The epidemic uroboros: regularity and uniqueness of a phenomenon that is new each time

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The word we selected for our FBK Dictionary series for the research Center for Health Emergencies is epidemic, a term from which pandemic is derived, arguably the most significant in recent years.

Coronavirus, US Election, Classroom, Weschool, new Prime Minister's Decree. These were the top five words googled by Italians in 2020. Four out of five were related to the Covid-19 pandemic that rocked the planet that year, and the first one, in particular, got stuck in a specific box in our memory, to stay. But what is an epidemic? How does it differ from a pandemic? How does it originate, grow, and expand? How is it dealt with? And why does it recur cyclically?

Eternal returns

Let's start with the last question first: **why do pandemics recur cyclically**? As **Giorgio Guzzetta** tells us in his show Pandemie, **changes in viruses are responsible for it.** Viruses are very special biological entities: they have no autonomous existence and perform their vital functions only when they are hosts of another body. With good reason, they can be called **the main pathogens responsible for pandemics**: compared to bacteria (responsible as well, as was the case with the plague, for example), **they have on average a much higher transmission rate. More importantly, they constantly mutate,** which makes it **likely over time that they will be able to circulate in human populations,** for example, after having been exclusively animal for a long time. Thus, an event perceived as *disruptive* by ordinary people, for an epidemic scientist is a **statistically expected event** that "sooner or later" must happen: Athens typhoid fever, Justinian's Disease, Black Death, Spanish Flu, and COVID-19 are the result of a chain of random events that lead a pathogen to become pandemic.

Looking at the course of history, therefore, we see that pandemics are a recurring historical fact and occur periodically in society, somewhat like what happens with earthquakes. **As "progress**

progresses", in an increasingly globalized world with ever-changing ecosystems, events such as pandemics will become more and more frequent. This seems like a paradox, considering how with the power of science we are increasingly able **to manipulate the environment**: yet, as in the case of global warming, we **sometimes overlook** the **consequences of our actions** and unknowingly create favorable conditions for an epidemic.

Darwinism and the will to power

The principle of life is essentially to **multiply itself**: genomic mutations occur randomly, through genome transcription errors or environmental changes. However, only those mutations survive that are best adapted to the environment or, at most, are useless but not harmful.

This discussion is also applicable to viruses: as mentioned above, they mutate frequently and proliferate when a change facilitates their transmissibility (e.g., by air). Other mutations may relate to the ability to persist long enough in an organism. Still others allow the mutated virus to partially evade the immune system protection that human organisms had built up as a result of previous infection or vaccination. Then there are mutations that affect the transmissibility of the virus.

But **when does a virus ignite an epidemic**? The first thing to know is that **most viruses that affect humans are zoonotic, i.e., animal in origin.** In its constant mutations, the **"species jump" can happen: a virus that was previously only animal, after a series of "trial and error", becomes dangerous to humans as well.** However, it should be noted that even viruses that have long used humans as hosts can undergo mutations such that they become more virulent and harmful to the organism (as in the case of Zikavirus).

If the virus manages to survive long enough in the human host, such that it infects and proliferates; if its transmission rate is high enough, i.e., if the number of new infections caused on average by an infected individual (called the base reproduction number, denoted R0) is greater than 1; and if we realize too late that the problem we observe is caused precisely by the virus (because, for example, it is initially asymptomatic), or if we do not identify it in time as the cause of the problem (because, for example, the symptoms are nonspecific, similar to those of other diseases), that's when the virus becomes pandemic.
So this is the **road that leads to a pandemic**: and it is the fact that we can recognize it that allows us – and has sometimes allowed us – to stop a pandemic in time.

It is important to note that it is generally inconvenient for a virus to kill its host, the death of which is a "side effect," due to excessive damage to the organism: this could in fact, before death, reduce its chances of transmission, cause overly aggressive immune responses, excessively destabilize the host environment… and if the virus kills its host, sooner or later it too will die. However, a pandemic virus kills. **As a function of life, life kills other life**; and by virtue of that, it sooner or later determines its own demise. To compare microscopic and macroscopic systems – so familiar to the worlds of physics and somewhat less so to those of biology -there is another species (the human one, *ed*.) that for the past few centuries has begun to impact in an increasingly important way on a much larger organic system on which its existence depends. In this case, the finale is not known, although there are some worrying indicators.

The case of the Nipah virus: human impact on ecosystems

In 1998, a very high number of people began to die of encephalitis in Southeast Asia. A mystery disease was first detected in Malaysia, and some cases were also seen in Bangladesh, southern China, Indonesia, and northern Australia. Only slightly more than half of the people who contracted the disease would survive. It was initially thought that mosquitoes were the agents of transmission, so much so that a series of measures were implemented to try to prevent as much as possible the population from becoming infected. However, death rates would not drop. Oddly enough, someone noted, Muslim communities were being spared the virus.

After a little more than a year, a young Malaysian virologist, Kaw Bing Chua, unconvinced by official explanations, tried unsuccessfully to contact local authorities. He then reached a study center in Colorado, bringing with him a rather hot cargo: some infected tissue samples. In the U.S., he was able to identify the pathogen thanks to the center's advanced electron microscopy systems. Thus, he discovered a new species of virus that belonged to the measles family: **paramyxoviruses**, a family that infects only mammals, such as **pigs**. In retrospect (which does not always succeed), a team of researchers managed to reconstruct the history of the "species barrier jump": in Nipah, the town where the disease broke out, the pork industry was booming as a result of growing demand from the Chinese market. To meet this demand, entire **areas of palm forests had been cleared** to make way for intensive livestock farms. Bats, which had their natural habitat in these forests, had to move into the roofs of pig farms. Here began a **period of intense biological exchange** between bats and pigs: before long, the virus would make the species jump from bats to pigs and from there to their breeders. As soon as the agent of transmission was made known, a drastic solution was implemented in Malaysia and other parts of Southeast Asia: thousands of pigs were crammed into deep holes and killed by the military. The pandemic came to a sudden halt.

Beyond the case just described, **intervention in ecosystems does not have as a necessary logical consequence the development of a pandemic virus. However, the more ecosystems vary, the more variability is built into the environment, and the greater the chances of a virus developing a species jump.** This story, like any epidemic, needs to be considered under the lens of **statistical thinking**, the kind of thinking that seems so lacking in the daily lives of us all and yet is fundamental to the rational way of proceeding in science.

The question – and together the admonishment – we can draw from this story is: **what should we do to reduce the likelihood of a risk becoming a danger**?

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