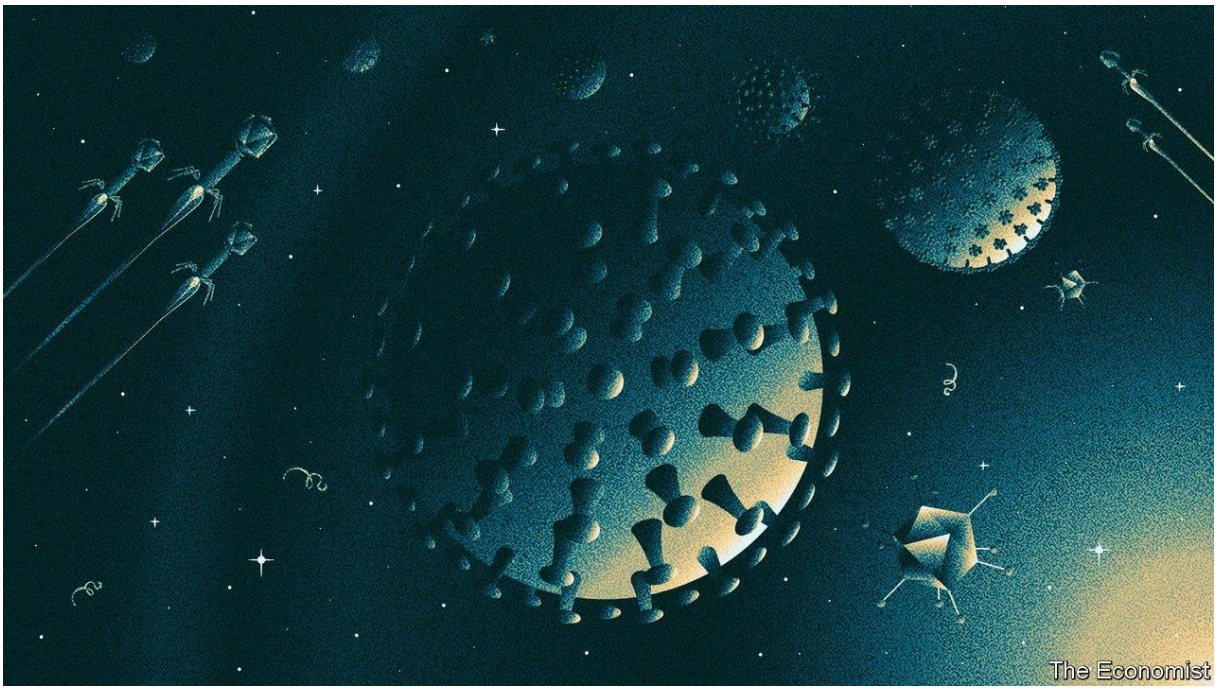
How viruses shape the world

They don’t just cause pandemics



Humans think of themselves as the world’s apex predators. Hence the silence of sabre-tooth tigers, the absence of moas from New Zealand and the long list of endangered megafauna. But sars-cov-2 shows how people can also end up as prey. Viruses have caused a litany of modern pandemics, from covid-19, to hiv/aids to the influenza outbreak in 1918-20, which killed many more people than the first world war. Before that, the colonisation of the Americas by Europeans was abetted—and perhaps made possible—by epidemics of smallpox, measles and influenza brought unwittingly by the invaders, which annihilated many of the original inhabitants.

The influence of viruses on life on Earth, though, goes far beyond the past and present tragedies of a single species, however pressing they seem. Though the study of viruses began as an investigation into what appeared to be a strange subset of pathogens, recent research puts them at the heart of an explanation of the strategies of genes, both selfish and otherwise.

Viruses are unimaginably varied and ubiquitous. And it is becoming clear just how much they have shaped the evolution of all organisms since the very beginnings of life. In this, they demonstrate the blind, pitiless power of natural selection at its most dramatic. And—for one group of brainy bipedal mammals that viruses helped create—they also present a heady mix of threat and opportunity.

As our essay in this week’s issue explains, viruses are best thought of as packages of genetic material that exploit another organism’s metabolism in order to reproduce. They are parasites of the purest kind: they borrow everything from the host except the

genetic code that makes them what they are. They strip down life itself to the bare essentials of information and its replication. If the abundance of viruses is anything to go by, that is a very successful strategy indeed.

The world is teeming with them. One analysis of seawater found 200,000 different viral species, and it was not setting out to be comprehensive. Other research suggests that a single litre of seawater may contain more than 100bn virus particles, and a kilo of dried soil ten times that number. Altogether, according to calculations on the back of a very big envelope, the world might contain 10^{31} of the things—that is one followed by 31 zeros, far outnumbering all other forms of life on the planet.

As far as anyone can tell, viruses—often of many different sorts—have adapted to attack every organism that exists. One reason they are powerhouses of evolution is that they oversee a relentless and prodigious slaughter, mutating as they do so. This is particularly clear in the oceans, where a fifth of single-celled plankton are killed by viruses every day. Ecologically, this promotes diversity by scything down abundant species, thus making room for rarer ones. The more common an organism, the more likely it is that a local plague of viruses specialised to attack it will develop, and so keep it in check.

This propensity to cause plagues is also a powerful evolutionary stimulus for prey to develop defences, and these defences sometimes have wider consequences. For example, one explanation for why a cell may deliberately destroy itself is if its sacrifice lowers the viral load on closely related cells nearby. That way, its genes, copied in neighbouring cells, are more likely to survive. It so happens that such altruistic suicide is a prerequisite for cells to come together and form complex organisms, such as pea plants, mushrooms and human beings.

The other reason viruses are engines of evolution is that they are transport mechanisms for genetic information. Some viral genomes end up integrated into the cells of their hosts, where they can be passed down to those organisms' descendants. Between 8% and 25% of the human genome seems to have such viral origins. But the viruses themselves can in turn be hijacked, and their genes turned to new uses. For example, the ability of mammals to bear live young is a consequence of a viral gene being modified to permit the formation of placentas. And even human brains may owe their development in part to the movement within them of virus-like elements that create genetic differences between neurons within a single organism.

Evolution's most enthralling insight is that breathtaking complexity can emerge from the sustained, implacable and nihilistic competition within and between organisms. The fact that the blind watchmaker has equipped you with the capacity to read and understand these words is in part a response to the actions of swarms of tiny, attacking replicators that have been going on, probably, since life first emerged on Earth around 4bn years ago. It is a startling example of that principle in action—and viruses have not finished yet.

Humanity's unique, virus-chiselled consciousness opens up new avenues to deal with the viral threat and to exploit it. This starts with the miracle of vaccination, which defends against a pathogenic attack before it is launched. Thanks to vaccines, smallpox is

no more, having taken some 300m lives in the 20th century. Polio will one day surely follow. New research prompted by the covid-19 pandemic will enhance the power to examine the viral realm and the best responses to it that bodies can muster—taking the defence against viruses to a new level.

Another avenue for progress lies in the tools for manipulating organisms that will come from an understanding of viruses and the defences against them. Early versions of genetic engineering relied on restriction enzymes—molecular scissors with which bacteria cut up viral genes and which biotechnologists employ to move genes around. The latest iteration of biotechnology, gene editing letter by letter, which is known as crispr, makes use of a more precise antiviral mechanism.

From the smallest beginnings

The natural world is not kind. A virus-free existence is an impossibility so deeply unachievable that its desirability is meaningless. In any case, the marvellous diversity of life rests on viruses which, as much as they are a source of death, are also a source of richness and of change. Marvellous, too, is the prospect of a world where viruses become a source of new understanding for humans—and kill fewer of them than ever before.