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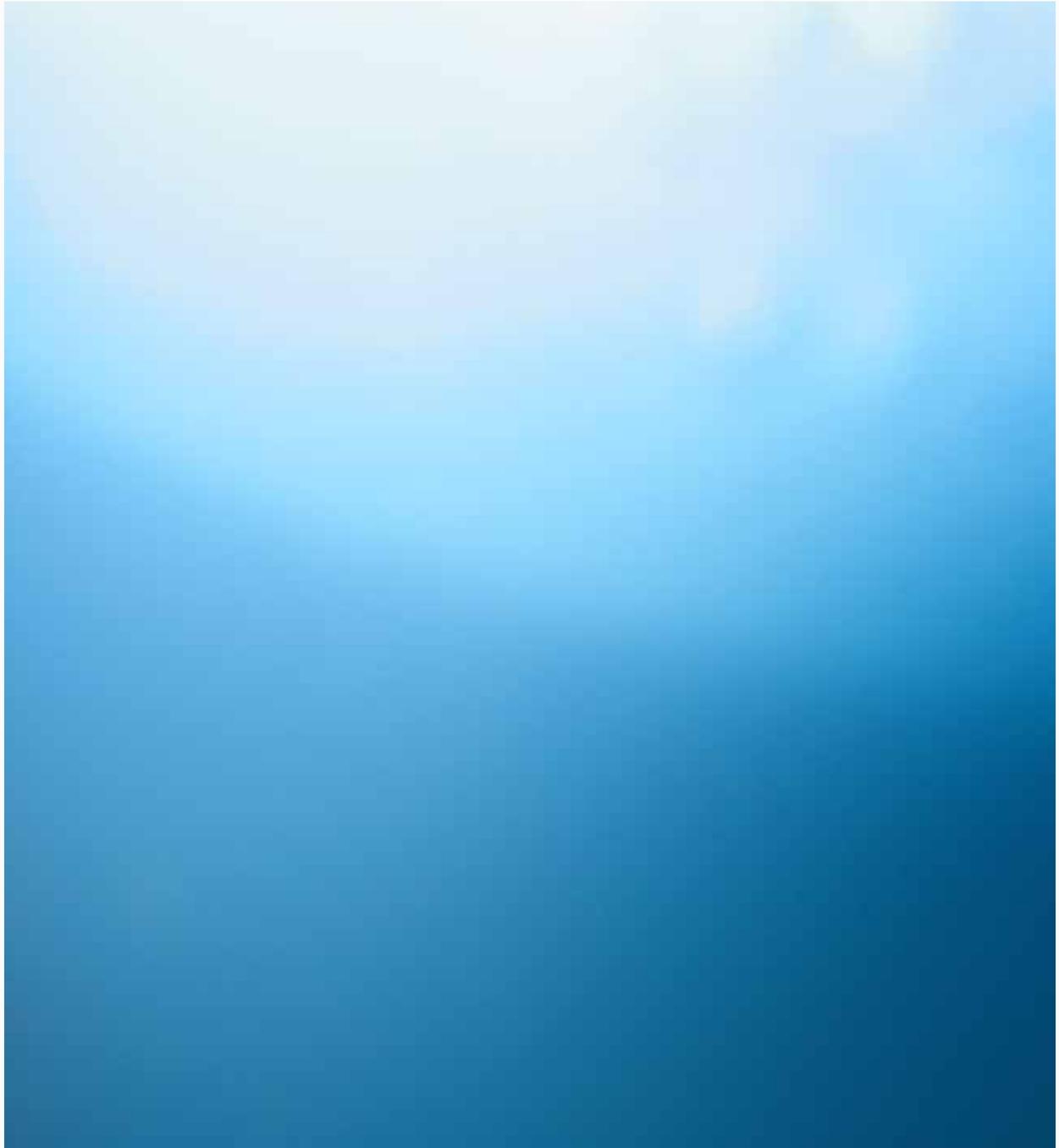
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## Abstract

The immune system defends hosts against internal and external biologic threats. It also records an antigenic map of the environment such that it can appropriately respond to stimuli as benign or threatening. A lesser-known function of the immune system may be to sample the microbiome for potentially beneficial traits it can add to the host inventory. Rather than executing wholesale destruction of pathogens, the host can benefit by domesticating invading organisms or parts thereof. The function can be summed in the word "xenovation", innovation achieved through the selection and integration of foreign traits. Implications for biologic evolution, meme evolution, and computing evolution are discussed.

## Discussion

Components of pathogens can be processed and rendered benign or useful through various mechanisms. A historical example of this phenomenon is the domestication of one prokaryote (or at least its energetic machinery) by another to form a eukaryote. A current example is the processing of pathogen antigens for surface redisplay to other players in the immune system. The ability to protect against reinfection is a trait acquired via the pathogen. It is intuitively appealing to speculate that the immune system is in a perpetual state of exploration for innovative traits through domestication.

The exact mechanisms by which immune cells domesticate microbial traits remain to be elucidated. How sequences associated with those traits might end up in the germ line also remains to be investigated. What is evident, however, is that host genomes demonstrate components that originated from the microbial world and were acquired somatically at some point rather than through direct lineage. In some cases, such sequences may produce nefarious traits or even help the pathogen. Examples include oncogenes. The extraction of sequences and traits may be an important part of the co-evolution of pathogens and the immune systems.

Memes are superior to genes in enabling evolution in part because they can be acquired somatically from others at low biologic cost. A host can learn memes by sampling a vast inventory of traits of others, processing them, and integrating useful ones into its own inventory. Meme transfers are most likely to occur when traits are encoded in communication universalities such as common language among groups.

The design of computing systems in many ways mimics that of their biological counterparts. When thinking about computing evolution, it could be useful to borrow once again from Mother Nature. Current computing designs involve operating systems and software programs that can evolve through updates. Digital viruses have become a substantial threat to the integrity of computing systems, and developing anti-viral software has become a major industry. Antiviral software currently consists of tools for identifying, quarantining, and destroying potentially harmful invading code. What if host operating systems could sample viruses for useful traits to domesticate and integrate into the host computing system? What if, rather than executing wholesale destruction of rogue code, the antiviral software programs processed viruses and rendered their components benign or even useful? What if antiviral software could be used to accelerate computing evolution?

Seen through the window of my 10th-story hotel room, the Seoul skyline was sprouting. Cranes everywhere were lifting apartments and office buildings ever taller to accommodate growth. Yet looking down at the streets, there were few signs of children. The current growth of Seoul was largely due to migrations from rural areas. I had just come from Yeochon, the once bustling agrarian village of my childhood that is now drained of all people except some aging elders.

For the country as a whole, Korea's population decline began in 2008. Never mind trying to point this fact out to the builders. They reflexively believe in the wisdom of the saying "they don't make any more dirt", and the verticalization of Seoul is a testament to that phrase. It turns out Koreans aren't making people either. The builders' train of thought appears to be on a head-on collision course with depopulation.

All over the world, socio-economic advances have been turning developing countries into developed ones. Virtually every developed country today is population decline. If these two trends alone continue, the global human population would hit an inflection point and enter a secular period of demographic contraction.

The possibility of this demographic "singularity" — a point at which the future will be different than anything we have seen in the past — occurring is small. The probability that the shift to global depopulation will occur in our lifetime is even smaller.

Indeed, continued population expansion is what is deeply ingrained into current expectations. Malthusian concepts have been reinforced by empirical data to date: world population has been growing since antiquity, interrupted by wars, disasters, pandemics, and famine. There are many rehashed doomsday predictions today about looming overpopulation, unsustainability, and resource depletion. Paul Gilding's "The Earth is full" talk at the 2012 TED conference is just one example.

Contrast these apocalyptic forecasts with current facts. Population is already declining in many other countries, including Japan, Brazil, China, Germany, Italy, Hong Kong, Singapore, Kazakhstan, Ukraine, Belarus, Moldova, Estonia, Latvia, Lithuania, Bulgaria, Georgia, Armenia, Bosnia, Croatia, Slovenia, and Hungary. Many more are on the brink. If it were not for international immigration, both the United States and the EU would have declining populations today. The total population of the continent of Europe, including Russia and non-EU countries, peaked in the year 2000.

Many factors play a role in population decline, but the one that stands out is sub-replacement fertility (defined as any rate below 2.1 children per woman in developed countries). Over 40% of the world's population lives in nations with sub-replacement fertility, a common feature among the most prosperous countries. The potential causes of sub-replacement fertility include high costs of living and low job security, urbanization, contraception, changes in female social roles, government policies, decreased religiosity, postponement of family, and partnership instability.

For now, many countries, especially the world's poorest nations, are still growing to offset declines elsewhere. For richer countries that have sub-replacement fertility, the decline is offset by immigration from poorer countries, thereby masking signs of potential global depopulation. A report by the Foreign Policy Research Institute

states that the phenomenon of sub-replacement fertility is rapidly spreading to developing countries.

Potential implications of global depopulation are enormous. Stress on infrastructure and services would recede. One might imagine a declining population moving to urban centers and vacating rural areas. In reverse homesteading, large tracts of land could be abandoned and returned to open land. Natural habitats could reappear, along with fauna and flora. Many of today's environmentalist concerns could self-resolve and be forgotten. Will there be a remaining rationale for war over resources when the scarcest natural resource is human resources? There will be many more interesting consequences we may be puzzling through.

However, the possibility of global depopulation is not baked into any investment manager's models today. Yet it is precisely these low-probability high-sigma scenarios currently priced at zero by the market that can yield transformative profit windfalls.

For the investor, current assumptions about the increasing scarcity of natural resources could be turned upside down if competition for assets wanes. Demand for oil, minerals, land, and water could fade and commodity prices could collapse. Deflationary pressures could compound natural trends toward lower prices enabled by innovation. Real estate prices could decline everywhere other than the premium locations. Credit markets could decline due to debt deflation. A lot would depend on whether the central banks would continue to target low-grade inflation in the face of declining aggregate demand or allow low-grade deflation.

In the face of deflationary pressure, assets would have to be held for yield rather than a speculative hope of a profitable sale to a growing pool of buyers. Indeed, investors should invest in assets only if the potential yield stream more than compensates them for the expected decline in asset prices.

Where will yield be in a depopulating world? Bonds would have negligible yield due to high demand and low supply of issuers. Buildings have rent yield but carry maintenance costs. Land has crop yield. Gold has negative yield. Stocks — equity ownership in human endeavor that creates value for shareholders — could be the best place to find yield.

The potential yield may be most high in healthcare. Healthcare is the commodity and the luxury good that everybody wants. Non-discretionary demand and pricing power associated with patents enable very high and very stable profit margins for companies and their investors. In the context of global population, per capita demand for healthcare skyrockets. Healthcare consumption may increase exponentially after the age of 50. In a depopulating world, the demographic stack would resemble an inverted pyramid and the percentage of people over the age of 50 would mushroom dramatically. Indeed, the percentage of population in China above age 65, who consume healthcare at a rate that is at least 5 times higher than their teenage counterparts, is expected to increase from 5% today to 25% by the year 2050.

Currently, 17% of U.S. GDP goes to healthcare and has been growing incrementally but inexorably. As the percentage of older people goes up acutely through lengthening life spans compounded by low replacement rate, the percent of GDP spent on healthcare could start growing geometrically. Could it reach 50% or even higher? As high as that sounds, human demand for healthcare is primal and as the recently upheld Obamacare tax shows, society will find a way to pay for it, privately or publically.

For all enduring institutions with long-dated or permanent mandates, we believe it is prudent to have a portion of their portfolios exposed to healthcare in the current environment. For institutions whose liabilities expand with increasing human lifespan, such as pension funds and social security, investing in healthcare companies that

expand human life span may be the best and perhaps only method of matching asset growth to liability growth.

We also believe it is prudent for enduring institutions to hedge the portfolio against the possibility of global depopulation that could dramatically and negatively impact prices of commodities, real estate, gold, and other assets. The asset price deflation may begin to be priced in long before actual global depopulation occurs if it becomes a mainstream media topic. If depopulation emerges and policymakers are able to maintain inflation, healthcare should still perform very well on both a relative and absolute basis. If depopulation emerges and deflation ensues, healthcare should still perform well on a relative basis. If population continues to expand and age, healthcare should perform well on a relative basis and very well on an absolute basis. Thus, healthcare as the depopulation hedge is a rare hedge that does not drag on performance if the event does not occur.

No doubt, global depopulation is an outlier hypothesis. Despite current data and trends that suggest that it could one day, and possibly soon, become a reality, it is priced at zero today with severe upside. You know the market has read Nassim Taleb's *The Black Swan: the Impact of the Highly Improbable*. You know the market has read Michael Lewis' *The Big Short*. You know the market will still miss the next big one hiding in plain sight.



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