written as, "Je pense,

donc je suis", and subsequently Latinised as "cogito ergo sum") was made more explicit in Bentham's 1789 publication [2] *Introduction to the Principles of Morals and Legislation* in which, as remarked above, it is explained that "The question is not, Can they reason? nor, Can they talk? but, Can they suffer? " (It is to be remarked that people who are immune to clinical pain [39] are not thereby preserved from suffering in the Benthamite sense, while conversely – as masochists know – suffering is not a logically necessary consequence of pain.)

Since the time of Bentham, scientific progress on many fronts has greatly advanced our understanding [38] of the way humans and other animals think, but there are many aspects that remains mysterious. The plausibility of the Cartesian picture has clearly been undermined by the detailed verification of the Darwinian idea of a continuous relationship – via extinct hominids – between modern humans and other animals. Nevertheless the definitive confirmation of the Benthamite picture remains elusive. The problem is that the kinds of experiment that provide information about the extent to which animals "reason" and "talk" can not tell us whether they "suffer". A similar continuity of relationship, and the same kind of uncertainty, applies to infants of our own species. When a baby cries because it needs feeding, one normally assumes that its suffering is real – but how can one be sure? (In the analogous case of a portable telephone that emits complaining noises because its battery needs recharging, one normally assumes that its apparent suffering is merely simulated.) We know – if we can trust what we remember – that suffering expressed by an older child is likely to be real (though it might also be a case of deliberately misleading simulation) but our (conscious) memories do not take us back far enough to tell us how it felt to be less than two years old.

In view of the ethical – not just academic – importance of this issue, it is worthwile going back the question of what happenned in the first phase of hominid evolution to see if the evidence favouring the hominid solitude hypothesis stands up to closer scrutiny.

11. Alpha models of anthropisation

Whether of not the evolutionary anthropisation process – whereby the mean anthropic quotient $\bar{q}$ of our ancestors grew from zero to a value comparable with unity – had already started before the hominid bifurcation time t_0, it is of interest to know whether it started suddenly or in a more gradual manner. This question is important for the light it can throw on the analogous and related issue of the individual anthropisation process, whereby the
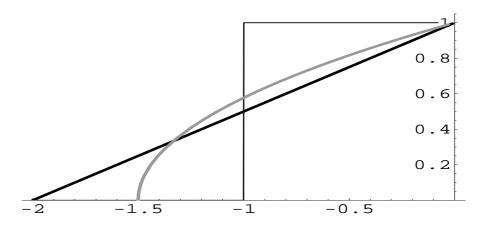
34

Figure 3: Examples of conceivable hard (high α) models for evolution of anthropic quotient $\bar{q}$ as a function of time, in units for which the anthropomorphism timescale τ_A (measuring the area under the curve) is set to one. The linear case $\alpha = 1$, is indicated by a heavy dark line. The sudden takeoff case $\alpha = 2$ is indicated by a pale line. The extreme discontinuous limit $\alpha \to \infty$ is indicated by a thin dark line.

anthropic quotient q of a human infant grows from zero to a value comparable with unity in early (pre or post natal) life.

It is reasonable, in the absence of other information, to describe the most obvious qualitative possibilities for such evolution by a simple power law ansatz of the kind I shalL refer to as an alpha model. This means the supposition that the development of the variable $\bar{q}$ in question will be governed by an evolution equation of the power law form

$$\dot{\bar{q}} = \bar{q}^{1-\alpha}/\tau_\alpha \,, \tag{63}$$

in which α is a fixed positive dimensionless index and τ_α is a fixed timescale, which seen to be specifiable in terms of the corresponding value of the anthropomorphism timescale (50) by

$$\tau_\alpha = (1 + \alpha)\tau_A \,. \tag{64}$$

The all-or-nothing case in which $\bar{q}$ behaves as a Heaviside function, jumping discontinuously from 0 to 1 at an initial moment $t = t_i$ given by $t_i = t_1 - \tau_A$, is obtained as the limit $\alpha \to \infty$. The opposite extreme case, $\alpha = 0$,

35

corresponds to the smooth limit for which the relevant solution to (63) will be of exponential form

$$\bar{\mathsf{q}} = \exp\left\{\frac{t - t_1}{\tau_A}\right\} . \tag{65}$$

Between these extremes, in the generic case $\alpha > 0$, the relevant solution will have the power law form

$$\bar{\mathsf{q}} = \left(\frac{t - t_i}{\tau_i}\right)^{1/\alpha} \tag{66}$$

in which t_i is the initial take-off time, and the total duration

$$\tau_i = t_1 - t_i \tag{67}$$

of the rise of $\bar{\mathsf{q}}$ from 0 to 1 will have the finite value

$$\tau_i = \frac{\tau_\alpha}{\alpha} = \left(1 + \frac{1}{\alpha}\right)\tau_A . \tag{68}$$

In cases for which the index is in the high (hard) range, $\alpha > 1$, these models represent what is describable as a sudden take-off, as exemplified in Figure 3 by the case $\alpha = 2$. On the other hand, as shown in Figure 4, in cases for which the index is in the low (soft) range, $\alpha \leq 1$, the gradient $\dot{\bar{\mathsf{q}}}$ remains finite, albeit with a jerk in the marginal case of the simple linear model, with $\alpha = 1$.

In view of the presumption that the anthropic quotient should (like ordinary intelligence) be loosely correlated with brain size, it is instructive to compare the possibilities illustrated in Figures 3 and 4 with palaeontological evidence [40] of the steady rise of cranial capacity – from the level characterising apes such as gorillas and chimpanzees to the level characterising modern homo sapiens – during the period since the hominid branch-off time t_0 and particularly during the last couple of million years (which as remarked above, is about the shortest possible time for neo-Darwinian evolution to have brought about such radical change) during which most of that cranial expansion seems to have occurred, after the branch-off of the genus homo from the (subsequently extinct) genus australopithecus. This important bifurcation appears to have occurred at a rather well defined moment that is identifiable with the initial time t_i of the linear alpha model specified by

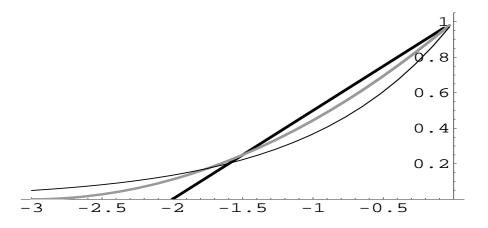$$\alpha = 1, \qquad \tau_A \simeq 1\,\mathrm{Myr}, \qquad \Rightarrow \qquad \tau_i \simeq 2\mathrm{Myr} . \tag{69}$$

Figure 4: Examples of softer (low α) models for evolution of anthropic quotient $\bar{q}$ as a function of time, again in units for which the anthropomorphism timescale τ_A (measuring the area under the curve) is set to one. The linear case $\alpha = 1$ is indicated by a heavy dark line. The more gradual (quadratic) take-off case $\alpha = 1/2$ is indicated by a pale line. The smooth exponential limit case, $\alpha = 0$, is indicated by a thin dark line.

Since it satisfies the condition $\tau_i < \tau_1$ for the value $\bar{q}_0$ of $\bar{q}$ at the branch-off time t_0 to vanish, this model is evidently consistent with the hominid solitude hypothesis. It can be seen from Figure 5 that this particular model nicely fits what may be referred to as the linear excess conjecture, to the effect that that q is proportional to the amount by which the brain volume exceeds a threshold roughly at the level exemplified by modern apes such as gorillas and chimpanzees.

Such a linear excess conjecture is however compatible also with other softer alpha models, because (as has been emphasised by Holloway [41]) the paleological evidence is far too scrappy to exclude the eventuality that cranial expansion had a much earlier and gentler take-off. The simplest such possibility is that of the smooth exponential limit model, characterised by

$$\alpha = 0 \, , \qquad \tau_A \simeq 3 \, \mathrm{Myr} \, , \qquad \Rightarrow \qquad \bar{q}_0 \simeq \exp\{-2\} \, , \qquad (70)$$

which is evidently incompatible with the hominid solitude hypothesis, because the ensuing value, $\bar{q}_0 \simeq 0.135$, of the mean anthropic quotient at the hominid branch-off time is not entirely negligible.

The foregoing reasonning has boiled down the issue of the validity of the hominid solitude hypothesis to the question of whether the piecewise linear

model (69) is more plausible than the smooth model (70), but the outcome remains inconclusive. The rather larger value of τ_A in (70) is favoured by the estimate (61) but only weakly, as the underlying theoretical considerations are of a crudely approximate nature. The meagre palaeological evidence seems to favour (69), but there are substantial gaps that might be filled by missing links, which could tip the balance the other way. Future archaeological discoveries may conceivably be able to settle the issue.

11. Anthropic status of other animals.

The relatively recent and sudden onset of the very rapid and spectacular cranial expansion process shown in Figure 5 – after a hundred million years or so of mamalian evolution (and parallel avian evolution) during which brain expansion was much slower and less systematic – suggests to me that whatever brought it about is likely to have been that last of what I have called the "hard steps" [1, 8, 9] in our evolution, meaning steps that were *a priori* unlikely to have occurred within the time available at our terrestrial site, so that their actual occurrence here makes planet Earth an exceptional case within the general category of biologically favorable environments in the universe.

It is noteworthy that the hominid branch-off value obtained for the anthropic quotient from the the model (70) has an order of magnitude, $\bar{q} \approx 10^{-1}$, that is about the maximum that could plausibly be attributed to non-hominid apes without violating the anthropic finitude requirement; if it is supposed that the total ape population would have had at least three times the value (59) of the hominid subset, and that they would have been around for at least ten million years which is 3 times as long as the anthropomorphism timescale (61), so that their total anthropic measure would have exceeded that of the hominids unless their average anthropic quotient was lower by a factor of at least 3×3.

If the hominid solitude hypothesis is false, the question arises of whether, as well as apes, there are other "sentient" animals to which non-negligible anthropic weighting should be attributed. It is however rather hard to see any plausible way of going beyond the hominid branch to the characterision of some more extended category of animals to which a non-negligible anthropic quotient might be allocated, without greatly exceeding the amount reasonably allowable by finitude argument discussed above. According to the reasonning presented in Section 3, the presumption that our "privileged" human status was not improbable *a priori* will entail an anthropic finitude
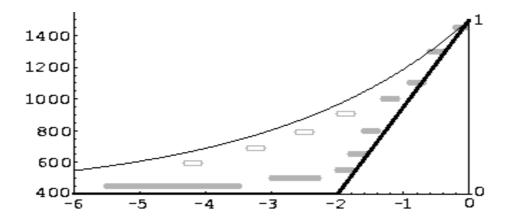
Figure 5: Plot against time in Myr of anthropic quotient $\bar{q}$ for the piecewise linear model (69) (heavy dark line) and for the exponential model (70) (thin dark line), as compared with cranial capacity in cm^3 beyond a baseline at 400 cm^3 (typical of modern chimpanzee) for the brainiest known hominid species at each epoch. Available data [41] for the latter are shown by thick pale horizontal segments: the first two represent the anthropithicine species afrensis and africanus; the others belong to the genus homo, successively representing the species robustus, habilis, ergaster, Java (archaic erectus), erectus, Heidelberg (archaic sapiens), and finally Neanderthal (whose record brain size is unsurpassed even by ours). The model (69) provides a good match to the data, which seems to indicate the occurrence of a jerk, 2 million years ago, when the genus homo suddenly branched off from the genus astralopithecus. That jerk may however be an illusory artifact of the incompleteness of the data: it is quite conceivable that between 2 and 4 million years ago there were other (still missing) link populations whose fossils would – if discovered – provide more definitive data lying closer to the smooth curve of model (70), as hypothetically suggested by the hollow horizontal segments in the plot.

requirement to the effect that that the total anthropic measure $\mathcal{A}$ of all terrestrial animals – and hence a fortiori of any subset of them – should not greatly exceed the limit

$$\mathcal{A} \lesssim \mathcal{A}_2 \,, \tag{71}$$

in which it is to be recalled that $\mathcal{A}_2$ is the measure of the human past, which is not very large (greater only by a factor of about 5) compared with the measure $\mathcal{A}_\star$ of the lives of the witnesses of According to the reasonning in the preceeding sections, this condition is marginally satisfied just by the extinct hominids, whose measure $\mathcal{A}_1$ is obtainable from (52) as $N_1 \tau_A$ with N_1 given by (59) and τ_A given by (61). For some more extensive population of N animals with average anthropic quotient $\bar{\mathsf{q}}$ over some timescale τ the corresponding measure will be

$$\mathcal{A} \approx \bar{\mathsf{q}} N \tau \tag{72}$$

so the condition (71) will be expressible as

$$\bar{\mathsf{q}} \lesssim \frac{N_1 \tau_A}{N \tau} \,. \tag{73}$$

The use of this formula was illustrated above in the case of apes, for which the conclusion $\bar{\mathsf{q}} \lesssim 1/9$ is obtainable from the rather conservative suppositions $N/N_1 > 3$ and $\tau/\tau_A > 3$.

As a criterion for membership of a population with a not entirely negligible anthropic quotient, a presumably necessary if not sufficient condition would be to have a brain size at least comparable with that of apes. This qualification would include many kinds of large herbivore (such as deer and buffalo) that have been present with global populations of hundreds of millions over many tens of millions of years, which gives $N/N_1 \gtrsim 10^2$ and $\tau/\tau_A \gtrsim 10$. This means that, to satisfy the anthropic finitude condition (71), the typical anthropic quotient q of a large animal of that kind cannot be much more that a tenth of a percent, $\bar{\mathsf{q}} \lesssim 10^{-3}$.

A less negligibly small value of q would however be conceivable for intelligent mammals of a more exclusive category. A plausible possibilities – suggested by our familiarity with domestic cats and dogs – is that of large carnivorous predators. This would include felines, as exemplified by lions in hot countries, canines, as exemplified wolves in temperate countries, and of course dolphins in the sea. However, as the combined population of such

carnivores could not have been much less than ten million over tens of millions of years, which gives $N/N_1 \gtrsim 10$ and again $\tau/\tau_A > 10$, the analogous application via (73) of the anthopic finitude argument tells us that the typical anthropic quotient for one of these intelligent (and potentially friendly) carnivores can still not be much more that one percent, $\bar{q} \lesssim 10^{-2}$.

With respect to cats – which are notoriously autistic – this conclusion may not be so hard to accept, but (if the present author is representative) people fond of dogs will find it counterintuitive that their anthropic quotient – interpreted as a comparitive measure of sentient perception – should be so low, despite the fact that these animals have a rather high intelligence according to many practical problem solving criteria [42]. It is however to be remarked that the "intelligence" of "dumb" animals would indeed be found to be zero if measured by the language dependent tests used for the evaluation of the rather rigourously defined kind of intelligence quotient that has been specifically developed (from the concept of mental age) for human children.

The foregoing conclusion that animals outside the hominid subfamily are unlikely to have at more than extremely small anthropic quotient, $q \ll 1$, can perhaps be accounted for most simply, in the sense of Ockham's razor, by the hominid solitude hypothesis, which would disqualify them from having any anthropic measure at all. A weaker conclusion, to the effect that such a disqualification should indeed apply to very small animals, such as ants, has already been drawn using reasonning akin to that employed here by Standish [43], who did not however allow for the possibility of a fractional anthropic quotion, but took an all or nothing position, to the effect that an animal is either "conscious" or not. It is to be noted that, like many other authors, Standish uses the term "conscious" for what I prefer to qualify as "sentient", to avoid the confusion that arises from the use of the word "conscious" to describe the kind of state that can be turned off and on using anesthetics, not only by medical practitioners in the case of humans, but also by vetinarians in the case of other animals – presumably including ants – whether or not they are "sentient" in the Bentham sense.

The reason why Standish was not able to extend his negative conclusion to animals much larger than ants was that he worked in terms of a privileged class defined in terms of the masses of the individuals involved, which meant lumping humans in, not just with elephants and mammoths, of which there used to be a lot, but also with far more numerous creatures such as antelope and deer. That contrasts with the present approach, in which the relevant priviledged subclass class – with measure as given roughly by (38) – has

41

been defined much more exclusively to consist, not even of all humans, but only those belonging to our present technically "advanced" global civilisation (beginning about the time designated above as t_2).

The underlying notion of "progress" has come to be widely regarded as "politically incorrect" after having been explicitly mocked by Gould in the openning chapter of his *Wonderful Life* [44]. More particularly, the present kind of anthropic approach – considering ourselves as a privileged subclass – has been implicitly criticised by Dawkins in his introduction to *The Ancestor's Tale* [17] where it is underlined that "if elepants could write history" they too would have considered themselves to be the privileged target class towards which evolution was aiming. However that kind of criticism misses an essential point that is emphasised in the discussion by Standish [43] of the significance (if any) of finding himself to be (like the present author) from Australia rather than a much more populous country like China. Whereas one should not be surprised to find oneself in a small subclass that (as in this example) could not have been singled out in advance, the essential point is that one can indeed draw meaningful Bayesian conclusions if one finds oneself in a subclass that is distinguished not just subjectively (post facto) but objectively.

The objectively privileged subclass on which the present analysis is centered can be characterised *a priori* by its mastery of technology – particularly that of information processing, including the writing of history. The accessory fact that, unlike elephants, we use fingers rather that a prehensile trunk, is merely an interesting incidental feature, not a defining property of the privilege in question. It is proverbial that if pigs had wings they would fly, and similarly if history really had been written by elephants they would indeed have constituted a privileged class of the relevant kind. However that is not what has actually happenned (in our particular Everett chanel [10]) on this particular planet. On the contrary, the upshot of this work is that even elephants (not just ants) are unlikely to have the high degree of sentience – as measured by anthropic quotient – that characterises not only the privileged class of members of our technologically advanced civilisation, but also the uncivilised human "savages" (whether or not they were "noble" in the sense of Rousseau) who were our immediate ancestors, as well as people of the earlier species of homo from whom we are more distantly descended.

12. Conclusions.

The purport of the anthropic principle (as I understand it) is that the *a priori* probability of finding oneself to exist, in the Cartesian sense, should be proportional to the corresponding amount of "thinking", in the Benthamite sense of sentient perception rather than intelligence. (It is scientifically indispensible to have some *a priori* probability ansatz, but other conceivable versions of anthropic principles might prescribe other ways of doing this.) The main issue addressed in the present work is whether, as humans, we are now alone on Earth, in the sense of the hominid solitude hypothesis, which would have it that the only other terrestrial species qualifying – as sentient beings with ordinary (mortal) "souls" – for such anthropic measure are exinct hominids (of the genus homo and perhaps also the genus australopithecus).

It is shown here that there is significant, though by no means conclusive, evidence in favour of this solitude hypothesis, and that even if it is false the anthropic quotient of other (non-hominid) terrestrial animals (meaning their anthropic measure rate, as calibrated by comparison with humans) must almost certainly be very small.

As a bi-product of this investigation, the past (and likely future) anthropic measure of our human species has been evaluated within the framework of the Foerster model, which describes the most recent – memetic – phase of hominid evolution (since the emergence of homo "sapiens") in terms of a coefficient that is shown here to be roughly derivable from neo-Darwinian theory of the earlier – genetic – phase of evolution. This accounts for the order of magnitude coincidence between the information content of the genome and the expected peak value $\approx 10^{10}$ that is likely to be reached by the global human population in the not so distant future.

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