Artificial Multipandemic as the Most Plausible and Dangerous Global Catastrophic Risk Connected with Bioweapons and Synthetic Biology

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**Abstract**: Pandemics have been suggested as global risks many times, but it has been shown that the probability of human extinction due to one pandemic is small, as it will not be able to affect and kill all people, but likely only half, even in the worst cases. Assuming that the probability of the worst pandemic to kill a person is 0.5, and assuming linear interaction between different pandemics, 30 strong pandemics running simultaneously will kill everyone. Such situations cannot happen naturally, but because biotechnology is developing analogously to Moore’s law, it may become possible in the near future (10-50 years from now), because of biohackers, CRISPR, bioprinters, AI-assisted DNA-programing, and weapons of “knowledge-enabled mass destruction” published on the Internet. It could also happened in case of large-scale biological war, or if a rogue country released its entire biological arsenal simultaneously. We also will address other scenarios and risk increasing factors as well as mitigation and adaptation strategies.

**Disclaimer**: No actual information about how to build biological weapons has been used in this article or known to the authors and all information came from openly available sources.

**Keywords**: global catastrophic risk, existential risk, synthetic biology, human extinction, pandemic

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## 1. INTRODUCTION

Bill Joy(Joy, 2000) first used the phrase “knowledge-enabled mass destruction” with respect to the genomes of dangerous viruses potentially being published on the Internet. Nick Bostrom(Bostrom, 2002) and others have discussed the risks of technology both in general(Jonas, 1984)(Kass, n.d.)(Davis, 2012) and synthetic biology in particular(Rees, 2003)(Green, 2014b) including the often listed risk of synthetic biology as a possible source of a killer virus, which could exterminate humanity.

The biological community has written on these concerns as well, with, just for a few examples, Fraser & Dando(Fraser & Dando, 2001), Petro, Plasse, & McNulty(Petro, Plasse, & McNulty, 2003), Lemon & Relman(Lemon & Relman, 2006), and Palmer, Fukuyama, & Relman(Palmer, Fukuyama, & Relman, 2015), Inglesby & Relman(Inglesby & Relman, 2016) all having voiced serious concerns. Phil Torres looked recently on agential risks and showed that the number of actors able to create a global catastrophe is growing exponentially, most of all because of success in synthetic biology (Torres, 2016). In recent years Cooper (Cooper, 2013) and Sotos (Sotos, 2017) connected biorisks with Fermi paradox and Millet (Millett & Snyder-Beattie, 2017) wrote about existential risks of synthetic biology.

Recent modification of the bird flu virus sparked concerns of an artificial pandemic as well as the re-creation of the 1918 “Spanish” flu and publishing its code has certainly only further provoked these fears(*Reconstruction of the 1918 Influenza Pandemic Virus*, 2011)(Tumpey, 2015).

The recent exponential growth of the Ebola virus outbreak during its first stages in West Africa also provoked discussion about possibility of a global pandemic, even without artificial enhancement. Turchin has previously written about the possibility that Ebola could become a lethal global pandemic were its exponential growth not stopped(A. Turchin, 2014).

In the 1990s the term “syndemic” was introduced by Merrill Singer to describe the non-linear interactions between two or more infectious diseases in population(Singer, 2009).

Turchin has outlined the idea of a multipandemic before in his map of global catastrophic risks connected with biological weapons and genetic engineering(A. Turchin, 2015).

To put a finer point on the matter, multipandemics have happened before. One historical example was the decline of the Native American population after contact with Columbus and other European explorers, who brought many infection diseases to which Native Americans had no natural genetic resistance. A large percentage of the indigenous population died, but it is not easy to learn exact numbers, as we don’t know the total population of pre-Columbian America and there are also other social factors affecting decline. Some estimates are that around 90 per cent of total population died. The Europeans brought smallpox, typhus, measles, influenza, bubonic plague, cholera, malaria, tuberculosis, mumps, yellow fever and pertussis, which were chronic in Eurasia(Stannard, 1992) Other scientists think that population decline resulted more from social factors such as migrations and wars(Haines, 2000).

Much of the technology needed to create dangerous biological weapons already exists. For example, in late 2007, a set for genetic engineering was distributed as free software called the Genetic-Engineering Competitors Create Modular DNA Dev Kit. In 2003, scientists from the Institute of alternative biological energy (USA) under the guidance of the famous Craig Venter synthesized from commonly available chemicals quite lively bacteriophage phi-X174 (a virus safe to human and animal that is introduced into the bacterium Esherichia coli). In 2002, by Eckart Wimmer of Stony Brook University, New York, published a paper on the synthesis of the poliovirus from molecular pieces (Wimmer, 2006). Synthetic viral particles were completely indistinguishable from natural on all parameters: size, behavior, contagiousness. The word "synthesis" is applicable to this work in the most literal sense: from knowing the nucleotide sequence, scientists built the artificial virus exactly the same as chemists would synthesize complex molecules. Synthesis itself took three years. Yet in 2003, a year after this work, scientists from the Institute of Alternative Biological Energy synthesized a bacteriophage from elements ordered by catalog in only two weeks. Green has argued that this type of easy access to risky technology is unethical(Green, 2014a)(Green, 2014b)(Green, 2016).

In this paper we investigate more deeply the concept of a multipandemic, which is a subtype of syndemic that is distinguished from other forms of coinfection in that it is a global risk, consisting of *many high-mortality* diseases affecting the entire human population simultaneously. Another difference with classical “syndemic” is that we can theoretically ignore possible non-linear interactions, which will surely be important, but which can’t be predicted if we speak about future hypothetical pathogens. Instead we look into a linear model, in which most deadly factor is the number of pathogens running simultaneously. In ignoring non-linear effects, our model therefore represents a best-case scenario, not a realistic or worst-case scenario.

## 2. SIMPLIFIED MATHEMATICAL MODEL OF MULTIPANDEMIC

### 2.1. Linear interaction of idealized pandemics

Let us examine a mathematical model of a multipandemic, which when could be adapted to real life. In this model each pandemic kills half of a population, and so the existential risk question is how many of such pandemics running simultaneously would it take to kill everyone. (For simplicity, in this article we will not discuss in any depth prions, bacteria, fungi, antibiotic-resistance genes, toxin producing algae, transmissible cancer cell lines, insect and animal pests, “green goo” and other pathogens that could serve as vectors for multipandemics. We will concentrate on viruses, but it is clear that the existence of diverse types of pathogens makes the situation even more complex and dangerous. All that will be said about viruses below is applicable to other types of pathogens.)

If the total number of people in the world is N (and for simplicity we will estimate that N=10 000 000 000, as it will probably reach this digit around 2050), and each pandemics has a probability to kill a person P= 0.5.

Then the M ­– number of simultaneous pandemics, which would kill *everyone* is equal to:

M = $log\_{\frac{1}{P}}N$ $≈$ 33.21 (1)

On the other hand, we need at least 100 fertile people living in one place to prevent human extinction(Hanson, 2008). But if we do not account for refuges, most survivors will be scattered and will not be healthy fertile humans adapted to survival. So the real number of survivors S would need to be bigger, closer to 10 000 at least, and most of them will die in post-multipandemic chaos. If we account for that, only 20 simultaneous pandemics could produce human extinction.

M = $log\_{\frac{1}{P}}\frac{N}{S}$ $≈$ 20 (2)

The total mortality of a pandemic P depends of two factors: the proportion of people it will affect A and proportion of affected people it will kill (case-fatality) F.

P= AF (3)

The extinction-level M number of simultaneous pandemics strongly depends of their total fatality rate P. If it were 0.9, when only 7 such pandemics would put humanity on the brink of extinction.

Contrarily, if the pandemics were rather mild, it would require many more. Total mortality from the Spanish flu of 1918 is estimated to be around 1 per cent. If 100 Spanish flu-like pandemics were to happen simultaneously, there could be still around a 36 percent survival rate, or around 3.6 billion people from 10 bln population.

However if 1000 Spanish flu-like pandemics occurred simultaneously, there would only be 0.004 per cent survivors, or 400 000 survivors scattered in the world, which would be near the survival threshold.

From here we could conclude that there are two divergent types of extinction-level multipandemic: one with only a few extremely lethal viruses, and another where most viruses are rather mild, but the sheer number of them results in catastrophic effect. In a real multipandemic it would probably be a combination of mild and strong viruses, and strong ones will kill most people, while milder ones might contribute non-linear effects and/or be the final blow.

### 2.2. Biological constrains of multipandemic

Now we will add some biological consideration to this simplified model. The next four factors reduce the danger of a multipandemic:

1. During a pandemic, typically two factors compete against each other, as it is difficult to a virus to spread if it kills its host too early. For example, to reach a total mortality of near 0.5, a virus might affect 70 per cent of a population and kill 70 per cent of the affected people, yielding a 0.49 mortality rate. There are not many known viruses which could do this in a human population, but if bird flu became human transmissible, it could possibly do it.

2. People are distributed unevenly on the Earth, live on islands, etc., which may place limits on a pandemic.

3. Total mortality of 0.5 on a global population may seem too extreme as the only well-known example of pandemic with such high effect was the bubonic plague, the “Black Death,” which killed 30-60 per cent of Europe’s population in the 14th century. But some animal pandemics are even more deadly, like the now eradicated Rinderpest, that killed 90 per cent of all cattle in affected population, but did not affect the entire globe.

4. The pandemic tends to die off as it kills its own super spreaders and its replication number falls below 1. As different pandemics may use the same routes of proliferation, they may become concurrent for super spreaders, compete with each other, and reduce further transmissions. For example, if two different viruses are spread sexually, they will kill first most sexually active people. So two pandemics should be counted as really different if they use different modes of transmission. This severely limits the number of possible simultaneous pandemics, as the main transmission ways are approximately 10 (including airborne drops, airborne dust, surfaces, blood, sex, food, water, insects, animal bites, bird contact, and saliva). But it is still enough to create around 20-40 rather different pandemics, if we include variation in speed of dissemination, type of organisms (viral, bacteria, fungi) and incubation periods.

But there are also several biological factors, which increase the *a priori* probability of multipandemics:

1.There are examples of entire species wiped out or nearly wiped out by individual pathogens. There is a fungal pest, Panama disease (*Fusarium oxysporum*), which has plagued domesticated edible bananas and killed almost an entire cultivar, the Gros Michel in some locales. See also the devastating amphibian fungal pandemic, Chytridiomycosis, and White-nose syndrome in bats due to Pseudogymnoascus destructans, which is causing the populations of some species of North American bats to collapse. Perhaps fungal infections have higher extinction potential than viruses.

2. Entire species of mammals could be eradicated by just one pathogen, as one recent study showed. The native black rats of Christian island were completely wiped out by Trypanosoma between 1898 and 1908(Wyatt et al., 2008).

3. Many potentially dangerous viruses exist which could be adapted to attack humans, intentionally or not. The US currently identifies 65 viruses and toxins which should be controlled. It is estimated that “320,000 different viruses infect mammals”(Anthony et al., 2013), and potentially many of them could be adapted to attack humans if genetically modified. Currently there are 128 known families of viruses which can affect humans (most of which are not deadly)(*Viralzone database*, n.d.).

4. Some experiments easily produce very deadly mammal pathogens, such as a new strain of mousepox(Jackson, 2001)(Bostrom, 2002) by adding an immunosuppressing gene to the virus. A similar situation occurred with the recent bird flu gain-of-function mutation experiments; created by passing the wild non-air-transmissible virus through just 10 ferrets. Such techniques do not require genetic engineering or other sophisticated technology and could be done on a rural farm(Enserink, 2013). The virus kept its lethality and killed all ferrets(Scientist, 2011).

5. Syndemic effects, that is coinfection, or one infection shortly after another, increases mortality.

6. Human psychological and social factors such as panic migration waves, etc.

7. New ways of transmission exploiting structure of contemporary human society or by intentional acts.

This and other facts could overweight biological counter argument for multipandemic. We will return to more detail analyses of risk increasing factors later.

## 3. COMPARISON WITH COMPUTER VIRUSES HISTORY

### 3.1. Short history of computer viruses

The analogy between biological and computer viruses is, of course, built into the word itself. Goodman and Hessel have published a popular study exploring these analogies and further ones in some detail(Goodman & Hessel, 2013).

In 1971 first computer virus Creeper was created for scientific research in APRANET.

In 1981 first computer virus appeared in the wild was Elk Cloner, it used Apple floppy disks for cloning, and was created by a 15-year-old programmer as a joke.

In 1986 a 19-year-old Pakistani started first IBM computer virus epidemic with his Brain virus.

In 1988 the Jerusalem virus cause global epidemic, and its function was to delete all files on a computer on every Friday 13.

During middle of 1980s computer viruses remained rare, at a frequency near 1 per year, but towards the end of the decade their number started to grow very quickly. In 1990 there were several tens of known viruses, and in 1992 it was thousands of viruses.

In 2012 – 17 million viruses were known.

In 2015 – 1 million different pieces of malware were created a day(“Nearly 1 million new malware threats released every day,” n.d.)

We could roughly say that population of computer viruses grew 1000 times a decade – with the same speed as Moore’s law. But it didn’t crash the internet.

There are clear similarities between computer viruses and biological viruses. But there is one important difference. While many people have lost data or money on their computers because of malware, it is a restricted form of damage, as the computer owner is still alive – they are not biologically harmed. Biological viruses of course are not like this at all; their targets are living beings.

The most important period in the development of computer viruses was the 1980s. During that decade viruses went from near non-existence to the situation of a multipandemic by the end of decade, when many viruses had run amok and were aggressively destroying data, and defenses were almost non-existent.

There were several reasons for virus spread in 1980s:

* Increasing number of privately held computers, because growth of Apple and IBM PC popularity connected with Moore’s law.
* Development of virus building technology, which included the idea of a virus, programing skills, and large number of private individuals who could create them and owned computers.
* Creation of information exchange nets, first based on floppy disks, and later on Internet.
* The almost non-existence of antiviral culture and software.

### 3.2. Lessons from computer virus history and their application to future biotechnology

From the analysis of computer viruses we can come to several conclusions, which can be extrapolated to the field biotechnology (as well as other types of future artificial pathological replicators based on exponential technologies, including nanoreplicators and AI-viruses):

* It took approximately 4 doublings of Moore’s law from the first artificial virus released in the wild – to appearance of the field where many viruses are easily created and co-exist (1981-1989).
* It only became possible after private computers were built in millions. Therefore in biotech it will only be possible after some analogue of a computer is built and privately held in large number of copies, perhaps some sort of “bioprinter” (more on the bioprinter later).
* Retrospectively, the history of computer viruses now seems to be logically inevitable, but it was not easy to predict in advance, and the same could be true for the evolution of biotechnological viruses, where predictions always stop at just one virus.
* While many viruses existed simultaneously, they were not able to disable all computers or eventually crash the Internet, but many people experienced some kind of computer infection.

### 3.3 Speed of biotech development and possible timing of multipandemic

Recent works by Ouagrham-Gormley(Ouagrham-Gormley, 2012)(Ouagrham-Gormley, 2014) show some of the difficulties in the creation of classical biological weapons, as opposed to what is sometimes considered in popular culture. However, these barriers should not be relied upon in the face of consistent technological advance.

The biotech analog of Moore’s law is the Carlson Curve and it is even steeper than Moore’s law, which means there may be less time between the advent of the first artificial biological virus to a multipandemic(Carlson, 2003)(“Special report: Life 2.0,” 2006) Carlson’s law is measured by the price of sequencing DNA, which, for a human genome, has fallen from 3 billion dollars in 2000 to 1000 dollars in 2015, or 3 millions times, and is reasonable proxy for other not so easily quantifiable biotechnological successes. For example, the price of DNA synthesis is also subject to a decreasing cost curve, as Carlson has noted(Carlson, n.d.).

Biotechnologies in many respects have similar development speeds to computers, but with a later start. So if biotechnologies develop at roughly the same speed as computer technology, we can estimate that it will take approximately 10 years from first runaway artificial biotechnological virus to the condition of a dangerous multipandemic. Artificial bioviruses have been created in labs since 2000(Cello, n.d.), but never runaway, the same way as first experimental computer viruses have been created in 1970s.

Based on this, we can estimate that 2017 in the biotechnology field is like 1979 in the computer field, and if we continue this analogy, first artificial virus may infect people outside the lab before 2020 and multipandemic could happen as early as 2025. Such extrapolation cannot be used as a prediction, as our world is very uncertain. It could happen even earlier, if large actors start anonymous biological warfare, the same way as they now use cryptic cyber attack, or it could happen later, or never. As one example, in 2002 Sir Martin Rees made a bet that the first artificial virus will claim a million victims before 2020(Longbetsorg, 2002). So there is the possibility that a multipandemic could happen very soon, but also up to in any date in the more remote future, until some kind of universal defence will be created.

### 3.4 Universal self-replicating biological synthesizer as analog of PC in biotech

The creation of dangerous viruses could be made terribly easy if some form of a universal biological synthesizer were invented. Such a machine might consist of a computer, DNA synthesizer, and a biological organism (like E.Coli), which could be controlled by this computer. The DNA synthesizer component could also be made as a part of the living organism, so no restricted equipment would be needed.

Such an organism might be able to replicate itself, so it could be distributed across a large network of people who may want it. These purchasers could range from legitimate DIY scientists and entrepreneurs to dangerous biohackers and drug dealers. The synthesizing device could be like a self-replicating “bioprinter” which gives its owner the opportunity to create any organism or chemical at home. Therefore it would not be under control of authorities, which are now able to control custom synthetic DNA sequences ordered via the internet. This could result in a worst-case scenario, as it could be disseminated among incompetent, untrustworthy, and immoral individuals and organizations, such as rogue states, paramilitary organizations, doomsday cults, organized criminals, terrorists, drug-dealers, drug-addicts and malware producers.

Describing in detail the ways of making effective bioprinter is beyond the scope of this paper, and perhaps unethical to disseminate in any case, but the above-presented outline seems plausible. No doubt other ways are also possible.

## 4. POSSIBLE CAUSES OF A MULTIPANDEMIC IN DIFFERENT FUTURE EPOCHS

A multipandemic could happen at various stages of future technological development, and at each stage it could have differing causes. Here are ranges for several possibilities.

## 4.1. Current events

Multipandemic may take form of bird flues multipandemics. There are several strains of avian influenza, which occasionally infect humans, including H5N1, H5N6, H5N8 and H7N9 which are increasingly active in China as of January 2017. Each of them has high mortality rate, could be transferred by birds, but none of them has adapted to humans. Recent WHO statement is that limited human to human transmission is possible for H7N9(W.H.O., 2017). If several bird flu pandemics happened simultaneously, they could recombine easily in infected population, creating new strains, and also could reach any remote part of the world by birds.

## 4.2. Near term risks of the mutipandemic

Possible events in the near future (10 years), connected with national state or semi-state actors (including apocalyptic terrorists and/or cults, isolated and rogue states, and traditional states using bioweapons):

* An act of existential terrorism, where multiple pathogens of several classes are created and released in different parts of the world.
* Nuclear-biological war, where large numbers of different biological weapons would be used as the last stages for existential retaliation.
* A Biological Doomsday Machine could be built for the purposes of existential deterrence (analogous to the Soviet Perimeter or “Dead Hand” system) or global blackmail.
* A virus or other agent is created which is able to undergo quick mutations (or perhaps even provoke mutations in other pathogens).
* An accident in, stealing samples from, or a malicious attack on an advanced biological laboratory. This seems unlikely as a source for a full multipandemic, as a sufficient number of different pathogens are not likely to be kept in one location. However, security breaches can and do occur, as the 2001 Anthrax attack in the United States showed that thievery is possible, and the 2014 discovery of inappropriately stored smallpox at the US FDA/NIH displayed the risk of simple incompetence.

## 4.3. Biohackers epoch

More remote future accidents, where actors could be biohackers or other individuals or small groups (probably more than 10 years from now, i.e., after 2027, though the first artificial pandemic may be earlier, in fact at any time, as all the necessary technologies would already exist). Quite possibly all three of these developments could happen simultaneously:

* Creation of a bioprinter ­– a cheap way to program and create any biological organism, including the bioprinter itself.
* Small narrow AI-program to design dangerous DNA sequences (which could be embedded in a bioprinter, or even be remotely maliciously hacked).
* Continuing of the exponential growth of biotechnologies with doubling time 1-2 years, which will also include exponential growth of individuals interested in them and having access to them, including dangerous individuals.

## 4.4. Remote future

Malevolent Strong AI tries to kill all humans with the use of a mix of biological weapons (though it no doubt could also find other ways).

It is clear that a multipandemic is most probable in the second period, and is connected with the rapid development of biotechnology before the creation of strong AI.

As others have noted(Bostrom, 2014)(Thiel, 2014), with regards to the future, strong AI (if possible) is a wild card in general, and it is particularly so with the threat of a multipandemic. If strong AI appears before high-end biotechnology is created, it may prevent multipandemics, but strong AI has own risks. If strong AI is delayed for decades, all the bad things which could happen because of biotechnology might happen before the advent of strong AI, thus preventing any aid strong AI might give us. But narrow AI will surely play important role in biotechnological development.

While most attention is now concentrated either on risks of self-improving AI or on military robots, the real killer form of AI may be narrow and non-self-improving AI, which helps a possible biohacker to calculate most dangerous pathogenic genomes. In such an eventuality, we might not survive until the creation of strong AI.

## 4.5 Other types of biological risks similar to multipandemic in some aspects

Carefully designed single virus and the way of its initial transmission may also be able to kill all humanity, but such a virus would need to combine many features, including very high mutability, very high transmissibility, 100 percent case-mortality, ability to travel to islands and to compromise immune systems, etc. So it has to combine many features, probably coded by many different genes, and as result it will be something like a multipandemic but inside one virus. In multipandemic different features affecting different groups of populations may be coded in different viruses, which make it simpler for a malicious perpetrator. Its creation would be as complex as of Stuxnet computer virus, and seems improbable for any rational agent.

There is also a chance that just one simple (and randomly created) virus could kill almost everybody, and in this case a multipandemic would be overkill. We can’t say that it is completely impossible, but its very low probability event, as many viruses exist and created by natural selection every day. Creation of such virus may require many attempts (natural or artificial) and it is again similar to multipandemic.

Multiresitance to antibiotics of a single bacteria is also may be named a form of a potential multipandemic.

## 5. RISK INCREASING FACTORS

There are several factors, which are currently contributing to making a multipandemic more probable and/or dangerous.

### 5.1. Genetic and biological factors

1. Homo Sapiens passed through an evolutionary bottleneck 70 000 years ago and as a result our genetic diversity is low compared, for example, to great apes(Javier, n.d.). So the protection that genetic diversity provides against diseases is smaller for humans than for other species.
2. The whole biosphere is a naïve world to artificial viruses, like an unprotected computer network is to a computer virus. All organisms consist of cells, which could be attacked by specially design viruses. Organisms have built-in defenses, but those defenses are designed by evolution against known viruses.
3. Some pathogen combinations could be designed which increase total vulnerability. For example, like the natural syndemic of AIDS and tuberculosis, infection might be first slow and undetectable, and only weakening the immune system for a second, more lethal, opportunistic infection.
4. The problem of overload of the human immune system. If a human is attacked by several different viruses simultaneously, his or her immune system will have greater difficulty. Some viruses could pave the way to other infections (just as influenza can lead to bacterial pneumonia). The difference with previous point is that in each case it is random event, not a form of symbiotic relations between two pathogens.
5. Recombination. If several different viruses from one family are affecting the same cell in the same organism, they could exchange genes, thus creating new strains, some of which could be even worse. This is typical for influenza.
6. Some viruses are able to undergo such quick mutations that they create a situation similar to multipandemic, where many different viruses appear. The most notorious for it are the influenza virus and AIDS virus. There are many different strains of AIDS viruses and a human can be affected by several of them. There are also many strains of influenza, but each year only one tends to be dominant.
7. Birds can reach almost all remote islands, and they like to nest on islands. They could bring avian influenza and other diseases with them, thus infecting any humans seeking refuge there.
8. Non-linear synergy of infections. Coinfection is more difficult to survive. The same is true for superinfection, which is the next infection shortly after first.

### 5.2. Technological and social factors

1. Planes and other rapid means of transportation create a very interconnected world, where viruses can travel global distances very rapidly. This reduces the natural defense of distance that once protected humans and which partially still exists for many other species. International cargo shipments can also harbor disease vectors and pathogens.
2. Intensified interaction of biopathogen technology with associated technologies, including special chemicals or pharmaceuticals that enhance pathogenicity, use of drones as sprayers, the creation of genetically-modified animals as carriers (mosquitos, mice), etc.
3. Remotely hacking of bioprinters to create dangerous organisms in distant lands.
4. Illicit drug market and distribution networks could function as channels for viral dissemination and also as drivers for the dissemination of dangerous technologies.
5. Internet transparency facilitates the rapid exchange of ideas for “knowledge-enabled of mass destruction.” These ideas can travel all over world in less than second, and dangerous ideas can never be truly deleted, including the published genomes of viruses and idea for dangerous attacks.
6. A multipandemic will overwhelm the ability of the WHO and other health care providers to react, as it could start in many different places at once, sowing confusion, and rapidly consuming resources. Ebola was defeated because (after a half-year delay) many organizations finally sent the best resources to the epicenter of the epidemic in West Africa. This was a wiser solution than to enact a global quarantine, as that will not stop the local epidemic, and Ebola could have eventually killed millions, evolved into worse forms, and become a greater danger to outside world.
7. The problem of inadequate diagnostics. If many different dangerous viruses are circulating, in the absence of advanced diagnostic resources, medical practitioners will have a problem properly diagnosing diseases, especially novel ones.
8. Close contact with wild animals. In fact, humanity already exists in the state of a slow motion multipandemic by interacting with large pool of animals and their viruses. For example, this is what has brought AIDS, SARS and other viruses into the human population, but the process is quite slow. Additionally, technologically-enabled invasive species such as the *Aedes aegypti* mosquito, which hitches rides on transoceanic shipments, are known vectors for numerous diseases including zika, chikungunya, yellow fever, dengue, and others.
9. Agricultural animals such as pigs and birds as recombination reactors for new viruses. Swine flu (2009) appeared after recombination of swine, bird and human viruses in domestic pigs. The number of pigs in farms is constantly growing.
10. One may falsely hope that the start of the first pandemic could result in the destruction of much of biotechnological research and prevent the creation of other dangerous viruses. But because of the exponential nature of pandemic growth, it will be very mild most of the time of its growth. If its doubling time is 1 month, it will take around 3 years to infect 1 billion people, and most of that time only thousands people will be infected. So the first pandemic will not be able physically stop appearance of other pandemics for first 1-2 years, which a lot of time for such exponential technology as biotech.
11. There is also a hope that the first pandemic will result in drastic political actions against biohackers and biotechnology in general, which will slow research and possibly prevent the appearance of other pandemics. But as we see in the example of Ebola, political actions are lagging from quickly changing situations, for may be a half a year, and their global implementation may take even longer. Also it will not be easy to locate all privately own equipment and it will be also needed to build vaccines.
12. Most natural pandemics evolve over time to be less lethal, as the virus has to pass through many people before it reaches everybody. But this is not true for artificially engineered pandemics, where trillions of viral particles could be brewed in a lab without genomic changes and later sprayed on million victims, so it would need only 10 doubling before it reached all of the population, and so much less time for genetic mutation.
13. A multipandemic could also be based on “vertical integration” where one dangerous organism creates others. These could be non-viral complex synthetic organisms, like a prion-producing bacteria, or a virus which add the gene of a toxin in other organisms, or a cancer causing virus, etc.
14. Even if a particular human were to survive several infections, his or her health could worsen, as large viral loads may result in DNA damage, sterilization, and/or other injuries, so it will be difficult for that individual to participate in rebuilding of the civilization. Polio victims are a prime example of the permanent damage that viruses can cause.
15. Genetically targeted weapons. Racial and personal animosity (which are unfortunately widespread in the world) could lead to the creation of genetically targeted bioweapons against races, ethnic groups and even individual persons. This would overcome natural protection against viruses provided by genetic diversity, as different viruses could be targeted on different parts of human population.

## 6. MITIGATION AND ADAPTATION STRATEGIES AND COUNTER-FACTORS

**6.1.** **The first pandemic may encourage creation of a strong “antivirus” defence**

As we see in the computer virus example, the first epidemics were the most global and impressive. This resulted in widespread awareness of the risk and the creation of the first antivirus programs. After such programs became widespread, they created a strong enough level of defense (a sort of “herd-immunity”) to prevent unlimited propagation of viruses. Now, truly global pandemics that affect almost all known computers should no longer happen. Only the most vulnerable people and communities would likely be affected.

**6.2.** **The first pandemic may produce an international governmental crackdown on biotech which also could arrest biotechnologically development**

The first artificial biological pandemic will impress people much more strongly than the Jerusalem computer virus in 1988.Large investments in the creation of multilevel defenses would likely occur, which could include draconian measures against biohackers and other biological technologists, transportation or biotechnologically-relevant resources, knowledge and communication of these resources, and restrictions on equipment. If done well this might produce benefits, but if done poorly it might seriously impede biotechnological progress while not providing significant defensive benefit.

**6.3**. **Due to lack of preparation, the first pandemics will likely be the most destructive, while later ones will likely be milder**

The change in computer hackers’ behavior over time is also worth considering. At first, hackers created viruses mostly for fun, and then added a “destruct data” feature based on idiosyncratic motives. Later they moved to the production of “commercial” malware, which was intended to control computers, steal information, create botnets, ransom computers, etc. So contemporary computer viruses infect, but not kill based on the same evolutionary logic, which create less deadly viruses in nature. We can as yet only imagine what “biological ransomware” or a “flu botnet” might be like, though it is not completely beyond the scope of our imagination. But if biotech will be used as instrument of war, the next strains will be more and more destructive, not less.

**6.4.** **Need for biosafety labs for the creators of these diseases**

Creation and control of dangerous biological viruses is not as simple as for computer viruses. They could quite possibly kill their creators first. So the need for complex equipment like biosafety labs with laboratory animals (which are relatively rare) will make these facilities expensive and potentially visible. Lacking these facilities, the accidental creation of dangerous virus by an inexperienced biohacker could kill the creator and then start a pandemic from there.

**6.5. The development of universal biodefences could potentially make whole classes of possible bioweapons obsolete**

 The DARPA-created project INTERCEPT goal is “*to develop viral therapies that are effective against a broad spectrum of viral strains, and that can co-evolve and outpace new strain*”(DARPA, 2015). A semi-universal flu vaccine could be developed soon (though evolution and ill-intentioned biohackers could always find a way to evade it, as happened with antibiotic-resistant pathogens).(Sheikh, Gatherer, Reche, & Flower, 2016) Universal antiviral drugs have been researched by both IBM(Ichiyama, 2016) and DRACO(Rider et al., 2011). A multipandemic is only possible if the swords are not only stronger than the shield, but much stronger. Differential technological development, where we invest more in protective systems so they always outrun potential dangers, will be a key to this effort.(Green, 2016)

**6.6. Slowing down biotech development, or its concentration in several well-protected centers**

While this has trade-offs in terms of delaying potential future benefits from biotechnology, given that the potential benefits from biotechnology are finite and the risks – human extinction – could be considered infinite, the cost-to-benefit ratio, informed by the risk equation, would indicate caution is warranted(Green, 2014b).

**6.7. Specialized preparation for the prevention of a multipandemic should include the creation of early reaction and vaccination systems.**

Such systems will find new signatures of viruses, quickly estimate their danger and rapidly produce needed quantities of safe and effective vaccines. The speed of all the process from detection and identification to manufacturing millions (or even billions) of doses of vaccines is crucial. Currently vaccine preparation takes more than a year, but if all processes were reduced to weeks, a multipandemic would become less possible as it will limit the time of wild co-existing pandemics. This would also exclude most pathogens with slow mechanisms of transmission. This would be similar to the contemporary antivirus computer industry, which is able to identify signatures and send updates to users before the virus reach them.

**6.8. AI-based defensive control**

Defensive planners, governmental or non-governmental, should begin research into the creation of a ubiquitous defensive control system with elements of AI, an active sensor network which tracks materials, scientists, internet activities, and air samples for potentially dangerous DNA, and control systems to initiate rapid reaction to any threat.

**6.9 Narrow yet ubiquitous specialized protection systems**

For example, UV-air-sterilizers everywhere, rapid drone-delivery of medications, ubiquitous hepa-filtered air cleaning (such as the Tesla Model X’s “Bioweapon Defense Mode”), stockpiles of food and water, distributed biohazard equipment, remote refuges (including submarines(Alexey Turchin & Green, 2017)), and so on.

**6.10. Biohackers may help protect us by creating many defenses.**

Large numbers of biohackers could also create a situation where they will be able to adapt very quickly to protect against new risks, because the same technologies which create virus are also could be used for their detection and vaccines production. Such vigilance could help to protect themselves and others. Analogously to our current world of computing, the best computer security specialists come from the hacker community. The main question here is about the balance of sword and shield. Also, the ability to train as “penetration testers” on the human immune system, to determine the best defenses to bolster that system could itself have serious medical, legal, and ethical implications.

**6.11.** **Continuous vaccination against emerging pathogens**

Given the proper technological infrastructure, people could get weekly updates of vaccines, possibly even using home syntheses based on signatures downloaded from the Internet, similar to how computer antivirus software is updated.

**6.12.** **Artificial immune system**

 In the more distant future, personal biohacking could also be used to quickly change human physiology, to make it less vulnerable to illnesses. The first step here would be the initiation of an artificial immune system. Next would be cyborgization of that immune system based on nanotechnology, which may be almost invulnerable to biological pathogens, natural or otherwise.

**6.13** **Global Bioshield**

This would be something like a global immune system able to identify dangerous pathogens in the wild, and attack them through a distributed network of biosensors and artificial immune-like systems. It would also include monitoring systems in laboratories and other regulatory systems and capabilities(*37. Lifeboat foundation. Bioshield project*, 2006). The similar project “Nanoshield” has been suggested to mitigate the risks of nanotechnological replicators(Freitas, 2006).

## 7. CONCLUSION

The risk of a multipandemic has not been widely discussed in open literature, but it is one of the most serious risks connected with the rapid development of synthetic biology.

If biotech growth were very slow, dangerous accidents connected with it would be more distributed over time and would not result in a multipandemic.

But if biotech is set to grow at same speed that computers did, all sorts of dangerous accidents will be concentrated in time. As typical time of a pandemic is 1-3 years, potentially many pandemics could run simultaneously.

The biotech revolution creates the possibility for a multipandemic, but it also provides powerful instruments for defense. Unfortunately, due to lack of foresight, such instruments will likely not be implemented in full force until after first accident. If first artificial pandemic is very strong, for example as a modified bird flu capable of killing half of humanity, it could start of the chain of events which will result in civilization collapse and human extinction. A milder disaster might be enough to motivate us to become vigilant. Or even better, we might simply take heed of warnings and prevent a disaster before it may occur.

A major wild card here is the timing of the creation of strong AI, which could both reduce the risk of a multipandemic, or dramatically exceed its danger. Until that time, we think it is fair to say that a multipandemic is the most grave existential risk faced by humanity.

A multipandemic is unimaginably bad and that may be one reason why, up until now, it has been ignored. However, we know that multipandemics have occurred before from natural causes and we know that an analogous situation already exists with computer viruses. The advance of biotechnology will make the risk of an artificial multipandemic a reality in the near future. Hopefully we can use the same power of biotechnologies that produce these risks to prevent them by creating even more sophisticated defenses. This needs to be a major priority for near-term technological development.

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