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A theoretical treatment of memetic traits

using gene-meme, meme-meme and population equilibrium

Robert L. Shuler[1]
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[1]Shuler Research, former NASA
robert@shulerresearch.org

Abstract. **Background:** Conceived as a unit of lasting cultural (mostly vertical) trait transmission, memes now include transient horizontally transmitted fads. Memes may sometimes follow the logic of population genetics, e.g. learned birdsong, but not always over the diverse range found in human hosts. Much current work focuses on selection of memes rather than hosts. **Methods:** We analyze equilibrium between gene-meme and meme-meme competing propagators and consider whether a meme is linked to reproduction (e.g. vertical culture transmission), or not. We employ a genetic component and combined meme induced fitness components for hosts, while memes have replication factors to distinguish from what's good for the host (fitness). To anticipate future meme effects on population stability we use a Monte Carlo simulation roughly calibrated to the Industrial Revolution. **Results:** A basic effective calculus of memetic trait competition and interaction with genes is derived and analyzed. The transient nature of short term memes may be a defense against accumulation of deleterious memes. Horizontally transmitted (panmictic) memes with high spreading rate will often not equalize with a genetic trait, spreading outside of natural selection of the hosts, presenting a cumulative existential threat. Vertical transmission reduces replication rate and allows group selection against deleterious memes. Competing mutually exclusive memes contribute to inequality and altruism, but compete through adverse fitness since exclusivity assumes low conversion. **Conclusions:** The advantage of a portfolio of groups or species may not accrue to a single group. This analytical understanding elevates meme-risk to the level of a candidate solution to the so-called Fermi Paradox, as interstellar travel might require a planet wide group.

Keywords

Meme, memetic, culture, altruism, extinction, evolution, natural selection, Fermi Paradox

1. Introduction

The word "meme" to mean roughly "behaviorally transmitted trait" originates from Richard Dawkins' book *The Selfish Gene* appearing in 1976 [1], one year after E. O. Wilsons's *Sociobiology: The New Synthesis* [2]. The idea of socially transmitted behavior as culture, learning, fad or habit is thousands of years older, but the mid-1970s were a time of new understanding that a variety of behaviors were influenced by natural selection, and the basic idea seems to have been to consider non-genetic traits as entities undergoing propagation and natural selection. This paper is more concerned with how such dynamics affect host populations.

The idea was never precise, and Dawkins endorsed several extensions of it. Originally, as best one can gather from the historical record which is somewhat called into question by the many extensions, it was intended to be the smallest recognizable unit of cultural information, the building block of ideas, and an independent replicator subject to mutation and natural selection. [3]

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In the age of the Internet, "meme" came to be associated with a variety of transient phenomena that might last only days or even hours. These have been studied empirically with a view to eventually coming upon an analytical understanding through that route. Log normal distribution has been found for fast growing memes, while slower memes enjoy only linear popularity. [4]

Watching cat videos or similar fare we consider a behavior, or trait. The *videos themselves* are like baseballs or food, something used or consumed when expressing traits regarding entertainment or nutrition. Physical traits of biological species are genetic as expressed in a particular environment. If a trait is of any other kind (memetic), we define it as behavioral, and it should be a verb. Even if a meme induces hosts to alter their physicality, it is the behavior we consider to be the trait.

Models of fast spreading and fast dying memes often need to be complex and typically there is an explosive rise to some limit of popularity and then a slower but still rapid decay. [5] The nature of the spread followed by decay, occasional repetition of prior memes, perception of harm from many memes either active or passive, and instinctive use of words like viral and contagion by the public have led to serious use of epidemiological models to describe meme propagation. [6] Fast spreading-dying behaviors are often called fads. However, the media content which is the subject of some of these models spreads and dies much faster, and we are not treating it as a meme unless it is retained and influences behavior.

Australian philosopher Kim Sterelny emphasizing lasting cultural aspects distinguishes three mechanisms: (a) niche construction leading to group selection, (b) vertical flow of information from parents to children, and (c) replication and spread of memes. [7] He argues the first two are definitely important in establishing lasting change, but spread of memes only *might become* important.

The first two are what human evolution experts have been telling us for some time. The last must be considered against the similarity of spread to that of a pathogen, which implies some kind of harm that is expunged by an immune-like reaction. And as well, it can be considered against studies that find social media and attendant meme propagation to increase sub-group formation, isolation and polarization, such as their use in the delegitimization of 2016 US presidential candidates. [8] Loosely we can call this third category "Internet memes." These fast spreading ideas if given weight can sometimes cause revolutions, and in the pre-Internet era were more associated with words such as propaganda and ideology. *Making propaganda* we consider a meme. P*ropaganda itself* the BBC termed "viral misinformation" and noted 20% comes from celebrities but accounts for 69% of engagement. [9] Misinformation appeals when people don't get what they want.

In studying memes in connection with culture creation, Scott Atran concludes that "unlike in genetic replication, high-fidelity transmission of cultural information is the exception, not the rule." [10] A study comparing informational (truth, moral lesson) vs. emotional (disgust) factors in meme propagation found that greater disgust (ingestion of a contaminated substance) resulted in greater propagation. [11] These two findings do not inspire confidence in memetic transmission, especially Internet memes. To some extent non-local media generally and Internet memes particularly may be thought of as horizontal (or lateral) as opposed to vertical cultural transmission, exposing people to ideas outside their local society that they would not have encountered several centuries ago, much less thousands of years ago. But, as recently as 2019 it was reported that geography, even in the Internet age, is still important in transmission of Internet memes. [12]

Lynch and Baker concluded from an analysis of birdsong memes that increased variability in memetic transmission support "high levels of among-population differentiation . . . in spite of high levels of migration . . . [allowing] accumulation of new mutants in different populations before migration can disperse them." [13] One supposes increased migration along with faster meme-driven group formation will affect human populations, part of which Ross and Rivers already found. [8]

At least one mathematical model of memetics was proposed by Kendal and Laland in a short 2000 paper in the *Journal of Memetics*, now defunct, but the paper is available on the authors' website. [14] It uses concepts of dominance, susceptibility to invasion, and population frequency algebra reminiscent of population genetics. The authors even say, "We reject the argument that meaningful differences exist between memetics and the population genetics methods." The actual formulation appears to contain many considerations similar to, perhaps influenced by, the field of social learning. Social learning places a great deal of agency onto individuals, and we agree with its approach for social learning per se. But we find many meaningful differences between memetics and population genetics. While there are similarities in certain areas, the differences are key to understanding the subject.

In particular, we reserve the word "fitness" to describe the ordinary reproductive success potential of a meme host. The spread of the meme is called a replication factor, and includes a statistical average of the sort of individual preferences social learners might express in their choices. A fast spreading meme may reduce the fitness of its hosts, and this we explicitly model. Exactly how the meme is connected to ordinary reproductive fitness will determine the course of natural selection, not the replication ability of the meme alone. We find most prior treatments obscure the relation between genes and memes, and we wish to throw light on it, find results that are unobtainable with a population genetics approach, and characterize exactly when we might use population genetics with memes.

The goal of this paper is to establish a theoretical basis, if a modest one, for behaviorally transmitted traits. As far as we know, and as obvious as it is as a goal, this theoretical basis has only been done for specialized topics. It was wished for and anticipated in Susan Blackmore's *The Meme Machine* as recently as 1999. [15] Blackmore suggests memes are no longer inferior to genes and qualify as independent replicators, though they may be less well developed in evolutionary terms. She suggests selection pressure favored those that made good choices regarding who or what to imitate, and imitated intelligently.

A characteristic of memes we wish to specifically address is that they may be associated with reproduction of the physical meme carriers (hosts) through vertical cultural transmission, or their replication may be entirely separate from the reproduction of the carriers (Internet memes, for example). This separation of meme spreading from the reproduction of hosts causes unexpected results. Meme fitness as its own replicator is rather weakly linked to the fitness of the host as regards host replication – unless groups remain small and meme (culture) transmission is largely vertical, to offspring in the group.

Memes are not the first evolutionary experiment with lateral trait transmission. Bacteria are able to hand off genetic material independent of the reproductive process. Evolution largely suppressed this kind of lateral transmission between co-equal complex beings. It remains as viral pathogens and in rare cases an evolutionary step, such as the inclusion of mitochondria into eukaryotic cells, or the use of the Arc protein in mammalian memory which seems to be a repurposed retrovirus. [16] There is also similarity to microbiomes, though they are not usually considered a trait.

2. Approach

There is no concept of a "generation" with memes. As information they may never be completely destroyed. They may reside statically in the environment, also as information, when not actively influencing a host.

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Instead of meme fitness we define a ***meme replication factor*** R_M which is based on a ***time period T***. Depending on the speed of a meme's propagation, the time period could be a month, a year, and so forth, whatever is convenient. The replication factor is the number of new instantiations of the meme in a host created from each existing instantiation in a single period *T*. If propagation is allowed to run its full course, the period T can be variable, such as time until the next mutation. Usually in our case the host is a human, but it could be a computer, monkey, bird, or almost anything over which a meme can have influence. We assume there is some intrinsic replication rate based on the appeal and difficulty of transmission, and that is what we are trying to get at with the replication factor.

The ***population of hosts is P***, and the ***instantiations of the meme in P is*** P_M. Denoting the number of instantiations at the end of the period as P_M` and neglecting for the moment population change over the period we can write:

(1) $P_M \leq P$

(2) $P_M` = \text{Minimum} \{ P_M (1 + R_M) , P \}$

We will cease writing the "Minimum" constraint for brevity, though it continues to be implicit. It is evident that the meme does not *directly* have the power to increase or decrease population P. It must act through genetic traits to accomplish that.

Our first step will therefore be to explore the relation between genes and memes. For genes we find it not necessary for the comparison to use the full capability of population genetics. We examine only one allele for a dominant trait and count ***trait instantiations*** P_G within hosts as the relevant factor of interest. Thus we have a constraint similar to (1) on P_G:

(3) $P_G \leq P$

We assume an ***average population growth rate of*** R_P, prior to meme introduction and including mortality if needed, and to be defined over time interval *T* rather than generationally, thus we have:

(4) $P` = P (1 + R_P)$

This brings us to the question of fitness. For our gene-meme comparison, we need to set up a competition. We thus assume the genetic trait of interest has a poitive beneficial fitness. Here again we must adjust from a general time base, in which fitness is usually defined, to the period time base. Then we let F_G ***be the excess instantiations of the genetic trait of interest***, over and above R_P, in one period.

For convenience we let average population growth be zero: $R_P=0$ so that $1+F_G$ ***is the relative per period increase in the genetic trait***. What's important is not that the population is in equilibrium with its environment, but that we are only interested in the relative changes caused by the gene of interest, and the invading meme. The spread of the genetic trait in one period is then given by:

(5) $P_G` = P_G (1 + F_G)$

$\Delta P_G = P_G` - P_G = F_G P_G$

The ***meme induced fitness*** *(of the host, not of the meme)* ***is assumed to be*** $-F_M$, with the minus sign explicit to remind us of its deleterious nature. This sets up a competition. Otherwise it would be beneficial for both the genetic trait of interest and the meme to spread among the whole population. We can now write (with the "minimum" function omitted for brevity):

(6) $P_M` = P_M (1 - F_M) (1 + R_M) = P_M (1 - F_M + R_M - F_M R_M)$

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Removing the second order term and writing for the change in meme host population:

(6a) $\Delta P_M \approx P_M (1 – F_M + R_M) – P_M = (– F_M + R_M) P_M$

These are not all new individuals. The $R_M P_M$ components are conversions. The $– F_M P_M$ term is a presumed loss of individuals if the induced fitness from the meme is deleterious.

3. Development

3.1 Panmictic Meme-Gene Equilibrium

There are two conditions for full equilibrium. First is population equilibrium, in which the number of individuals does not change. Physical ΔP is set to zero and conversions are ignored:

(7a) $F_G P_G = F_M P_M$

The second equilibrium condition is cessation of spread of the meme, which is realized when the meme hosts die as fast as the meme infects (converts) new ones:

(7b) $R_M P_M = F_M P_M$

Population equilibrium (7a) is achieved when the population growth from the new gene is offset by the population loss from the deleterious meme. If there are no factors that oppose the meme, its condition for spreading is $R_M > F_M$. If it spreads faster than it kills, it will reach 100% penetration. It is difficult to prevent the spread (i.e. awareness) of memes. Later we will consider meme defenses including dominance and exclusivity, but undefended memes spread as indicated.

If population equilibrium is obtained *before* the meme achieves 100% penetration, *and* panmictic meme transmission allows it to reach the entire host population, *and* the meme induced fitness for the host is deleterious in a population fitness sense, *and* if no other factors change the intrinsic population growth factors (recall we assumed it was initially in equilibrium), *then* the population theoretically declines until it is extinct. There is nothing selection alone can do to stop it. Evolution can stop it by introducing a new gene or meme with sufficiently positive fitness boost, but this does not eradicate the meme. It becomes memetic load, like genetic load.

We call this ***meme extinction risk***, the risk of extinction from deleterious memes whose propagation is not checked by natural selection, because they spread faster than their hosts die. Further it is cumulative. ***A negative balance in incoming meme induced fitness will eventually cause extinction***. We will discuss counter strategies below.

Notice the presence of conditions which make problems hard to detect. It's hard to identify the source because correlations are displaced in time. Symptoms are relieved when the population is in equilibrium. But as the meme spreads equilibrium is again lost. There is a delay built into the system which confounds most kinds of control loops, natural or created by the species.

3.2 Vertical Transmission of Memes

Instead of panmictic transmission of the meme, we now assume vertical transmission along with reproduction, confined to a small cultural group. After *N* periods children mature and some number mate into out groups. They can carry the meme with them and infect new groups. Otherwise there is little contact between groups and no meme transmission.

This condition does not change panmictic mating for gene transmission. It reduces meme transmission approximately by some parameter of the order of *N*. We assume the meme replication rate is applicable only during one of N periods. Then we have new equilibrium conditions:

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(8) $P_M R_M / N = F_M P_M$

Aside from the immediate benefit of reducing the meme replication rate by an order of magnitude, group selection comes into play. A fast spreading meme will easily establish itself in a small group, and if deleterious, the performance of that group will suffer. They may lose a battle, or be ostracized from mating, and the meme may not spread at all outside the group. These chance events are difficult to quantify and model, so we leave it at equation (8).

3.3 Defensive Conditions

It seems possible nature might generate several meme-capable species before producing one with adequate defense against harmful memes. Now we examine some defensive conditions.

The use of vertical culture transmission we have already discussed. This is a meme itself. It is therefore dangerous itself. Modifications to it may well be deleterious. A possible modification is to hold ideas from other cultures under suspicion until those cultures have exhibited superior fitness characteristics. This approach also inhibits the spread of useful ideas, and is discriminatory. A great many people in the world advocate abandoning suspicion of vertical culture.

There is selective pressure in the vertical culture system to increase mating time, at least with respect to modulating meme transmission. In the U.S. average age of marriage has increased from 20 to 27 years since 1950. [17] While we do not posit there has been time for this to evolve from the selective pressure we postulate, it certainly might confer an advantage precisely in the age in which information and Internet memes increased their spread. Marriage age has other constraining factors. In 1985 marriages beyond the late 20s were less stable due to inadequate role performance. [18] The Institute for Family Studies reports stability now increases into the 30s. [19]

Increased generation time can be used to impart more complex cultural memes which might possibly have less deleterious or even positive fitness. The closest thing we found was parental investment, which by hypothesis benefits fitness of the offspring. Studies of parental investment are often oriented toward explaining mating patters and sexual behavior and which parent provides the care rather than focusing on offspring success [20-22] including modern game theory approaches which predict lower likelihood for mutually cooperative relationships based on unequal cost factors, although they do address reproductive fitness. [23]

The above are passive defenses. Memes or meme hosts are not specifically attacked. It should be possible to increase efficiency further by positing a more specific defense. If the defense is generally against all memes, it amounts to a retreat from being a meme-capable species. More likely it would be selective. We posit several types of selective defense.

Resistance against marrying into groups with *extremely different and unproven* culture, essentially an in-group vs. out-group defense, might either increase the time N required to export the meme, or reduce the export rate, or both. For example, after an out-group has stood for some time and its fitness is observed to remain positive, as high as or even higher than the general population, then marriage into the group or accepting mates from it might be held in higher desirability. Even without vertical confinement, this sort of “test of time” fitness evaluation might be a useful screen against fast spreading memes, by reducing their spreading rate until the fitness is evaluated. This might remove the most dangerous memes. But memes with delayed effects would still be spread. The spread of negative emotional content memes [11] might be as cautionary tales.

Another selective criterion might be to *limit the lifetime of non-vertically spread memes*. In this case we are positing directly the transient behavior of Internet memes. It also could apply to vertical memes in the intergroup marriage export phase, but on an overall slower time scale. Limited lifetime memes would overlap less, and have much lower cumulative effect. Perhaps faster spreading memes would have the shortest lives. Perhaps boredom is an instinct developed in part as meme defense.

In either case, it is implicit there is some mechanism for identifying whether a meme (behavior, practice, etc.) is part of the accepted repertoire, or still under suspicion. A simple estimate of the *proportion of adopters* is an example of such a means. Children would be able to judge whether to learn (adopt) a meme according to its level of acceptance, so that vertical transmission is not unduly inhibited by the defense. There are some problems with this simplistic view, however, so we only mention it in passing and leave it to the reader to evaluate whether it is worth further investigation. For example, it appears similar to the "hundredth monkey syndrome" which has been mostly discredited. [24]

An interesting possibility is *occasional adaptive resets*. Selection is on length of accumulation and modification. Long term memes are assumed to be more useful than short term memes, but still after a long time negative modifications may pose a risk. Religions change every few thousand years. Civilization, itself a complex of memes, rarely has lasted longer than a thousand years. However, without a competing meme species to study, it is problematic to say whether a civilization collapses from the negative meme accumulation, or if the species has an evolution-selected tendency to reset before the entire species is swept along in meme-driven extinction.

3.4 Meme-Meme Competition Background

Nogueras and Cotta studied meme propagation in multimemetic algorithms, comparing panmictic and other network (and therefore propagation) topologies, and also comparing good and bad memes. [25] They conclude that the "increased takeover time" associated with the non-panmictic topologies are "essential for improving the chances for good memes to express themselves in the population by improving their hosts," and that performance "memes are more successful in a spatially structured MMA (multimemetic algorithm), rather than a panmictic MMA, and the performance of the former is significantly better." We can make an informed speculation how this relates to the present work. We established above that often the meme effect on hosts that operates through influence on reproductive fitness is slow compared to meme replication. We were viewing it in the negative, but suppose the meme is beneficial, and competes with bad memes (which harm host fitness). Then we arrive at Nogueras and Cotta's result.

A topology which limits spread opportunities reduces all replication (R_M) values relative to fitness values (F_M or F_G). As long as the meme has not saturated the population, the diversity of genes in hosts not infected with the meme may still outcompete it using the population equilibrium condition (7a). As long as $F_G P_G > F_M P_M$, and population P_G is relatively separate from P_M, group selection can remove P_M.

Earlier we mentioned an empirical study of human Internet memes that concluded geography was still important. [12] It is not clear at the moment how evolutionary pressure might have brought this about. Perhaps it is simply a holdover or from unknown causes. But it would seem to be beneficial. If globalism were to cause a panmictic spread of memes, our analysis as well as the Nogueras and Cotta study suggest that more aggressive meme defenses would be needed.

The propagation of two viral-like memes in a network is studied by Wei, et. al. using a susceptible-infected-susceptible (SIS) model extended to handle two infectious agents. [26] The contagion strength of each meme along with a probability per unit time of self-healing of an infected node are defined as basic propagation parameters. Propagation on two separate networks is compared with

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cross contamination. This might be compared to our vertical and horizontal propagation.

In an earlier study Wei, et. al. apply their methods to study competition of true and false information rumors on two networks such as Facebook and Twitter, simulated by a composite network (much as the first study). [27] It is perhaps clearer in this study how the infection model studies of meme competition ultimately are decoupled from genes and the fitness of population members. The author further suspects that analysis of social systems without consideration of natural selection and how the system will change is subject to the following fundamental fault. The analysis may be correct at the current time. But natural selection may change conditions and behavior, and the analysis may not have lasting value.

Much of the remaining literature on meme competition derives various results from the idea of competition for limited resources on information platforms, or attention from the minds of potential hosts. For example Weng et. al. used competition for limited individual and collective attention to find support for “heterogeneity in the popularity and persistence of memes . . . without the need to assume different intrinsic values among ideas.” [28] From limited user attention Gleeson et. al. derived heavy-tailed distributions of meme popularity. [29] More recently Spitzberg attempted a comprehensive model based on competition “at multiple levels to occupy information niches.” [30]

This type of model satisfies the urge to understand people’s use of the Internet. But few memes of the type studied by these models are semi-permanently established with a lasting role in human culture. They are assumed to be transitory. We have suggested based on our analysis that quite possibly Internet memes have these properties precisely because of the extinction risk they pose if they were long lasting memes. The limited human attention span, in that view, is the agent for the risk motive and not the *causus primus*. People may have limited attention because the material is of limited or negative value, or by limiting attention they limit their risk exposure.

The agency aspect of social learning emphasizes Atran’s thesis that processing by a multimodular mind (essentially one created by evolution) reduces the fidelity of transmission and creates constant, rapid mutation, especially when processed by children. [10] However, systematic study supports the idea that children irrationally mimic their parents’ choices (for example in food). [31] On the other hand, in a social learning study Wisdom et. al. show that “participants combined multiple sources of information to guide learning, including payoffs of peers’ solutions, popularity of solution elements among peers, similarity of peers’ solutions to their own, and relative payoffs from individual exploration.” [32] The study finds that “when peers’ solutions can be effectively compared, imitation . . . can also facilitate propagation of good solutions . . .,” a good meme defense.

Social learning can also be non-rational in a strict sense. A long standing puzzle is human behavior in an ultimatum game in which one person proposes how to divide a pool of money, and the other decides to accept, or reject in which case no one gets anything. Game theorists claim it is rational to accept very small portions, but actual human participants rarely settle for less than 40%, perceiving less is unfair. Boyu Zhang shows how social learning in an environment in which there are strategies and mutations (memes) contributes to this real world outcome. [33]

Social learning is often associated with the evolution of cooperation in games such as Prisoner’s Dilemma and public goods. While it was initially assumed to be a primary enabler of the evolution of cooperation, Matthew Burton-Chellew and associates have been showing that as people learn about game theory they decrease their cooperation, and social learning has a specific role in this. [34-35] The author’s own work demonstrates that this is not misguided, as excess cooperation by the poor with the wealthy leads to a worsening of their situation and an increase in wealth inequality. [36] Further, small changes in inequality in a couple of population deciles can empirically ac-

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count for a national average motorway death rate difference of a factor of three. [37]

3.6 Meme Equilibrium

Equilibrium for short term memes would have to do with channel saturation and has been investigated adequately in the literature we cited. We first consider long term non-interacting memes. One does not forbid or encourage the other, etc., and they may both exist in a population as long as they or their combination do not cause extinction, and both will approach 100% saturation if not opposed by a meme defense. The only case not already considered is when both memes are expressed in the same individual. How do their properties combine? Under the assumption of no direct interaction, for small replication and fitness values, a linear approximation to their combination should suffice. Anything else constitutes interaction.

We will attempt to find the equilibrium conditions under which meme-driven growth equalizes with population growth. To this end we use the concepts from analysis of market volatility and individual equity vs. market returns: [38, chapters 1 and 3]

a) In a geometric progression, geometric positive increments must be greater than negative increments to achieve net zero return (e.g. 10% down is balanced by 11.1% up, and as the deviation increases the required difference in up/down increases). Fitness is a geometric increment so this condition applies to populations of meme hosts.

b) In a portfolio of investments (in our case a portfolio of species) components of which yield geometric returns (as above), the average value can be obtained. But if randomly selecting just one element of the portfolio (one species), the median value is the expected return. Often with geometric progression or high volatility the median is less than the average.

Memes potentially increase volatility. We might in the future switch from carbon to silicon based life (aka artificial intelligence) after 10,000 years of strongly meme-based civilization, whereas the switch from prokaryotic to eukaryotic cell structure took 1 to 1.5 billion years. [39]

We will use a spreadsheet model to perform a Monte Carlo simulation of various meme profiles, varying in their volatility (magnitude of induced fitness deviations, which we call dispersion) and central bias (average of the deviations, which we call bias). Fifty populations will be simulated as they absorb 1000 memes randomly generated by selection of one of two values of a binomial with the desired dispersion and bias. The fitness values are not for a specific time period, but the cumulative population change attributable to each meme. We model the Industrial Revolution as a multi-meme event, and see if any fit and how they vary. The results are shown in Table 1.

Table 1. Various fits of Monte Carlo simulation to 800% world population increase since start of Industrial Revolution

F_M up	F_M down	Bias	Dispersion	Max	Min	StdDev	Median	Average
5.37%	-4.63%	0.37%	5.00%	23096%	64%	4018%	864%	2265%
3.26%	-2.74%	0.26%	3.00%	6563%	151%	1262%	859%	1295%
2.23%	-1.77%	0.23%	2.00%	2809%	256%	448%	783%	856%
1.72%	-1.28%	0.22%	1.50%	2036%	236%	390%	770%	837%
1.22%	-0.78%	0.22%	1.00%	1383%	386%	248%	807%	853%
0.71%	-0.29%	0.21%	0.50%	1075%	551%	117%	805%	789%
0.46%	-0.04%	0.21%	0.25%	1022%	686%	70%	806%	821%
0.33%	0.08%	0.21%	0.13%	847%	694%	29%	780%	782%
0.26%	0.16%	0.21%	0.05%	845%	784%	13%	814%	814%
0.22%	0.20%	0.21%	0.01%	820%	810%	2%	815%	815%

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3.7 Discussion of Meme Equilibrium

The number of long term memes since the start of the Industrial Revolution depends on how one categorizes and counts them. For low-dispersion influenced fitness, there is a certain amount of scaling possible. The shaded green area in Table 1 contains the cases the author thinks more likely. For dispersions below 1%, median and average values converge and standard deviation drops. Low dispersion cases presumably would correspond to biological evolution if it is characterized by small changes. There is no real reason to believe meme fitness changes are small. However, the standard deviations for dispersions of 2% and higher are quite large. Do we really believe there is a good chance the world population might in 2020 be 1.6 billion (barely more than before the industrial revolution) or 33 billion (likely not sustainable with present technology)? Thus the choice of the green shaded area as most likely was made largely on the basis of getting the standard deviation reasonable. This suggests the upward bias of meme evolution in humans in the last 250 years is around 0.2% fitness improvement per meme if it is (rather arbitrarily) divided into about 1000 memes. If one believes there were more memes, the value of each is proportionally lower. The function is nearly linear for these small change rates. The binomial dispersion, that is, the variance from meme to meme on average, is almost certainly less than 1.5% and more than 0.1%. Values below 0.5% are relatively safe, i.e. reasonable standard deviations.

In biology one expects a *negative* bias in mutations. How then does life survive? From a few big positive mutations? Probably not. Life is divided into organisms (collections of cells) and species (collections of inter-mating individuals) in a sort of portfolio approach. Individuals die and species are expected to fail eventually, removing the worst mutations, but the portfolio keeps growing. Evidence either from the portfolio (all life) or a still-existing species will always show a positive median mutation benefit, which in statistics is called survivor bias.

Humanity has plans and desires to greatly increase the upward bias. Our risk-based derivation actually can be inferred in both directions. If the upward bias is increased, that means bigger chances are taken. There are likely big successes and big failures. If, for example, the upward bias is doubled to over 0.4%, the dispersion will likely be above 5% and the standard deviation will mean that most of our future probabilities will contain relatively more dystopian scenarios.

3.8 Special Cases of Non-Linear Meme Interaction Can Emulate Genetics

A simple case of meme-meme interaction is suppression of one of the memes. Morality and compassion memes demand suppression of selfish impulses. Fairness memes demand we treat others as we would like to be treated, and we have seen that such a fairness meme apparently overrides rational application of game theory in the ultimatum game.

A second, perhaps less likely but not completely discountable reason for suppression, may be the source of a meme. It may come from a culture that is under domination. It may come from a parent or other caregiver who is not the favorite of the child, and be contaminated by rebellion.

In the vertical transmission of memes, a child receives cultural memes primarily from two parents, and secondarily from other members of the vertical culture group. Much of the time those other members will be associated with one parent or the other, for example family members or business and trade associates. So if memes are not expressed evenly in the society, that is if all persons do not express all the same memes all the time, then the child essentially gets two sets of memes, a mother set and father set.

Many memes are mutually exclusive to some degree because of time and energy costs. For example, a hunter may not also be a caregiver, at least not primarily. A farmer may not also be a doctor or lawyer because he or she is often unavailable, out working in a remote field.

It is possible then to have a situation of dominant and recessive memes, either in the manner of Mendelian genetics where the dominance and recessive qualities come from within the memes naturally, or because they are imposed by external circumstance and influence.

Observable traits can also be influenced by many memes. For example honesty may be influenced by ethical, religious, rational and cooperation memes. This sounds like a continuous trait. So it might actually be appropriate to use some of the techniques of conventional population genetics. Possibly similar considerations influenced Kendal and Laland. [14]

3.9 Meme Competition Analyses

We now consider memes that are hostile to each other, and express this by actively reducing the fitness of the hosts of enemy memes and/or their meme's replication factor. This reduction comes at a cost to the meme hosts enforcing it, in a manner similar to punishment costs in cooperation and the theory of evolutionary games. The reason in that case is to punish non-cooperative defectors. The punishment cost is offset by greater game rewards due to cooperation in games such as Prisoner's Dilemma and public goods games.

In our case we presume similar action arises to defend against the negative potential of invading memes. However, though that is an existential threat, it provides no automatic reservoir of increased payoff with which to fund the enforcement action. That could lead to domination and exploitation strategies being substituted for extermination and re-education. But in our analysis we will only consider the relative survival of the competing memes and their hosts.

Partly to simplify our analysis, we assume the competing memes, *M1* and *M2*, cannot both exist in the same host. The hosts will choose sides for this type of combative meme.

Let K_1 be a reduction in fitness imposed on *M1* by *M2*, C_2 be the fitness costs incurred by *M2* in doing so, and vice versa for K_2 and C_1. Further, let the actual fitness reduction/cost be proportional to the ratio of host populations, and let the reductions apply equally to replication factors and induced fitness. The modification factors are then $K_1C_1P_{M1}/P$ and $K_2C_2P_{M2}/P$. Note that the total population is the *relevant* population. Perhaps it is only local population for a tribal dispute. Only in world campaigns is it the world population.

Now we rewrite the gene-meme equilibrium conditions (7a) and (7b) for ***two memes*** by substituting $F_{M1}P_{M1}$ for the genetic term F_GP_G:

(9a) $F_{M1}P_{M1} = F_{M2}P_{M2}$

(9b) $R_{M1}P_{M1} = F_{M1}P_{M1}$

And add the fitness reductions/costs:

(10a) $F_{M1}P_{M1}^2 K_1C_1/P = F_{M2}P_{M2}^2 K_2C_2/P \Rightarrow F_{M1}P_{M1} = F_{M2}P_{M2} (P_{M2}/P_{M1}) (K_2C_2/ K_1C_1)$

(10b) $R_{M1}P_{M1}^2 K_1C_1/P = F_{M1}P_{M1}^2 K_1C_1/P \Rightarrow R_{M1}P_{M1} = F_{M1}P_{M1}$

There is a third equation for spreading equilibrium of *M2* not shown. The spreading condition does not appear to be changed since we elected to apply the same reduction factor to replication and induced fitness. If one wishes to change this assumption, then (10b) will change.

Equation (10a) has been rearranged to look like (9a) with all the modifications on one side. Total population *P* divides out entirely (though not necessarily if the parties face asymmetric external relevant populations). The meme host population ratio reflects an advantage to the larger meme host population. The ratio of fitness reductions/costs reflect tactical, strategic and raw physical or technical ability advantages.

If the sides are nearly balanced, the war is a dead cost with no benefit.

If significantly unbalanced and large fitness reductions can be inflicted to make a short war, then game theory logic dictates the side with advantage compare the induced fitness reduction from allowing invasion of the other meme, to its costs in conducting the war. For example, P_{M2} would incur fitness reduction F_{M1} if they allow *M1* to invade. They would incur this indefinitely. If they wage war they incur $(P_{M2}/P_{M1})\ (K_2C_2/\ K_1C_1)$ for a limited time. Let's consider two cases:

a) If *M2*'s advantage is primarily population, they are already ahead and it may not take long to reduce the remaining P_{M1} to surrender (perhaps they will give up their meme or at least agree not to evangelize it). This is the case of conventional war by a major power.

b) If *M2*'s advantage is primarily ability to impose greater costs than they receive, the war will take a long time and they will not be able to control its termination date. This is a situation of asymmetric war against a more numerous power. The objective is to be so annoying the more numerous power agrees to back off and not export its meme.

In both cases we consider that the result may stop short of extinction if agreements about meme spreading can be reached. This is theoretical. The author makes no claim that such agreements are achievable or enforceable. In the Cold War both sides aggressively exported their memes. When it ended, Russia did not cease as a major power, give up state control of major corporations, and in the long run did not cease expanding its hegemony. It quit selling communism.

Returning to the balanced situation, note that one can hide behind iron or bamboo or capitalist tariff/security curtains, but memes will eventually propagate anyway. If one side obtains a slight advantage, a credible threat of some version of war may persuade the other either to adopt the competing meme, if they can be persuaded it is not so deleterious, or mutual agreement may be reached for neither side to export their memes to the other side, along with agreements to manage population growth and resource consumption to avoid future conflict. This becomes a cooperation game, and there will be many "rounds" with cheating, punishment, and so forth. It is very difficult to enforce such an idea in a free society where individuals and corporations may wish to persist in exporting their memes.

While much of this may strike the reader as not new, it maps what is already well known into our model of memetic traits and their spread and interaction with population genetics. We have essentially claimed almost every non-genetic aspect of society other than resource holdings is some kind of meme. If a theory of memetics had not been able to reproduce these commonly understood generalities, it would be in trouble.

3.10 Special Cases – Inequality, Power, Truth and Altruism

In competing exclusive meme equilibrium, if we assume that most new converts will occur vertically among the newborn (not always true) then we can examine several interesting cases by looking at the population fitness factors. Rewriting (10a) for their ratio:

(11) $$F_{M1}/F_{M2} = (P_{M2}^2/P_{M1}^2)\ (K_2C_2/\ K_1C_1)$$

If equation (11) is nearly balanced then changes in imposed and incurred costs will govern. From this we conclude that opposing exclusive memes likely do not start out as exclusive. If they do, they would only gain traction when a well-established exclusive meme didn't exist or had de-

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clined for unrelated reasons. Non-exclusive memes are easily invaded by exclusive memes because they offer no resistance. Eventually random mutations will produce a competing exclusive meme. Losing memes would either vanish before effective memes that exclude them, or the stimulus to exclusion might "kick in" when some threshold of threat was met, either a sign of extreme exclusivity in the lesser populated meme, or threatening spreading rate. So we might expect to find one of the following cases for a pair of competing memes if at least one of them is exclusive of the other:

a) One meme dominates and the other either vanishes or exists below the threat threshold.

b) The memes exist in a near balance so that (11) is approximately satisfied.

The following discussion is limited to case (b), near balance, and observes the condition for changing the balance. The result of the change in fitness factors will be a change in meme host population, tipping the balance one way or the other.

WEALTH INEQUALITY: Consider a mutation *M1`* of *M1* which changes either incurred or imposed costs, but not necessarily both. We assume the variant, at least initially, is accepted as non-exclusive. It will freely propagate in the *M1* host population but not in *M2* as it is identified as *M1-type*. We might create a wealth accumulation meme within the general capitalism meme by using the idea of reducing the number of children in order to make each more wealthy. Then the wealthy version *M1`* incurs a higher fitness cost $C_1$`. If *M1`* spreads widely in the population of *M1-type* hosts then *M1* population declines relative to *M2* by the factor $C_1`/C_1$ from direct cause, and then declines further as described below. We wouldn't expect this population fitness effect to completely explain inequality (e.g. see [36]), but we view it as one of several likely contributors.

POWER: As P_{M1} decreases, the ratio P_{M2}^2/P_{M1}^2 rises while F_{M1}/F_{M2} has fallen. With this positive feedback P_{M2} will continue to rise and P_{M1} will decline to a very small fraction of the population. This may halt when P_{M1} realizes the existential threat and/or sufficient wealth allows P_{M1} to again increase its reproduction rate. If P_{M1} becomes extremely small then it continues to exist only at the pleasure of P_{M2} unless it also accumulates power of some kind. Thus wealth accumulation memes are likely to include beliefs or techniques about power.

TRUTH: Wealth is an extraneous factor in our model, acting only through costs of acquiring it. The same is true of "truth." Suppose consuming a certain substance (e.g. alcohol) increases reproduction rate, but causes wealth to decline (accidents, poor health or judgment). A meme which exposed this relationship (a truth meme) would remove the reproductive advantage if adopted. So the truth meme would incur a cost and decline just as did our wealth meme.

COMPETITIVE ALTRUISM: Now we introduce a variant of *M1* called *M1`* which has an incurred cost increase in C_1 as did the wealth meme, but also increases the imposed costs K_2 on the *M2* population. If the following condition is met, other things unchanged, this variant increases P_{M1}/P_{M2}:

(12) $K_2`/C_1` > K_2/C_1$

Notice that the incurred fitness costs may mean that certain members of the *M1* population will die before reaching their reproductive potential. The *M1`* variant can spread laterally within *M1* and does not require any children to do so. We've already established that a non-exclusive meme can spread and become permanently lodged in a population even if it is deleterious.

However, if (12) is met the population of *M1* hosts increases. This may even aid lateral spread of *M1`*. Altruism can exist for this case without kin or group selection, though there must be a competing meme for it to have a material advantage. This is subject to the mutual exclusivity assumption, which confines the memes to mostly vertical propagation. Thus, it is not useful as a conversion defense, only in exclusive meme defense. Other altruistic cases will emerge below.

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3.11 Evolution of Exclusivity

We can use the technique of the previous section to analyze other evolutionary changes, such as the evolution of memes with exclusivity. Since evolution usually occurs on a near-continuum of small changes, this brings up the degree of meme properties, which might be either the degree the meme advocates or the degree the meme host chooses to attach to it. For example, how much cost should be inflicted on an enemy meme, at what expense to oneself? Which of several enemy memes, arrayed on a spectrum of friend-foe, should be targeted by exclusivity actions?

To avoid a new calculus of continuous trait analysis, we will use the idea of meme quanta, that there are discrete mini-meme variants of a general meme idea, representing *either* actual variation in the memes or in host implementations of them. These variants we assume can be analyzed as discrete memes. They are non-exclusive of other meme variants within the same general meme idea until some threshold of distinction is reached, which does not concern us at the moment.

All of these will spread within the host population which doesn't exclude them, but since they express degrees of action they cannot all be dominant primary memes. We make a significant assumption in the interest of analysis, that *the most evolutionary advantageous meme (conferring the greatest host fitness) is the most frequently expressed form*. This can be argued from a social learning point of view, that people will likely copy the most successful memes. And it can be argued from a strict evolutionary point of view, that if holders of a certain meme have more children over generations they will come to dominate.

Neither is entirely true, however. If large families in financial hardship are the most reproductively fit, still not everyone may copy that meme. Since within a non-exclusive group of mini-memes we cannot guarantee vertical transmission, children may not express the same meme variant as parents. So this second assumption may produce results which are somewhat but not entirely true when compared with empirical data. Its use does not affect whether larger meme increments are supportable once established, only the analysis of their evolution in small increments.

Assume that most memes are deleterious. While we gave a simulation study that showed positive medians that was after all meme defenses had been applied, and frankly over a remarkable period in history. Even the fact that humans are not yet extinct means there is survivor bias in using human data.

Consider a meme *M1* established in a population of hosts and an invading meme *M2*, bringing with it a fitness burden F_{M2}. By chance or other means there appears a variant *M1*\` opposed (or more opposed) to *M2* so that $K_2` > K_2$. It brings to bear imposed fitness $K_2`$ against *M2*, and incurs cost $C_1`$ from doing so. The already established *M1* primary variant already imposes and incurs costs K_2 and C_1.

The fitness difference between *M1* and *M1*\` is given by the difference between $K_1C_1$ and $K_1`C_1`$. We take all differences between *M1* and *M1*\` to be expressed by the imposed and incurred costs and $F_{M1}=F_{M1}`$. If the difference between *M1* and *M1*\` is small enough *M2* does not take notice then imposed fitness $K_1=K_1`$. We now have three cases:

a) If $C_1`<C_1$ then *M1*\` is unconditionally more fit, and is efficiently exclusive.

b) If the conditions of (12) are met then *M1*\` is relatively fit while in competition with *M2*, but might decay out of the population if the competition ends.

c) If the conditions of (12) are *not* met, then *M1*\` might still prevail if the *M1*-type host population is partitioned and subject to group or kin selection, otherwise decaying.

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Again much seems familiar from the approaches to genetic evolution of altruism and selfishness. Points of view in the literature are summarized in a commentary by Sober and Wilson. [40] The author speculates that multiple well-conceived approaches might lead to the right quantitative answer if meticulously developed, something Sober and Wilson do not dispute. It happens that the above approach relies on individual selection loaded with factors which derive from the actions of groups, at least groups of meme hosts. This is not meant to commit the author philosophically to one approach or the other. The importance here is not group or individual selection, nor is it meme selection exactly. It is a combination of meme propagation and selection as it interacts with individual and group selection. Certainly there may be different altruistic genetic tendencies in the hosts. In this section we weren't even concerned with altruism. It emerged when analyzing the evolution of exclusive memes, a consequence of the individual fitness burden of imposing exclusivity. The above populations all also might well have identical genetics and the analysis is unchanged.

It seems that all factions of human society currently dream of a cost-free formula for imposing their point of view (each side generally believing their point of view is right or at least justified). Perhaps the Internet has encouraged this idea, which itself might well be a meme. Our analysis simply suggests cost-free is not attainable, a kind of "Second Law of Memetics," and warring factions of altruists are a likely outcome.

In summary, there is selection pressure, at least at the individual level (we have not analyzed groups per se) to evolve exclusive memes, upon which the preceding analysis of competing memes depends. Whether they will evolve is conditional with at least three main cases. The analysis shows that two of the cases are linked to some degree of altruism. That those two cases would show some similarity to genetic analyses of altruism is not entirely surprising. It is a little surprising that this is exhibited within the *M1* population in case (b) without group selection. Dependence on conflict to maintain the trait in two cases is troubling. Many interesting questions are raised by this analysis which we must defer to future investigation.

4. Discussion

In this section we discuss the weight of all the results in the context of two areas under active investigation.

4.1 Relation to Risk Compensation

Risk compensation posits that risky behavior has value. When it is made safer, people take greater risk, motivated by the value the risky behavior has. A related theory, risk homeostasis, posits something similar except that the behavior change is only due to a sort of risk thermostat, not necessarily some value in the risky behavior. Each explains some things well. Neither is satisfactorily quantitative. The author has developed a quantitative version of risk compensation from evolutionary principles (loosely called crash rate theory) while working for NASA. Its use was mentioned earlier in connection with quantifying an effect of wealth inequality. [37] In summary, corporations or people who choose a near optimal risk vs. payoff position may not do so because of rational planning, but because the ones that happen to choose the better positions survive better, either personally or financially.

We do not need a sentient entity to ascribe the use of this kind of strategy. It could well be in use by nature because of evolutionary selection. Memes are very high risk and very high value. Nature appears to have managed the risk with various heuristics (like short term memes) and using a portfolio approach (small groups, vertical culture transmission, perhaps even multiple hominid species as we do not know all the causes of the extinction of our relatives yet).

However, if humans employ this evolutionary approach and greatly increase the induced fitness volatility through their own meme-leveraged technology and research, then likely they will suffer the crash events that act in a feedback loop to establish the optimal position. Some of these will be large and unanticipated. Memetics and crash rate are entirely different theories working in different ways (mostly, they share a common evolutionary basis). The volatility comes from the speed and power of memes in memetics. It comes from greed and over confidence in crash rate theory. The author had no idea of connecting the two when undertaking this investigation, but the similarities of the forecasts make a case that each offers a degree of confirmation of the other.

4.2 Relation to the Fermi Paradox

In 1975 Michael Hart wrote a paper attempting to explain the absence of extraterrestrials on Earth. [41] The thinking was that the Drake Equation suggested there could be an astronomical number of planets suitable for life, and there should be a large number of civilizations. If they followed the progression that humans *seemed* to be following at the time, at least a few of them should have had the disposition and desire to colonize the galaxy. Even with modest 7% light speed travel, and time to terraform planets and make them into self sufficient entities along the way, an outbound civilization would colonize the Milky Way in approximately one million years. Hart coined the term Fermi Paradox for this apparent contradiction, based on a casual conversational remark years earlier by Fermi. It was a genius meme design, as the topic has become extremely popular.

At least three books have been written on the subject and many papers. A full background is beyond the scope of this paper, but for example Webb's book details 75 proposed solutions. [42] We do need to mention a particular feature of the problem in order to dissuade the reader from dismissing it out of hand based on estimations of the disposition of one particular species. The paradox only yields to solutions which *must* apply to all species, with no exceptions. Humans might decide not to colonize the galaxy. But if there are thousands of civilizations, those who study the problem deem it unlikely *all* would follow the same decision.

In his paper Hart discounts social explanations, saying social theories are not well developed. Since his paper, theories of sociobiology, evolutionary cooperation and game theory as applied to cooperation have been developed to an extensive degree. The author has developed theories of crash rate (briefly explained in the earlier reference [37]) and provided quasi-empirical support for Burton-Chellew's warning that cooperation declines under intelligence and social learning. [36, 35] And herein we at least take some steps toward a general theory of memes, long and short term. It may be time to give social causes a second look.

There is nothing particularly unique about humans in our meme theory. We specifically allowed it to apply to other kinds of beings, even mechanical ones. We assume it would universally apply. It does make a difference whether a species (or other group of beings, if for example they are not biological) organize into vertical meme transmission units, that is cultural units, or amalgamate into one large meme transmission group.

However, the resources to surmount interstellar distances *may* possibly require planet wide consolidation and cooperation, and aggressive sharing of ideas and methods. These are exactly the conditions for which we found memes most dangerous. If the united group has sufficiently consolidated all other groups, fails severely (or undergoes an adaptive reset, rejecting established memes), and has used up critical starter resources, evolution on that planet is unable to follow this path again with variations.

5. Conclusion

We have introduced a calculus for meme-gene equilibrium which considers not only meme propagation but effects on host fitness and changes in host populations. It shows that memes, if not restricted to propagate along with reproduction (vertically, in small cultural groups), are easily lodged permanently in a host species, infecting eventually all its members. These memes then are not removed by natural selection, because of the spread independent of reproduction. The accumulation of them poses a meme extinction risk. Moreover, the dynamics are not entirely new. Meme transmission is somewhat analogous to DNA sharing by bacteria, which is not done by more complex organisms.

We have seen how meme defenses are necessary, and likely the waning popularity of short term memes is a heuristic-driven defense. Memes could forbid or antagonize other memes, and a great deal of social conflict might be traced to meme defense if this point of view were taken in its analysis. However, if memes are used to defend against memes, the defensive memes may also pose extinction risk. Mutually exclusive memes are effective defenses, but only by affecting fitness. They also offer insight into mechanisms of inequality and altruism.

Focusing on long term memes having a mostly linear combination effect with other memes, we used a Monte Carlo simulation to derive conditions for population equilibrium based on the median response. The model was roughly validated by fitting it to world population growth since the start of the Industrial Revolution. Average meme fitness advantages of more than a few tenths of a percent have the potential to be de-stabilizing. In a portfolio of species, with nature being a sort of accidental portfolio manager, high induced fitness memes may be an advantage of great value. The lifetime of individual species may be shortened by a similar effect as innovation has had on the lifetime of companies in equity markets (see [38] “Lifetime of Companies”). Individual species expect the median return.

Dominant and recessive memes are likely and would follow something similar to Mendelian genetics. Linear low-interaction memes behave like a dominant gene, except that they are not linked to host reproduction and the independent spreading rate must be accounted to gauge their strength in selection, making them hard to deselect just because they are deleterious to the host.

Altruism emerges in the evolution of exclusive memes, which seem to be the only viable kind of long-term-meme defense. In limited cases exclusivity can emerge on its own, but usually it is costly and requires altruism. In that case, it can emerge either as expected due to group selection or in one peculiar case if there is only meme competition.

Finally, given the extinction risk uncovered and the likely necessity of planetary consolidation to support interstellar travel, we propose meme risk as a possible solution to the Fermi Paradox.

We have not analyzed group formation in this paper (recall birdsong and the postulated effect of memetic variation on group formation in Lynch and Baker [13]). It is a logical candidate for further investigation. Simulations and empirical investigation are also needed.

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