Robert Koch Institute
Federal Centre for Health Education (BZgA)

THE VACCINATION BOOKLET FOR EVERYONE

With commentary by

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FOREWORD

Vaccination is one of those topics that really gets under our skin. And it's one that affects us all. People around the world, people in Germany and the people in your family. Never before has the topic of vaccination been talked about so much and so intensively as during the COVID-19 pandemic. And never before have so many people been vaccinated in such a short space of time as during the COVID-19 vaccination campaign.

With each and every news bulletin, new questions arise – no doubt in your mind, too. Which vaccine? Should I get vaccinated? If yes, why? If not, why not? While many eagerly await their vaccination appointment, others are sceptical about vaccination. In some cases, both of these mindsets apply.

The aim of this booklet about vaccines and vaccination is to help you deal with the situation. It contains sound background knowledge about vaccines and vaccination – and it's provided free of charge to give everyone the chance to read it. There's also a useful accompanying website, so it can easily be found there as well. The booklet has been produced with the help of Eckart von Hirschhausen, Germany's best-known

doctor and medical science journalist. Since the start of the pandemic, he has run an informational campaign, produced documentaries and provided other contributions, both as an observer in an intensive care unit and as a participant in a vaccination trial. In the commentaries that supplement this booklet, he readily shares his personal experiences and views on the topic of vaccination.

At the Robert Koch Institute and the Federal Centre for Health Education, we have been and continue to be busy. We believe vaccination is hugely important and we're looking forward to getting back to everyday life as we know it. You naturally have your own views on the topic of vaccination and whether or not you get vaccinated is and remains entirely your decision alone. Our efforts are designed to ensure that when making your decision, you have the best possible information at hand.

The Editorial Team

CONTENTS

1

The vaccine research race – marathon, sprint or obstacle course

It can sometimes be likened to running a marathon. With smallpox, it took almost two hundred years from administering the first vaccine to actually eradicating the disease. At other times, it's more like a sprint. The first COVID-19 vaccines were approved just a year after the virus broke out.
But there are also times when the situation resembles the story of the hare and the hedgehog race. This is the case with the flu virus, as a constant stream of variants and mutants emerge. Every year, new vaccines have to be developed, some of which are obsolete by the time they go to market. The situation is similar with coronaviruses – it could well go from a sprint to an obstacle course. But whatever happens, vaccine research is more than equipped to cope.

One virus, many vaccines

Never in human history have so many vaccines been developed, tested and approved in parallel as in the first 12 months of the COVID-19 pandemic. As of the beginning of May 2021, a total of 14 different COVID-19 vaccines had been approved in at least one country somewhere in the world. More than 200 additional vaccines were at the development stage – some with good prospects for early approval, while others were nowhere near it.

It's quite normal for a variety of vaccines to be developed in parallel for one and the same disease. For example, a number of research teams had been working on polio vaccines since as early as the 1930s. Even after the first vaccine was approved in 1955, research continued – including as part of a collaboration between virologists in the Soviet Union and the U.S. Clinical trials on the efficacy of their vaccine began in 1957, and it was first licensed as an oral vaccine in 1960. Meanwhile, in the search for an AIDS vaccine, which began in 1981, several dozen candidates have been tested, but all with little success.

The fact that currently hundreds of vaccines are being developed and tested against one virus all at the same time is highly unusual. This is a state of emergency the likes of which had never been seen prior to the outbreak of the COVID-19 pandemic.

The virus genome on the internet

That so many vaccine researchers around the world have all set to work is primarily due to the fact that the pandemic is hitting the whole world – it's affecting billions of people and endangering the lives of millions. The tremendous speed at

which researchers were able to start work is largely due to a man named Zhang Yongzhen.

Zhang, then 54 years old, is a Chinese virologist at Fudan University in Shanghai. On 3 January 2020, he received a sample of a new virus from research colleagues in Wuhan. Within days, he and his team had decoded the complete genome of the virus. On 10 January, they put the genome online, making it freely accessible to anyone and everyone, so researchers around the world could start looking for a vaccine to combat the novel coronavirus. Many set to work right away.

Vaccine developed in the space of a weekend

10 January 2020 was a Friday. On Monday, 13 January, an until then largely unknown U.S. company called Moderna had already designed its vaccine and the first tests for approval were about to begin. A week later, a new expert commission was set up in the U.S. to focus entirely on testing new COVID-19 vaccines and drugs. At the end of that week, on Friday, 24 January, the founders of BioNTech, another largely unknown company based in the German city of Mainz, decided to focus all their research efforts on developing a COVID-19 vaccine. If before publishing the virus genome, Zhang Yongzhen had first asked his managers for permission, the entire vaccine development process would probably not have started for another several months.

Fast track testing

With millions of people around the world already ill with COVID-19 infections, countries and authorities everywhere accelerated their testing procedures – among other things, by combining testing phases and steps that would otherwise be carried out in sequence.

Even the smoothest fast lane would be of no use if no one used it. But almost from the outset, the situation was different with COVID-19 vaccines. Researchers around the world were interested in developing the much-needed vaccines, countries around the world were interested in supporting that research and new technologies helped to ensure that the research being conducted quickly produced results.

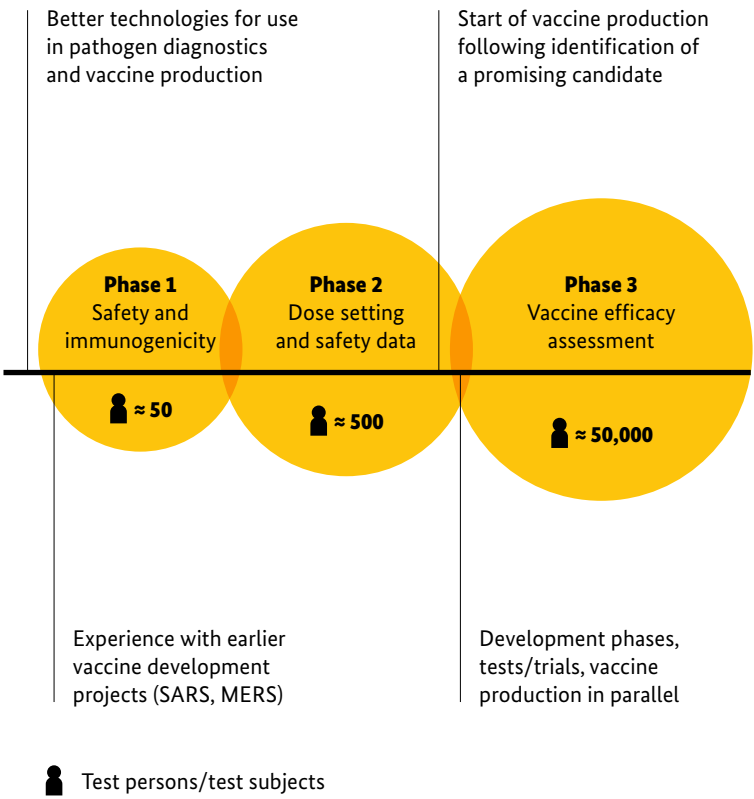
A football match lasts 90 minutes. A pregnancy lasts nine months. A watched pot never boils. If things have to take their course, what happens to vaccines if you speed up the testing process? While a definitive answer will only be found once the COVID-19 vaccination campaign is complete, the provisional answer is that accelerated testing has in no way diminished either the safety or the efficacy of the vaccines. For all vaccines approved in the EU, the results from the final clinical trial stage (Phase 3) have shown a well-balanced risk-benefit ratio. When a vaccine is approved by the EU, it means that it has been tested against all the criteria that apply in the EU and is considered both safe and effective. If a vaccine is not approved, it doesn't mean that it's unsafe or ineffective – but it could mean that there's not yet enough data to allow approval trials for the vaccine or that the developer has not applied for approval in the EU. The latter is the case, for example, with the COVAXIN vaccine being used in India.

Quality competition

In theory, the vast number of potential vaccines could make things confusing and chaotic. But in practice, the existing systems of medical research are well suited to filtering out the best from a large number of candidates. This is primarily due to the multi-stage approval process used. Only a vaccine that has cleared all the other hurdles makes it to Phase 3. This is

when a vaccine is tested on volunteers. Next comes the quality competition following approval.
Not all approved vaccines have the same efficacy profile. Their properties can also change depending on the situation. In acute phases of a pandemic, the vaccine with the highest

Path to approval
Clinical trial phases in testing vaccines



There are no stupid questions

Vaccination isn't new, and it's something I'm more than familiar with. As a former paediatrician, I well remember the conversations I had with various mothers and fathers. Concerned parents ask all kinds of vaccination-related questions – and so they should. It's better to ask and air your doubts beforehand so you can make a well-informed decision later on. That's why I'm more than happy to contribute to this booklet, if only in the margins.

I see myself as a mediator between the world of medicine and science and the people for whom the booklet is intended and must make sense. You can read my comments or ignore them. The choice is entirely yours – just as it is when it comes to vaccination.

degree of efficacy will have the advantage. In a phase that is more about prevention, it would be one with next to no side effects.

In tropical regions, a vaccine that doesn't require refrigeration will be more suitable. Where it is difficult for people to get to the vaccination venue, a vaccine that offers good protection after a single dose is better.

Even if safe and effective vaccines are already available for a specific a disease, they can always be replaced by ones that work far better. So the easier it is to research and develop vaccines, the better they will work.

Resistances and mutants

There are cases where our immune system has a memory like an elephant. If it's decided it doesn't like grass pollen, we'll suffer from hay fever every spring for the rest of our life. But with some vaccines, the immune memory weakens. The number of protective antibodies produced by the vaccine decreases – and over time, the immune system forgets that vaccination protection ever existed at all.

When vaccination is forgotten

Forgetting doesn't happen overnight, though. It's more like a language that you once learned at school and then no longer use. In younger years, you might have been able to converse quite passably in French, but years later, when you're spoken to in French, it takes a while before you come to grips with it again – that is, if you find your way back into at all. And the longer ago your last encounter with the foreign language, the more difficult it becomes to pick it up again and be able to make yourself understood.

Some vaccines, such as those against measles, rubella and yellow fever, offer longer-lasting protection. With these, it's more like swimming or riding a bike – having learned, you never forget.

Just as you should ideally brush up on your foreign language skills now and then, as protection weakens it's recommended that vaccinations be regularly refreshed– for diphtheria and tetanus every ten years and for whooping cough once in adulthood. But while vaccination dates and schedules are well observed for children, booster vaccinations for adults often go forgotten. In Germany, one quarter of those over 18 are no longer adequately vaccinated against tetanus and only one in ten are still immune to whooping cough.

When viruses mutate

Sometimes even the best memory doesn't help the immune system. This is the case when – due to a mutation – a virus changes in such a way that the antibodies no longer recognise it. Although not every mutation of a virus reduces vaccine protection, it can happen that quite by chance some part of the virus genome has been changed to the extent that the previous vaccines are less effective or are no longer effective at all. Mutations constantly occur in nature – in viruses and bacteria, in humans, in animals and in plants. Most of them disappear again because they worsen the organism's chances of survival or remain insignificant because they make no difference at all. Only if a mutation improves the chances of survival will it spread, gradually push back the previous variant or completely prevail.

If in pathogens a mutation improves their chances of survival, it means that they in turn worsen the situation for us humans. Bacteria become resistant to antibiotics through mutations, while viruses become resistant to vaccines or become more infectious. They can also be transmitted to living beings other than humans or all of these at once.

Influenza viruses are notorious for their mutability, and like the hedgehog in the fable, they are always one step ahead of vaccine development – the hare in other words. No other virus changes anywhere near as quickly or as dramatically as the flu virus – not even coronaviruses, despite the many reports about mutations.

Due to the spread of millions of cases around the world, many mutations also occur in COVID-19 and some of them have been shown to be more contagious than the original virus type.

Some of the mutant virus variants have changed to such an extent that they have developed at least partial resistance to the vaccines and thus weaken their effect. While there is still

no mutation that would defeat all of the approved vaccines, it is at least theoretically possible that a mutated virus could be resistant to all of the existing vaccines.
If that were the case, this new coronavirus could develop into a new threat against which new vaccines would need to be developed. The immunity acquired from previous vaccination would no longer help – anyone wanting to protect themselves against the mutated virus would then have to be additionally vaccinated with one of the new vaccines.
As already explained, that scenario doesn't seem likely at this point in time. But if it were to happen, we could expect vaccine development to be even faster and more targeted than it was during the original COVID-19 pandemic. After all, we've learned quite a lot about coronaviruses in the course of the past year.

New vaccines, new diseases

For vaccine research, 2020 was something of a marathon year. Never before has progress in this field been so intensive, so diverse, so rapid and so global. Many of the insights gained in the fight to combat the coronavirus will subsequently be used to find vaccines and treatments for diseases for which either no or only poor candidates have been available so far.

Ending the never-ending story of the flu vaccine

Flu vaccines are high up on the wish list – or at least the development of a single vaccine that can fight all flu viruses at once. Until now, it's been necessary to assess prior to the start of the annual flu season which flu viruses could be particularly dangerous over the coming months to ensure that the right vaccine is administered.

That means producing four active substances against four different flu viruses to make up the combined flu vaccine for the respective season. And in most cases, this includes an active ingredient against H1N1-type viruses, as these are particularly common and particularly aggressive. For the 2020–2021 season, the agent used was "A/Guangdong-Maonan/SWL1536/2019 (H1N1) pdm09", while for the 2017–2018 season it was "A/Michigan/45/2015 (H1N1) pdm09". These complicated names highlight the problem faced by vaccine researchers – that flu viruses sometimes mutate faster than we can vaccinate.

But that could well change: with the turbo speed made possible in the development of COVID-19 vaccines, flu vaccines could one day be developed within a given season. Researchers could monitor which virus mutations become dangerous and then quickly produce a suitable vaccine.

Another research approach works with what are known as RNA bundles. By using 4, 8 or

In the race to find effective vaccines, researchers and authorities work hand in hand to reach the finishing line with the desired result.

12 RNA strands in a single vaccine dose, different flu viruses could be targeted together and thus provide lasting immunity – at least more lasting than the seasonal vaccinations used so far.

Zika, malaria and other tropical diseases

There is also great potential where tropical diseases are concerned, as many of their pathogens have so far resisted vaccine research efforts. This is the case regarding malaria, dengue fever and sleeping sickness, to name a few, and it's by no means due to a lack of research conducted on each disease. For malaria, one of the most dangerous and deadly infectious diseases in the world, researchers have been working to find a vaccine for 70 years or more. It is only recently that the world's first-ever malaria vaccine (RTS,S) was approved. A preliminary vaccination programme was launched in Ghana, Kenya and Malawi in 2019, but vaccine efficacy is currently only about 30 percent.

New technologies can make new solutions possible where previous methods have tried but reached their limits and failed. For example, researchers in Chicago are working on RNA-based vaccines against dengue fever. The US-based company Moderna, which specialises in mRNA, was already running clinical trials on vaccines against Zika and other mosquito-borne diseases when in early 2020 all efforts were suddenly concentrated on COVID-19. Moderna will continue those trials at some point in the future.

Influenza (flu): one name, multiple viruses

Viruses of two types (A and B) with countless subtypes are grouped together under the name flu or seasonal influenza. There are at least 18 HA-subtypes of the A virus type (H for haemagglutinin) and at least 11 NA-subtypes (N for neuraminidase). These viruses are usually named after their H and N combinations. For example, the Spanish flu of 1918–1920 and the swine flu of 2009–2010 were both H1N1 type, while the avian flu types are H5N1 (since 1997) and H7N9 (since 2013).

Forcing the immune system to break a habit

New technologies can also provide solutions to problems that had not been thought of before. In the case of mRNA technology, this is evident in two medical issues – allergies and autoimmune diseases – which require exactly the opposite of what is needed in a pandemic. While with infectious diseases, the aim is to teach the immune system something new (for example, to defend itself against a virus), in the case of allergies the aim is to slow down the immune system or force it not to trigger the defence reaction it normally would.

A traditional vaccine is unable to work in that way. It reproduces a pathogen to a degree that enables the immune system to target it. An mRNA vaccine, on the other hand, behaves differently – mRNA stands for "messenger ribonucleic acid" and is found in every single cell of every living being. It provides the blueprint for the production of proteins. Proteins are also found in every cell and there are hundreds of thousands of different proteins in the human body.

The mRNA in a vaccine causes the body's cells to produce a single protein. In the case of COVID-19 vaccines, this is a protein from the envelope or outer layer of this particular coronavirus – known as the spike protein. In theory, apart from indicating a virus, a protein whose blueprint contains a piece of mRNA like this could also perform very different tasks.

Research into multiple sclerosis (MS), a neurological autoimmune disease affecting around 200,000 people in Germany alone, is especially advanced. With MS, the body's own immune system attacks the body's nerve pathways, as it perceives them as foreign bodies. This can cause a wide range of symptoms, including paralysis. In collaboration with researchers from the University of Mainz, the German company BioNTech has developed an mRNA molecule that (in animal experiments on mice) can suppress or even reverse the immune system's overreaction. Whether the var-

Viruses can be nasty

At the time you're vaccinated, you're actually healthy. The idea is to protect yourself against future disease. But is it really worth the risk? Can't your body deal with a virus without you being vaccinated? Unfortunately, nature isn't always kind and highly contagious viruses can be really very nasty. As a doctor, when confronted with severe cases of measles, encephalitis or COVID-19, you're often forced to stand by, unable to act. I for one am overjoyed that we've found a way to give people with weaker immune systems or pre-existing illnesses a chance to protect themselves. Survival of the fittest was yesterday – and is completely unacceptable. We're living in modern times, for which I'm grateful.

ious research approaches will actually result in a treatment for multiple sclerosis in humans will only become clear in the course of the next several years. According to BioNTech co-founder Uğur Şahin, in the best case scenario they may well result in treatments for other autoimmune diseases, such as diabetes.
Be it with mRNA or with other technologies, as one of the world's most widespread chronic diseases, diabetes would be more than a suitable candidate for the development of new vaccines. An even more suitable candidate would be cancer, the world's deadliest disease.

The search for a cancer vaccine

Several cancer vaccines are already available and are used for specific types of liver cancer and cervical cancer that are caused by infections. However, only about one-sixth of all cancers are caused by infections. While to date vaccines have thus not been considered for the remaining five-sixths, the situation is about to change. The mRNA technology being used so successfully in the COVID-19 pandemic can fight far more than "mere" viruses. The proteins whose blueprint the mRNA contains are not only found in viruses but also in cells.

Cancer cells also contain proteins, and because they are cells that really have no business being in our bodies in the first place, it should be possible to trigger the immune system to fight them as well. If we can develop antibodies against rabies and measles, why not against breast cancer and leukaemia?

COVID-19 findings aiding cancer research

It might be a simple question, but finding an answer is not so easy. Cancer cells are different in each cancer patient, so to attack them with mRNA technology, a separate, personalised mRNA vaccine would have to be developed for each and every patient. We'd have to look for a typical protein in those cancer cells, then construct an mRNA strand that produces exactly that protein and then vaccinate the respective patient with the mRNA. As with the COVID-19 vaccines, the immune system would then develop antibodies against the protein – and what combated the virus in the pandemic would then combat tumour cells in cancer.

Developing a separate vaccine for each tumour may sound like a mammoth task, but how much effort really went into designing the mRNA vaccine? The U.S.-based company Moderna needed no more than a weekend for the job back in January 2020. Once you know which protein you're targeting, the effort required to produce an mRNA is fairly minor. And if you also know how tolerable and suitable the mRNA vaccine's packaging is for the prospective patient, then nothing stands in the way of it being used. The experience that researchers and authorities have gained on similar topics with the COVID-19 mRNA vaccines can be easily transferred for use in the various mRNA treatments for cancer.

Such cancer treatments are not just possible in theory, they're already being tested. Clinical trials are currently being conducted for breast, prostate and skin cancer and for other forms of cancer as well. But it will probably take at least another five years before the first mRNA vaccine against cancer is approved. That may still be a long away off, but in the fight against cancer it's a source of great hope in the search for a new and effective weapon.

The tumour mutanome

In every cancer a whole series of mutations appear inside the cancer cells. Together the various mutations form to make what's known as the tumour "mutanome". And just as fingerprints are unique in humans, mutanomes are also personalised. Therefore in theory, this makes it possible to find individual treatments for each and every tumour based on the respective mutanome.

2

COVID-19 vaccines – their effects on the body

Imagine the processes in the body are similar to a concert. The heart keeps the beat, the organs are the instruments and blood circulation ensures they're all connected and playing together.
When a virus invades the body, it produces 'sounds' that are not part of the body's concert. It can sound as odd as an instrument that's out of tune or be as shrill as a trumpet, but whatever its sound, it sounds out of place – it doesn't fit in or belong. If the foreign bodies are allowed to multiply undisturbed, the sound of that single trumpet becomes an increasingly unpleasant cacophony of noise that drowns out everything else. But if the body's immune system – it's regulatory service – keeps the troublemaker out, then the concert can continue undisturbed. That's exactly the kind of effect a vaccination is meant to have.

How vaccination works

Why can't we just take a tablet to deal with a virus? That's how we treat headaches, high blood pressure, heartburn and cystitis. We have antibiotics for bacterial infections, but there are none for viral infections. It's not because researchers aren't smart enough to develop them – it's more because the virus is too smart (even though it doesn't have a brain).

Why antibiotics don't help when fighting a virus

Let's stay with the image of the body playing a concert. A bacterial infection can likewise be imagined as a gang of hooligans wanting to disrupt the peaceful event. As they start making trouble, we start feeling sick. The event organisers, mainly white blood cells, step in to deal with the gang. This is how most infections are overcome by the body's own means. But if the regulatory service can't deal with the invading bacteria, then the body alerts the antibiotics police. They can fight the bacteria by, for example, attacking a building block that exists in the cell walls in bacteria but not in the walls of human cells.

Things work differently with viruses. They're not cells, so they have no cell walls. And they don't reproduce – they attach themselves to the body's cells and let them do the reproducing instead. They're a bit like intruders, but not ones who can be arrested so easily. They can be likened more to vuvuzela horns that are smuggled into the orchestra – noisemakers that not only force the musicians to play them but also themselves make other noisemakers and pass them on to other members of the orchestra. If the antibiotics police can't help, then what can? What's needed is a better-trained, better-prepared squad of bodyguards – an internal security team.

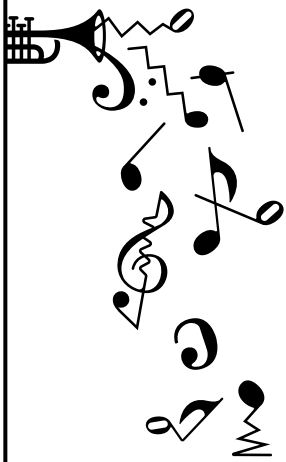
Bacteria and viruses	
Bacteria are small, single-cell organisms, most of them benign. These include the approximately 100 trillion bacteria that live in the intestines of healthy adults and aid their digestion process. Some – coli bacteria, staphylococci, myco-bacteria and others – can cause disease.	Viruses are relatively short pieces of genetic material enclosed in an envelope. They have no metabolism and can only reproduce in the cells of other living beings. They do this by penetrating a cell in a host and forcing it to produce new virus particles. Having done so, they then go on to destroy them.

Immune defence – the body's survival kit

The body takes a conservative view on life. Very conservative in fact. It doesn't like what it doesn't know. If something it doesn't know attempts to get in, it becomes aggressive. In some cases, very aggressive. It either kicks intruders out or kills them, often mobilising whole armies to expel them. Most living beings work like this, not just humans but animals as well. Over the millions of years in the history of life, this seems to have been the best form of survival. Anything that threatens to impair the way an organism (the body) functions is warded off. If the survival strategy is successful, the infection is overcome. And having triggered the defence process, the immune system forms antibodies that prevent any future attack by the same bunch of intruders. This is what makes us immune. In the course of evolution, those organisms

that were initially curious, let potential intruders in and gave them a chance to show they meant no harm, did not survive.

The human brain, however, works in very different ways. It's curious about the new and tries to recognise familiar patterns in everything it encounters, wanting to connect new with existing knowledge. The human body, on the other hand, is much more simple-minded – and when it comes to vaccines, the focus is on the body and how it reacts.



Discord
Viruses disrupt the harmony in the body. The immune system tries to restore order.

Vaccines – the immune system's teachers

No one expressed the guiding principle of vaccination more aptly than the Italian educational reformer Maria Montessori: "Help me to do it myself. Show me how. Don't do it for me. I can and want to do it myself." At the start of the 20th century, this is how Montessori described the ideal teacher-child relationship. It corresponds perfectly with the relationship between the immune system and a vaccine. While the actual vaccine has absolutely NO EFFECT on the virus, what is does is help the immune system to set up a defence against it. It gives the body's own regulatory system a kind of mugshot of the troublemaker, so they can be immediately intercepted upon entry.

Like a teacher, the vaccine gives the body the information it needs about the virus so it can develop antibodies even though it has not yet been infected. And like a sparring partner, the vaccine trains the immune system in how best to fight and win should the virus ever enter the ring. Thus, suitably trained and equipped, when the virus shows up, the body is able to defend itself or at least limit the outcome of the attack. How quickly and how well the training takes effect varies from vaccine to vaccine and from person to person. In the first few days after receiving an initial dose of vaccine, full vaccine protection has not yet built up so infection is still possible during that time. In a study of British hospital staff, the number of new infections halved in the 12 days after the staff's first COVID-19 vaccination – and in the weeks that followed, another significant drop in the rate was seen.

Childhood illnesses? Aren't they important for kids?

Children's immune systems have to develop and learn. They're taught and trained by exposure to pathogens and also to vaccines. But it's done in a gentler, more targeted way despite the risks associated with the respective disease. Wrapping children up in cotton wool doesn't work in the long run. If there's a vaccine to prevent disease, why should children be exposed to what could be a fatal disease?

Potentially, the immune system can be trained to tackle any kind of virus by introducing an appropriate vaccine. Anything that enters the body from the outside can then be dealt with by the body's regulatory system – the problem is that there are limits to what can be done. There are around 3,000

different types of viruses and a specific vaccine would have to be developed for each and every one – in some cases not just one because many virus types change so rapidly that the original vaccine no longer has an effect. And as a vaccination is essentially an intervention in the way the body works, it's not completely without risk. This is why vaccination recommendations focus on infections that are particularly frequent and particularly harmful.

Vaccine types

How can the body be helped to develop immunity itself? In vaccine research, a number of methods have been used to demonstrate the "show me how it's done" approach used in the Montessori method of education. From the outset when developing vaccines, two fundamentally different approaches have so far been applied. These involve the use of either live or dead vaccines. Two additional approaches – vector vaccines and the mRNA vaccines mentioned a while back – have only recently gained momentum. These new technologies have not displaced the old ones, as is often the case in research, and all four vaccine types continue to be used in parallel.

Live and dead vaccines – the traditional approach

A live vaccine contains small amounts of pathogens that, while capable of reproducing, have been weakened to ensure they don't actually trigger the disease. Despite having been weakened, the vaccine viruses are still able to trigger an immune response. For example, vaccines against measles, mumps and rubella all work in this way. This is because vaccination with a live vaccine imitates an actual infection – the resulting vaccine protection lasts longer and with some vaccines even for life.

By way of contrast, a virus-based dead vaccine only contains pathogens that have been killed and are no longer able to multiply. The body recognises them as foreign and triggers the immune system to produce antibodies without causing an breakout of the respective disease. This is how vaccines against hepatitis A and rabies work. Inactivated vaccines and the antibodies against them can quickly become degraded, meaning that after the first vaccination, repeated vaccinations (known as booster vaccinations) are needed.
In 20th century research, these traditional vaccines, which are based on attenuated or inactivated pathogens, were accompanied by protein-based vaccines. These contain non-replicable viral proteins or virus-like particles that cause an immune system response. For example, vaccines against hepatitis B and human papilloma viruses are based on this vaccine technology.
There are also viruses against which both dead and live vaccines are used. The best-known case is the polio vaccine. The original vaccine developed in 1955 was based on a dead vaccine; the subsequent oral vaccine introduced in 1960 worked with a live vaccine. In turn, the IPV polio vaccine now used in Germany is a dead vaccine.

Vector and mRNA vaccines – the modern approach

For most people, the last time they heard of vectors – if at all – was during their maths lessons at school. With vector vaccines, it's not a case of higher mathematics but a kind of delivery service. In this approach, a harmless carrier virus, which in itself has nothing to do with the disease being vaccinated against, has a piece of genetic material inserted into it that was taken from the virus the vaccine is meant to target. In the case of COVID-19, this is a component of the pathogen's envelope, or more precisely, its spike protein. While the protein cannot cause an infection itself, the body

considers it foreign enough to trigger the immune system. The immune system starts producing antibodies that are then ready to go into action if infection with the actual virus occurs. The job of a vector virus is to place the blueprint for the spike protein into the body's cells.

Before the COVID-19 pandemic, only two vector vaccines had been approved worldwide: one against dengue fever and one against Ebola. For the COVID-19 vaccines, many developers relied on vectors. Four of the 14 vaccines that had been approved in at least one country at the beginning of May 2021 work with vector technology – among them the vaccines from AstraZeneca and Johnson & Johnson/Janssen.

mRNA – the shooting star on the vaccine scene

mRNA vaccines are absolute newcomers to the vaccine world, having only been developed at the start of the COVID-19 pandemic. On 2 December 2020, the world's first mRNA vaccine – BioNTtech/Pfizer's COVID-19 vaccine – was officially approved in the UK. The mRNA in this vaccine enters the body's cells packaged in tiny droplets of fat and causes them to produce a single coronavirus protein. As with the vector vaccines, this is what's known as the spike protein. The immune system then identifies the protein as an unknown invader and starts producing antibodies against it. If a coronavirus shows up at a later date, the antibodies stop it before it can spread.

Compared to the vaccine technologies previously used, the mRNA approach has two advantages in production: the vaccine can be designed in a just matter of days and once approved, millions of vaccine doses can be produced in a very short space of time. The clinical trials for COVID-19 vaccines showed high efficacy and hardly any side effects for the mRNA vaccines produced by BioNTech and Moderna. In the first few

months since vaccination began and with several 100 million people now vaccinated worldwide, the two approved mRNA vaccines have proven themselves as excellent immune system trainers.

COVID-19 vaccines approved in at least one country in the world

6 virus-based dead vaccines	Sinopharm Beijing, Sinopharm Wuhan, Coronavac, (all China), Covivac (RU) Covaxin (India), QazVac (Kasachstan)
4 vector vaccines	Sputnik (RU), AstraZeneca (GB/S), Johnson & Johnson/Janssen (US/NL), Convidecia (China)
2 protein-based dead vaccines	RBD Dimer (China), Epivac (RU)
2 mRNA vaccines	Moderna (US), Pfizer/BioNTech (US/D)

Status: May 2021, country of origin in parentheses, EU approval marked in yellow

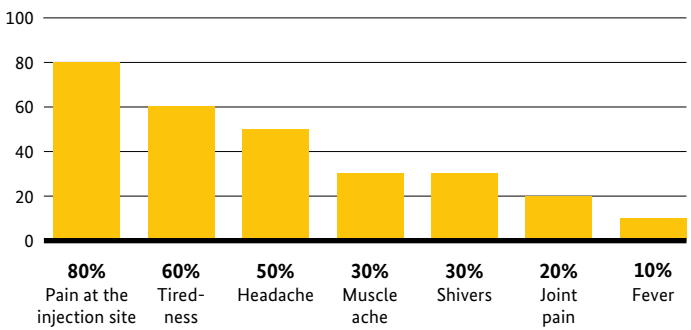
How the body reacts to vaccination

Regardless of the method used in vaccination, it always involves introducing a foreign substance into the body from outside. And no matter how it's done, the body SHOULD react. It should learn to recognise the foreign substance as just that, it should activate its immune system, and it should develop antibodies and defences.

Vaccination reaction

It can happen that the body manages to activate the immune system without you noticing. But as a rule, some clearly noticeable vaccination reactions (side effects) occur – redness at the injection site, malaise, fever, thirst, fatigue in the first few hours or days after a vaccination. For most people, however, these disappear after two to three days at the latest. The immune system has been triggered, it's done what it was trained to do, and the task of developing antibodies is complete.

Frequent side effects



Source: Robert Koch Institute. Reference: COVID-19 vaccination with mRNA vaccines

Allergic reactions

As a rule, allergic reactions occur not in a matter of days, but rather in minutes following a vaccination. They're not so much allergies to the active substance but to one of the other components of the agent that was injected. These accompanying or auxiliary substances are designed to help the vaccine be transported into the body, where it can then take effect. In the case of mRNA vaccines, these are droplets of fat in which the active substance is packed to help it enter the body's cells.

Other vaccine components known to cause allergic reactions include residues of animal proteins such as chicken protein, preservatives and latex components from the stoppers of vaccine vials.

With many allergy triggers, sufferers are already aware of them – people who are allergic to apples tend to leave them alone. But with new vaccines, it can happen that someone is allergic to one of the ingredients without them knowing it. For example, in some people one of the ingredients in the droplets of fat (polyethylene glycol) can cause allergic reactions. Such allergic reactions have nothing to do with the effect of the actual vaccine – polyethylene glycol is used in a wide variety of medicines and can also trigger allergies during their use as well.

For this reason, whenever people are vaccinated, they are supervised for a certain period of time after the vaccination. This is to ensure that in the event of a very severe allergic reaction, known as an anaphylactic shock which can happen within a very short space of time, appropriate, possibly life-saving action can be taken without delay.

Test Subject No. 20
Maybe you've seen the TV documentary "Hirschhausen als Impfproband", in which I took part in a vaccine approval trial. If not, it's still available in the ARD Mediathek (media on demand library). I was one of thousands of volunteers. We were all thoroughly informed about the possible risks in advance. I had no side effects at all – and no wonder. As I now know, I was randomly assigned to the control group, which only received a placebo. The real substance was about to be approved, as those who received it were better protected than those of us in the control group. That's why comparative studies – and patience – are needed in vaccine research.

Side effects, long-term effects

There are occasions in life where people are willing to accept even the greatest risks, such as when receiving treatment for cancer. Many patients are prepared to accept a greater risk of experiencing serious side effects in exchange for a better chance of survival. The situation is similar with operations. Every operation bears a risk – the more severe the operation, the greater the risk involved. But if an operation is the only chance of survival, both doctors and patients will be prepared to accept the risk it brings. At least most of them will.
The situation is different when it comes to vaccination. The person being vaccinated usually has no sign of illness and is in good health. By agreeing to be vaccinated, they want to protect themselves and others. But the risk they are willing to take is far less than with a cancer operation. Because vaccination bears both benefits and risks, particularly

strict standards are applied to vaccines. And as vaccination is voluntary in Germany (with some exceptions, as in the case of vaccination against measles), people can decide for themselves whether or not they think the benefit outweighs the risk. The better the information available to aid their decision, the more informed their decision can be.

Side effects

In the case of traditional vaccinations, such as for tetanus and measles, all of the risks and side effects are known down to the second decimal place. Many millions or even billions of people have received the vaccination and the effects it can have are statistically certain. Take measles: about two in every 100,000 vaccinated people will suffer severe side effects. That's still a risk, but only one of 0.002 percent. On the other side of the equation, there's the equally statistically proven risk that comes from not being vaccinated. Around 100 out of every 100,000 people die of measles (0.1%), and about 3,000 catch pneumonia (3%). With new diseases (such as COVID-19) and new vaccines, not all of the side effects that could occur are known at the time a vaccine is approved. This is especially the case regarding extremely rare side effects, as these usually don't occur during the trials conducted prior to approval. If only a few thousand or even ten thousand volunteers take part in these Phase 3 trials, a side effect that statistically occurs in only one in 50,000 cases may not occur at all prior to approval.

Of course, the situation changes after approval because then the vaccine is injected into hundreds of thousands or even millions of people. Only then can extremely rare complications be detected. This happened in 2009 in a case involving swine flu vaccinations. Five different swine flu virus vaccines had been approved and with one of them, the Pandemrix vaccine, cases of narcolepsy later occurred in one out of a total of

181,000 vaccinated adults and in one out of 18,400 vaccinated children. Those affected suffer from uncontrollable attacks of falling asleep and experience frequent falls.
During the COVID-19 vaccination campaign, a serious side effect has also occurred with the formation of brain thrombosis involving the AstraZeneca and Johnson & Johnson vaccines. It's a side effect that (as of May 2021) occurs in less than one per 100,000 vaccinated people, but it's one that can be fatal. In a situation like this, it's important that cases are carefully investigated and others are avoided wherever possible. This is why vaccines are intensively monitored for side effects, especially in the first few months after they are approved. In Germany, responsibility for vaccine monitoring lies with the Paul Ehrlich Institute, the Federal Institute for Vaccines and Biomedical Products.

Long-term effects
It takes a lot longer to observe potential long-term effects. Of course, with a new vaccine that has only been in use for a matter of a few months, it's impossible to know whether and what long-term effects will occur years down the line. Experience with a large number of vaccines over equally as many years has shown that most of the harmful effects of a vaccine occur shortly after vaccination. However, there are some exceptions. After certain vaccinations, such as those against influenza and HPV, a nerve disease known as Guillain-Barré syndrome can occur in very rare cases.

But the disease can also occur in people suffering one of the infections against which the vaccination is designed to protect. When Germany's Standing Committee on Vaccination (STIKO) recommends a vaccine and a vaccine-related side effect occurs that goes beyond the usual scope of a vaccination reaction, the state has a responsibility to help the person

involved. Depending on the degree of harm caused by the vaccine, the individual may be entitled to claim a pension. For COVID-19 vaccinations, this has yet to be expressly clarified by law.

Vaccine-related myths

The fact that we don't know everything about the risks and side effects of vaccines doesn't mean that they can cause all kinds of strange things to happen. Vaccines can't turn people into zombies, aliens or vampires. Nor do vaccines contain microchips or mind-altering drugs. But there is a story going round that sounds as if there could be an element of truth in it – that genetically engineered vaccines change the body's genetic material. It's just a myth, however – they don't. The mRNA vaccines don't even reach the cell nucleus in which our genetic material, our DNA, is stored. Whatever mRNA vaccines actually do, they do it outside the cell nucleus and nowhere near our genetic material. And while vector vaccines do reach the cell nucleus and also contain DNA, the DNA they contain can't mix with our own DNA.

Where vaccines are concerned, it pays to stick to the truth. Isn't the truth fascinating enough?

3

The history of vaccines – from past to present

It all began with a milkmaid named Sarah Nelmes in the English town of Berkeley. Like many farm workers, she suffered from cowpox (a harmless skin infection) but was somehow spared from contracting the often deadly smallpox. On 14 May 1796, country doctor Edward Jenner drew some of the fluid from Sarah's cowpox blisters and transferred it to his gardener's eight-year-old son. Seven weeks later, Jenner then purposely infected the boy with smallpox. The boy remained healthy and didn't contract the disease. This highly unethical human trial, which today would be expressly prohibited by law, made medical history and ushered in the era of vaccination.

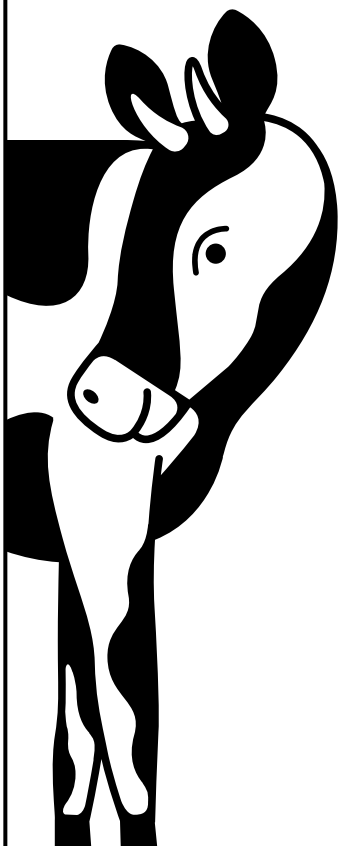
In the 225 years since Jenner's discovery, vaccines have since taken away the fear of more than two dozen infectious diseases – and that's only the beginning.

From smallpox to diphtheria

The Royal Society of England was not amused when in 1797 Edward Jenner submitted his report on the success of his smallpox vaccine. It wasn't a scientific study – how much evidence can a single case produce? If the country doctor had treated 20 or 30 children in the same way and with the same result, then the report could have been published – but that wasn't the case.

But Jenner wasn't put off. He treated a number of colleagues along with additional patients in the same way. A year later, he published the first study on vaccines – it covered 23 cases, but still no Royal Society approval. Not long after, in 1799, the first vaccine using Jenner's method was administered in the U.S. And not long after that, South America, the Philippines and China all followed suit. You could say that the world's first vaccine went 'viral'.

Things remained that way for the best part of the next 100 years. Vaccination (taken from



Vaccination
Derived from the Latin word *vacca* for cow.

the Latin word *vacca* for cow) was a cure for smallpox, nothing more. No one knew how it worked or why – the main thing was that it did.
In fact, it worked so well that it turned a former scourge of humanity into a controllable disease that could be fought. As many as 10 percent of young children in Europe died of smallpox before vaccinations were introduced. One hundred years after Jenner's first vaccination, only one smallpox death occurred per million people in the German Empire.

Foul air, evil pathogens

The second major breakthrough in vaccination came almost a century after the first smallpox vaccinations, with Frenchman Louis Pasteur and Germany's Robert Koch each playing major roles. In the 1870s and 1880s, the two men independently researched how infectious diseases develop and how to keep them under control.
Previously, the spread of disease had mostly been blamed on foul air – so-called miasma. It was only in the second half of the 19th century that researchers gradually realised that viruses and bacteria existed and could transmit disease.
The principle on which vaccination is still based today was discovered by Louis Pasteur in 1880 in his work with chickens. He had left a bacterial culture that caused fowl cholera to spoil. This weakened the bacteria so much that the test animals it was used on no longer died from the disease but only became ill. The chickens then recovered – they were completely healthy and also immune. In the years that followed, Pasteur developed various other vaccines against animal diseases before then going on to vaccinate a human being for the first time on 6 July 1885.
His young patient, nine-year-old Joseph Meister, had been bitten by a rabid dog. Pasteur's rabies vaccine had showed good results in trials on dogs and rabbits, but whether it

would also work on a child was completely uncertain. It did work and Pasteur's vaccine became a world sensation virtually overnight. He had succeeded in proving that vaccines could be used to cure infectious disease.

Antibodies for disease prevention

The next big step was taken by a Japanese and a German. In 1890, Kitasato Shibasaburō and Emil Behring discovered that antibodies that were produced by the body itself could help cure patients suffering from diphtheria and tetanus.

Hygiene saves lives

Back in the 19th century, the greatest medical progress came not from vaccination but from improved hygiene. Cholera was fought simply by using clean water. The cholera epidemic in Hamburg in 1892 was the last major outbreak in Germany and a year later, the Hamburg waterworks began filtering the town's drinking water supply.

Having doctors and midwives disinfect their hands helped to combat childbed fever, which killed scores of mothers shortly after birth. When assistant physician Ignaz Semmelweis introduced this simple measure in Vienna in 1848, he reduced maternal mortality in his obstetrics clinic to one tenth of the previous level. But despite his success, it was to be another 20 years before his method was adopted in other hospitals and clinics.

These defence substances, what we now know as antibodies, are not only suitable for use in the treatment of disease but also in its prevention. But back in the 19th century, achieving medical progress wasn't something that happened overnight. It wasn't until the 1920s that technology had advanced to the point where vaccines against diphtheria and tetanus could be produced. This ushered in the era of mass vaccination and with it protection for everyone.

From polio to measles

It was on 12 April 1955 that the bells began to ring out. Sirens blared and all across the U.S. people sat in front of their radios, hugged each other and wept with joy. Never before and never since has the publication of a medical study caused such a wave of enthusiasm. "The polio vaccine is safe, effective and potent," said Tommy Francis, the man who had led the study. Almost two million children had been involved, and some 200,000 volunteers had helped to test the polio vaccine developed by Jonas Salk. The result: 60 to 80 percent efficacy, and virtually no side effects at all.

It was probably the most generalised research campaign in medical history. Just as the U.S. had won the Second World War, they now wanted to win the war against polio. In the late 1930s, U.S. President Franklin D. Roosevelt had personally launched the campaign. Having contracted polio at the age of 39, he'd relied on the use of walking aids ever since. 12 April 1955, the day that marked the beginning of the end of the disease, also marked the 10th anniversary of his death.

While the polio story isn't quite over, it is nearing the end. While cases of polio are only being registered in a few countries around the world, it's important to continue vaccinating against it because the disease can flare up again.

The mercy of later birth

My mother guarded my vaccination pass with her life. It's quite a historic document. When I was vaccinated against smallpox and polio, the campaign slogan went something like "the oral polio vaccine is sweet, but child paralysis is bitter and cruel". Today, no child need fear smallpox because at some point, the viruses found no hosts. They're like opportunistic thieves – if no one leaves a door open, they get bored and go away. With polio all but eradicated, the vaccination campaign was a great success. A friend, now in his 80s, had infantile paralysis as a boy and still struggles with the after-effects. My generation certainly appreciates that it was spared the disease. I hope subsequent ones will as well.

Post-war boom in vaccinations

It wasn't only child paralysis. In the decades following the Second World War, there was a real boom in children being vaccinated against diphtheria, tetanus, whooping cough, measles, mumps and German measles. They have all lost their impact thanks to vaccination – and thanks to vaccines that Germany has long recommended be used in young children.

Former East Germany had a bit of a head start. The polio vaccine was introduced there in 1960 and only a year later, there were just four cases reported country-wide. Over in the west, in the Federal Republic of Germany, there were 4,000 new cases of polio and no vaccine. It was only in 1964 that former West Germany began administering oral vaccine against polio myelitis, drastically reducing the number of new infections almost down to zero. In addition to the seven traditional vaccines that infants receive (mumps, measles, German measles, polio, diph-

theria, tetanus and whooping cough) six additional vaccines have been added to the list of vaccinations recommended by Germany's Standing Committee on Vaccinations (STIKO).

STIKO recommends vaccinations against

Rotaviruses	The most common diarrhoeal pathogens found in infants and toddlers worldwide
HIB	Haemophilus influenzae: a respiratory infection caused by bacteria, which can have severe long-term effects and is especially harmful in babies
Hepatitis B	A viral infection of the liver
Pneumococcus	Or **Streptococcus pneumoniae** Aggressive bacteria strains that can lead to pneumonia or meningitis
Meningococcus	Aggressive bacteria strains that often cause life-threatening meningitis
Varicella virus	The cause of chickenpox – a mostly harmless disease that can be serious in around six percent of cases

Works like an antibiotic but against viruses

The tremendous effort in the search for vaccines was also due to the fact that a remedy to deal with another scourge of humankind had already been found in the first half of the 20th century. Antibiotics could be used to cure virtually all bacterial infections and inflammations. In 1928, the British bacteriologist Alexander Fleming had discovered the world's first antibiotic, which he called penicillin. It was a discovery he made quite by accident, however. Fleming had forgotten

a bacterial culture in his lab before leaving for the summer holidays. When he returned, the culture was mouldy and in the area where the penicillium mould was growing, the bacteria had disappeared.
Antibiotics soon became the magic potion in the fight against bacteria. But only bacteria – they don't work in treating viruses. Even today, after almost another century of medical research, there's no drug that could even begin to work against viruses in the way that antibiotics work against bacteria. Except, for a series of what are known as antivirals that can slow down both their reproduction and spread. In the fight against disease caused by viruses, there's no alternative to vaccination.

Global vaccination campaigns

Following the successful campaigns in the industrialised countries of the East and West, vaccination became an issue of global scale. In 1980, after the success achieved with smallpox, the World Health Organisation (WHO) set the goal of eradicating polio worldwide – and with similar success. Campaigns were also run to promote the use of other vaccines that were already commonly administered to infants in Germany. For example, in 1980 only six percent of all small children in Africa were vaccinated against measles. By 1990, that figure had risen to 58 percent, and it currently stands at around 69 percent.
These vaccination campaigns have made a significant contribution to extending life expectancy worldwide and in particular to reducing infant mortality. It's impossible to say exactly how large this contribution actually was, as three other positive developments have also played a decisive role. These are better hygiene, better nutrition and the provision of better medical care in the poorest regions of the world. It's a combination of all of these factors that in recent decades has greatly improved both the living conditions and the survival

prospects of people around the world. Only a century ago, on a global scale, one in three children died before the age of five. Just 50 years ago, that figure was one in seven, and 25 years ago it was down one in twelve. At the time of writing, it's one in 26.

The ethics of human experimentation

In the "Nuremberg Code" of 1947, basic ethical rules for medical experiments on humans were laid down for the first time. According to the Code, all such experiments require the express consent of the respective individuals. Their decision must be both voluntary and informed. These rules were formulated after the "Nuremberg Doctors Trial", which dealt with human experimentation during the Nazi era.

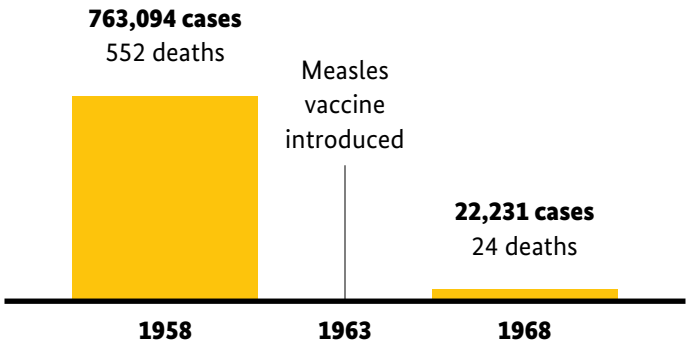
From AIDS to forms of cancer

The success of the vaccination campaigns conducted in the 1960s and 1970s could easily give the impression that viruses had lost their impact – that the answers had all been found and it was simply a matter of spreading the knowledge to the world. But then came the 1980s and AIDS.

AIDS, which stands for acquired immunodeficiency syndrome, was a completely new disease. It was first described in the U.S. in 1981. Its first victims were previously healthy, relatively young homosexual men, which quickly made it clear that it was a disease that was transmitted from person to person – it wasn't just a disease but an infectious disease.

It was also extremely deadly. There was no cure and no recovery. In the early years, the diagnosis "AIDS" was effectively a

Vaccines saves lives
Measles in the U.S.



Source: CDC

death sentence. The shock caused by the new epidemic was correspondingly great – and so was the incentive for medical science to get right down to work. What triggers AIDS? How is it diagnosed? How is it transmitted? How can its transmission be prevented? Is there a cure or can its impact be reduced or even halted? The AIDS research race was on.

A retrovirus gets in the way
As is often the case in science and research, as soon as you find the answer to one question, a whole set of others come up for which answers have to be sought. In 1983 and 1984, two research groups, one in France and the other in the U.S., independently discovered the human immunodeficiency virus (HIV) – a previously unknown virus that was identified as the cause of AIDS.
If HIV causes AIDS and if the immune system produces antibodies against all new viruses that enter the body, then it

should be possible to diagnose AIDS by looking for AIDS virus antibodies in blood samples. No sooner was this said than done. As early as 1985, the first AIDS test using this principle was approved.

And if a virus is the cause of the problem, then a vaccine should provide the answer – as in earlier virus-triggered epidemics such as smallpox and polio. Only this time, it was a case of easier said than done. There is still no vaccine against AIDS and that's by no means because people have given up searching for one. Around the world, research is currently being conducted on several dozen potential HIV vaccines. For some, clinical trials have even been held, but none has been promising so far. This is largely due to a biological quirk of the AIDS virus itself – it's a retrovirus whose genes (like those of most viruses) consist of RNA and (unlike with most viruses) are transcribed into DNA in the body. In the transcription process, a great many errors occur and from those errors, a vast number of different types of the AIDS virus emerge. This makes it difficult for the body's immune system to defend itself against the virus – and equally so for a vaccine to work. Perhaps all that's needed is a new scientific discovery or a new tool that can be used to find an effective AIDS vaccine. But even if a vaccine is never found, it doesn't mean that medicine has reached its limits. Quite the opposite in fact. Research and development of drugs for the treatment of AIDS has been far more successful. At the end of the 1990s, the first drugs were approved that could slow down the activity of the virus. Although the virus is still present in the body and is still contagious, it causes less damage. The AIDS drugs used today usually contain several of these antiviral agents. They have drastically reduced mortality in those affected and often enable them to lead almost normal lives.

The first anti-cancer vaccines

Once a death sentence but now treatable in many cases – that applies not only to AIDS but also to cancer. Early detection, operations, radiation and medication ensure that cancer isn't a hopeless cause. It can be treated and often beaten.

Vaccinations are also now helping in the fight against cancer. According to the World Health Organisation (WHO), 16 percent of all cancers are triggered by infections. This is where vaccines come in and two are already in use. The first, a vaccine against hepatitis B, reduces the risk of liver inflammation that is a cause of liver cancer. The second, an HPV vaccine, protects against human papilloma viruses. These cause 70 percent of all cervical cancers and are also responsible for throat and anal cancers. In Germany, the HPV anti-cancer vaccine has been recommended for girls between the ages of 9 and 14 since March 2007 (and for boys since 2018).

Even if everyone were to be vaccinated against hepatitis B, liver cancer would still exist. And even if everyone were to be vaccinated against HPV, there would still be cervical cancer. The problem is that in both cases, infections are not the only cause of the respective cancer. But thanks to the vaccines and vaccination, there are fortunately far fewer cases occurring. As we all place our hopes in a breakthrough that provides effective anti-cancer medicines, we tend to forget that we already have vaccines that can actually prevent at least some forms of the disease.

From flu to COVID-19

Of all the diseases for which vaccines are now available, influenza is by far the most common. It affects between 10 and 20 percent of the global population each year. While the mortality rate is very low in terms of percentage (only between one and five in every 10,000 cases are fatal), in absolute terms the large number of cases results in a large number of deaths. The World Health Organisation (WHO) estimates that between 300,000 and 700,000 people die from influenza each year.

Master of mutation

Why so many deaths despite vaccination? Sadly, the flu viruses are masters of evasion. Compared with the flu virus, there's no other virus that's so eager to mutate. In no time at all, it develops a vast number of mutations. These differ from the previous versions so the vaccine used in the previous season has to be replaced by a new one for the following year.

Partner jabs

It's not often that German researchers receive the Nobel Prize, but then the vaccine they developed to prevent cancer is brilliant to say the least. The HPV vaccine provides protection against several types of cervical cancer. It's also recommended for boys even though we males aren't equipped with a cervix. That's because getting vaccinated is never just about protecting ourselves – it's also about protecting others and achieving herd (community) immunity. HP viruses are also a contributor to cancers of the throat, the anus and the penis, the latter being something women don't have. That's why it's best if everyone gets vaccinated before having sex for the first time, regardless of their age or potential partner.

Although flu vaccines have been available since the 1940s, there's still no evidence of sustained immunity to influenza. This is despite the fact that every year, a new flu vaccine targets four different virus variants – all in the hope that this heavy ammunition will hit as many as possible flu viruses out there in the field.

The recent flu season 2020–2021 was particularly mild worldwide. This wasn't so much because the latest vaccine was particularly effective, but because there were significantly fewer flu infections. And that was largely due to the global safety measures put in place to combat COVID-19. Contact restrictions and the avoidance of large gatherings reduce not only the risk of COVID-19 infection but also the risk of catching the flu.

Spanish flu with origins in Kansas

The deadliest pandemic of the 20th century became known as the "Spanish flu". From February 1918 to April 1920, a particularly dangerous flu virus infected about a third of the world population and claimed somewhere between 20 and 50 million lives. The most likely outbreak site was a U.S. Army training facility in Kansas. The soldiers based there then took the flu out into the trenches of the First World War in Europe. The only real connection between the flu and Spain was the fact that the Spanish newspapers were particularly open when reporting about the new disease.

A virus against the world, the world against a virus

The main feature of the 2020–2021 vaccination season was the virus known as SARS-CoV-2. In the first few months of 2020, the coronavirus spread across the world from the Chinese city of Wuhan. This is when researchers around the world quickly set about developing vaccines to fight the COVID-19 pandemic the virus had triggered. The first two vaccines were approved in late 2020. Both are based on a technology that had never been used in the history of vaccination. These were the mRNA vaccines already described earlier.

From complete outsider to world best

But how did a technology that was virtually unknown in the public domain rise to the top of medical research virtually out of nowhere? Part of the explanation lies in fat, a substance we don't usually like to be associated with. The mRNA researchers succeeded in cleverly packing their active ingredient into microscopically small droplets of fat in such a way that it can easily enter our cells and trigger them to produce antibodies. Another explanation is that the new technology wasn't really that new. As early as in 1990, at the University of Pennsylvania in the U.S., the Hungarian biochemist Katalin Karikó began research on ways to artificially produce messenger RNA (mRNA), a central component of human cells that is needed to produce proteins in the cells. Karikó was 35 at the time and her chosen research topic would become her life's work.

But then something happened that had once happened to Galileo Galilei, Edward Jenner and Ignaz Semmelweis – something that's possible even after centuries of high-tech, cutting-edge research. A ground-breaking discovery made by a complete outsider is first ridiculed and then ignored by renowned experts in their field. Only this time, there was a slight difference: the outsider wasn't a man but a woman. No

one was interested in Karikó's work; not only did she not get the professorship she had hoped for, she received no state funding and was demoted to a lower rung on the university's research ladder. It seemed mRNA was an academic dead end. It took almost a decade for the tide to turn. In 1997, standing at the faculty's copy machine, Karikó met a comrade-in-arms, immunologist Drew Weissman. Together they developed a solution to get the mRNA into the body without the immune system rejecting it. In the same year, a research project on immunotherapy was launched at the University of Tübingen in Germany, and as part of that project chemistry student Ingmar Hoerr wrote his doctoral thesis on RNA vaccines. In 1999, he applied for his first patent on the technology and a year later, he founded the company CureVac to develop RNA vaccines.

From 2005 onwards, other researchers started entering the arena. One of them, Derrick Rossi, founded the mRNA start-up Moderna in the U.S. in 2010. Two others, Uğur Şahin and Özlem Türeci, had already founded BioNTech in the German city of Mainz in 2008. So when COVID-19 broke out in 2020, these three companies were all on hand to catapult the former outsider's method to the forefront of global vaccine research. As it happened, Katalin Karikó was actively involved in the breakthrough involving her own idea – she has been Senior Vice President and Head of Research at BioNTech since 2013.

Platform technologies

Another reason for the breakthrough is platform technology, a new approach being used in vaccine research. In this process, certain components are inserted into an already existing proven basic structure (the platform) for a particular vaccine. This is the case with the droplets of fat into which the active ingredient is packaged in the production of mRNA vaccines. If all the components of the packaging can remain the same and

it's only the content that changes from vaccine to vaccine, this simplifies not only production but also testing and approval. The extent to which a platform-based strategy can simplify production and multiply the number of products was demonstrated at the end of the 1990s by the Volkswagen Group. Cars from VW (Golf, Jetta, Beetle), Skoda (Octavia), Seat (Leon) and Audi (A3, TT) were built using one and the same technical production basis. The design and equipment of the cars differed from model to model, but the platform remained the same in each case – and with it most of the components and production processes.

Likewise, in the production of mRNA vaccines, if the fat droplet packaging platform always stays the same, then the question of possible allergies, for example, doesn't have to be answered each and every time. This saves both time and money without compromising safety. It also enables smaller companies and research institutes to participate in the vaccine race. If all the stages of a development process no longer have to come from a single source, companies specialising in the active ingredient have an importunity to work with platform specialists and in doing so significantly increase the number of possible vaccine developers and thus the number of possible vaccines.

4

Conflicts of interest – society's response

“All for one and one for all!” – that was the cry of the Three Musketeers in Alexandre Dumas’ novel of the same name. That kind of unity and cohesion, of looking out for one another, not only gives fictional heroes courage and strength – it’s also one of the best-known recipes for success. In the course of evolution, we’ve survived not as individuals, but as communities – as tribes, clans, families and the like.

Human beings are social beings and this makes vaccination a social or communal endeavour. People who get vaccinated protect not only themselves, they protect their families, friends, neighbours and other fellow human beings. But then human beings are not just social beings – they are individuals with their own bodies, minds and dignity. We might be willing to make sacrifices for others, but our main aim is to benefit ourselves.

Must I be vaccinated?

When epidemics break out, action must be taken. As more and more people become infected, fall ill or even die, measures have to be put in place. In most cases, the right course of action is taken. For example, after the cholera epidemics in London (1854) and Hamburg (1892), water supply and hygiene conditions in the poorer quarters were improved. There have, however, been times when the measures taken were wrong. When the plague struck Europe in the 14th century, it was generally recommended that the sick be bled and that aromatic herbs be burned to disperse the foul air caused by victims' "infected breath".

First mandatory vaccination

Mandatory vaccination was first introduced in Germany in 1807. It didn't apply in the whole of Germany, which didn't actually exist at the time, but in what was then the Kingdom of Bavaria.

19th century anti-vaccinationists

Such measures are often controversial. This was certainly the case with the smallpox epidemic that broke out between 1870 and 1871 during the Franco-Prussian War. To combat the epidemic, the government of the newly founded German Empire passed an Imperial Vaccination Act on 8 April 1874. All Germans were required to have children between the ages of one and twelve vaccinated against smallpox; those who failed to do so were threatened with three days in prison or a fine of up to 50 marks.

Mandatory vaccination had two direct outcomes: the number of smallpox vaccinations increased significantly, while the number of smallpox cases greatly decreased. The epidemic that lasted from 1870 to 1873 was the last major smallpox outbreak in Germany. The indirect outcome of mandatory vaccination was the emergence of an anti-vaccination movement. Followers rallied behind the magazine "Der Impfgegner" ("The Anti-Vaccinationist", as of 1881) and the "Deutscher Bund der Impfgegner" (German Association of Anti-Vaccinationists or the German Anti-Vaccination League, as of 1896).

The movement comprised various groups: vegetarians and nature lovers, anti-capitalists and anti-Semites, establishment and technology critics, Christian fundamentalists and anthroposophists. Their motives were quite different but nonetheless similar to those expressed by today's anti-vaccinationists (or anti-vaxxers as they are known):

- Whether to be vaccinated or not should be decided not by the state but by the individual.
- Vaccination might prevent one disease but causes others.
- There could be harmful long-term effects that are not yet known.
- During vaccination, animal material (at that time from cowpox scabs) enters the human body.
- Vaccination interferes with the natural course of events.
- Healthy people are strong enough to fight the disease themselves. Treatment with cold, heat, healthy food and fresh air suffices.

Vaccine incident in Lübeck

The world's biggest vaccination accident of the 20th century happened in 1930 in the German city of Lübeck. A total of 256 newborn babies had been vaccinated against tuberculosis using a contaminated vaccine. Instead of becoming immune, many of the babies became ill and 77 died of tuberculosis. Two years later, in 1932, the head of the Lübeck health department and the director of the hospital involved were found guilty of failing to adequately test the vaccine. They were subsequently charged with negligent homicide and sentenced to time in prison.

Between forced vaccination and the freedom to choose

In the debate about mandatory vaccination, the underlying conflict that emerged more than a century ago is as relevant today as it was back then. Is the decision about what happens to my body mine alone? Do parents decide exclusively on behalf of their underage children? Or are there cases where the state can have a say or perhaps even decide against the will of the people concerned?

There's no universal answer – it depends on the time and the place. A hundred years ago, the situation was different compared with how things are today. And it can be different in Muslim and Christian regions, for small children and for teenagers, and where smallpox and influenza are concerned. There are even differences between neighbouring countries. In Italy, France and Poland, some vaccinations are mandatory, while Austria and the Netherlands largely rely on voluntary vaccination – they recommend which vaccinations should

be given at which age, but the decision lies with the person to be vaccinated or their parents. In Germany, vaccination is not mandatory – not even for COVID-19. But there is one exception which was only recently introduced. Since 2020, proof of measles vaccination has been a prerequisite for children and staff in community facilities, such as schools and daycare centres. An appeal against the requirement was rejected by the Federal Constitutional Court, which found that the need for adequate vaccination protection against measles has priority over potential exclusion of unvaccinated children from childcare provision.

In cases where a personal decision could negatively affect others, the state can limit an individual's freedom of choice. This holds true in all policy areas: for example, in no country in the world can drivers freely decide whether to drive on the right or the left side of the road – the state has made right-hand or left-hand traffic mandatory for everyone.

Looking further afield

What's the difference between epidemic and pandemic? Pandemic means everywhere. That's why the COVID-19 pandemic won't be over until not only people in Germany have been vaccinated but also large sections of the global population. Although there's a long way to go, its importance remains. Because disease occurs and spreads more globally now than it did in the past, it must be ensured that the vaccines used to combat disease are distributed not just globally but also fairly. This can help prevent new mutants. In improving global health, the better off people are around the world, the better off we all are at home. And it's the same for animals – healthy people can only exist alongside healthy animals on a healthy planet earth.

The need for good arguments

In former East Germany, many more areas of life were regulated by the state compared with the situation in former West Germany. So it goes without saying that vaccinations were mandatory in the GDR. Some 20 different vaccinations were made mandatory for children. Parents who refused – and yes, some actually dared to do so – were summoned to an instructional talk with the district physician responsible for medical hygiene. Those who remained stubborn were summoned to an appointment at the Ministry of Health in Berlin.

In the Federal Republic of Germany, emphasis was almost always placed on education rather than coercion. Only smallpox vaccinations were mandatory (until 1976), all others were voluntary. The state thus has to find good, convincing arguments to explain to its citizens why they and their children should be vaccinated.

The vaccination rates for children are comparatively high. When pre-school children are medically examined to assess their readiness to start school, more than 90 percent have been vaccinated against diphtheria, tetanus, whooping cough, Hib, polio and measles. Only in the case of hepatitis B is the vaccination rate slightly below 90 percent.

The rate is significantly lower for adults. For people over 18, only three booster vaccinations are recommended: diphtheria and tetanus every ten years and whooping cough once in adulthood. But only about half of the adult population actually follow this recommendation.

Who benefits if I'm vaccinated?

Schloss Lössnitz or Lössnitz Castle sits high above the banks of the Elbe River in Radebeul near Dresden. According to the modern description published by the Saxon State Office for the Preservation of Monuments, it's a classicist building crowned by three towers, with a "representatively decorated entrance hall with ionic wall pilasters, console friezes and a coffered ceiling". The castle was built in 1895, not by a prince but by Friedrich Eduard Bilz (1842–1922) – a naturopathic entrepreneur who made his fortune as an anti-vaccinationist. The smallpox epidemic and the subsequent Vaccination Act of 1874 had awakened interest in health issues among many people in Germany. At meetings of vaccination opponents, Bilz, a grocer by trade, was one of the few who could formulate his arguments coherently without using technical terms. His following grew slowly at first and then in 1888 it suddenly took off: his naturopathy encyclopaedia, "Bilz, The New Therapy: A textbook and reference work for everyone in sickness and in health", sold 3.5 million copies and became the nucleus of a naturopathy group – Schloss Lössnitz became its flagship spa clinic.

Incidentally, this is what Bilz's encyclopaedia advised in dealing with smallpox vaccination: "The best way to stop the poisoning effect of the vaccination is to suck out the vaccination site vigorously by mouth immediately following vaccination."

Even back then, there was good money to be made from a cleverly-worded anti-vaccination critique. But of course, that's not the only way to get rich. As in every major crisis past and present, accusations abound that some people are making lots of money from it – have even caused it and ignore the suffering of countless others because they themselves stand to benefit from the outcome.

Heroes and villains

Some of the accusations are not without foundation. There is no crisis without winners, and extreme situations regularly produce not only heroes but villains. This was also the case with COVID-19. But in pandemics, villainous stories tend to be a fringe occurrence. At their centre are medics and researchers wanting to combat the virus raging around them. They set about searching for the right medicine, the right surgical method, the right vaccine to alleviate or even end people's suffering. But of course, researchers are only human. In addition to benefiting others, they may also want to benefit themselves. Perhaps they hope to become rich or famous or even both as heroes of the pandemic. They know that to do so, they have to achieve success in beating the pandemic.

Is autism linked to vaccination?

The short answer is: no.

The longer answer is that there is no link between vaccination in young children and the occurrence of autism.

The origins of the rumour: in 1998, using data on 12 children, physician Andrew Wakefield claimed that there could be a connection between autism and vaccination. Years later, Wakefield was proven to have manipulated the data he used. In 2019, a Danish study using data from 657,461 children born between 1999 and 2010 proved there was no link.

The AIDS transmission myth

When AIDS broke out in the 1980s, the origin of the virus was unknown. Among the assumptions at the time were that the virus had escaped from a biological weapons laboratory or it was a secret service conspiracy. Since then, virologists have established beyond all doubt that the virus has been present in African apes for thousands of years and probably jumped from them to humans about a century ago. The oldest known human blood samples containing the AIDS virus date back to 1959.

To achieve the desired success, they have to work closely with national governments, authorities, institutions and in many cases with companies. While researchers may be able to find a vaccine by working entirely by themselves, they cannot approve their vaccine for use. Nor can they produce millions of vaccine doses or distribute them throughout a country or even around the world. That's why there's always been close cooperation between government, industry and research when it comes to developing and producing vaccines. This is completely independent of whether the researchers work for pharmaceutical companies, at universities, in hospitals or for state-run institutions.

Diversity in research

This level of diversity can now be seen in the development of COVID-19 vaccines. Let's stay with the 14 different vaccines that were licensed in at least one country just 16 months after the pandemic began. Five were developed in China, four in the U.S. and/or Western Europe, three in Russia, and one each in India and Kazakhstan. The developers include state

institutions (such as the Russian Academy of Sciences), universities (such as Oxford University), state-owned companies (such as Sinopharm) and private companies (such as Sinovac, BioNTtech and AstraZeneca).
There is similar diversity in vaccine prices. There are vaccines that are distributed at cost price, those whose price has been set by the government and vaccines for which the producers have negotiated a price. Prices can also vary depending on the quantities ordered and the delivery dates agreed.
It could be that some of the parties involved are particularly interested in their share price. Others might want to ensure their party wins in the next election. Still others might hope to gain foreign policy advantages from vaccine exports. There will no doubt be a multitude of other motives as to why someone pushes ahead with the product of a particular vaccine. But one thing is certain whatever the incentive: success is measured by how well the vaccine combats the pandemic and by how much it benefits people.

Saving 50 million lives

We can neither see nor identify the most important and most frequent beneficiaries of vaccination. These are the people who don't get sick, don't die and don't have to be vaccinated. If COVID-19 hadn't been stopped, if it had been allowed to run its course so that sooner or later it would have infected every person in the world, about half a billion people would have become seriously ill and about 50 million people would have died. Those who were spared this fate thanks to the various measures, medicines and vaccines all benefit from the fight against pandemics. We might not know who they are, but what we do know is that it could be any one of us – you, me, a member of our family or someone among our friends.

If I don't get vaccinated, what happens then?

Initially, nothing at all. This is because the immune system is not pre-informed – it only acts when the virus attacks and then often that's too late. Others, whose immune systems have the advance information from the vaccination, are better prepared for the attack.

Without a vaccination, nothing happens at first either to the immune system or the individual. If vaccination is voluntary, the state may not penalise you if you don't get vaccinated. In real life, however, it can certainly feel quite differently. In many cases you're not dealing with the state but with companies that set their own rules. An airline, for example, may make vaccination a condition for travelling by plane. Shop owners might require a vaccination to enter their shop, a concert organiser when you try to purchase a ticket, and so on. This isn't some form of arbitrary harassment. First and foremost, it's about protection. It's about protecting their other customers from infection and about protecting their company from being taken to court. For example, will a bus company have to pay damages or compensation for pain and suffering caused if passengers catch the disease from someone who hasn't been vaccinated? And then there's the competition: if the competition only sells tickets to those who have been vaccinated and people only buy from them, it makes sense to follow suit and demand proof of vaccination as well.

A risk for us – and for others

Competition can also play a role in government restrictions for non-vaccinated people. If Spain only wants to let holidaymakers who have been vaccinated against COVID-19 use its beaches in the summer, it wants to ensure that all holidaymakers who have made reservations can enjoy them-

Back on stage

Most of you will know me from television or from my books. Even though I'm still a doctor at heart, I'm in my absolute element on stage, performing live in front of an audience. I love spreading happiness and sharing my ideas through direct interaction with people. And I really miss performing in front of an audience, in front of you all.

Like everyone else who works in entertainment, I look forward to the day when we can stand in front of an audience again – one that has been vaccinated and is protected, or perhaps is comprised of people who have recovered from the disease. In all areas of life, the only thing we should infect each other with is laughter.

selves without worrying about becoming infected.

For people in Germany, that might seem like an attractive option after more than a year of life in the pandemic. But the main reason for those entry restrictions is to protect the local residents as well.

The plague was brought to Europe in the 14th century by long-distance traders from the region around the Black Sea. Smallpox was taken from Europe to America in the 16th century, wiping out entire native communities in many places.

In the 21st century, an unvaccinated exchange student from Berlin caused an outbreak of measles in France – and in 2020 infected travellers spread COVID-19 around the world. Unvaccinated people can become infected and pass the virus on – they are a risk to themselves and to others.

Everyone is free to decide for themselves the level of risk they're willing to take. But their freedom of choice reaches its limits where their decision could affect others or

expose others to harm. In many situations, just where those limits lie in individual cases is a matter of dispute – be it a road traffic issue or infection protection. And whenever something is disputed, there are debates big and small, regulation and legislation, lawsuits and court decisions.

Easing of the situation after the vaccination campaign

During a vaccination campaign, the risk to which others are exposed is assessed differently than when the campaign has come to a close. At some point, everyone who wants to be vaccinated has been vaccinated. In the case of the COVID-19 pandemic, Germany will probably reach that point in autumn 2021 – the U.S. is likely to get there during the summer months. But in many African countries, it won't be reached until 2022 or 2023. Once it has, the unvaccinated may no longer pose a risk to society, but they will still pose a risk to themselves – and to two other non-vaccinated groups:

- Those who don't want to be vaccinated
- Those who cannot be vaccinated for medical reasons (such as allergies) or because the vaccine has not been approved for use in the group in question (such as children)

For the second of these groups, the state must continue to ensure that the risk of infection is kept low. But as it does, access restrictions for the unvaccinated should no longer be the primary tool. That just leaves one major disadvantage for those who don't want to be vaccinated – they can get the virus, become sick and even die. At the end of the day, it's their decision, their self-chosen risk.

Bringing an emergency situation to an end

Unlike all the other vaccination campaigns that have gone before it, the expectations for the COVID-19 campaign are different. The others were designed to ensure that something changed for the better: that fewer people would suffer, fewer children would have to die, and that the victory over a disease would improve people's lives. By way of contrast, the COVID-19 vaccination campaign has been designed to ensure that the better life we once had returns – that the emergency situation comes to an end and that life goes back to the way it was before.

From pandemic to epidemic

From a purely virological standpoint, this is not the way things will happen. We have to assume that even with the best possible success, the vaccination campaign will not completely eradicate the coronaviruses. A virus that has infected hundreds of millions of people worldwide and is also as mutagenic as this particular coronavirus has shown itself to be will not entirely disappear. It will remain with us and will probably become endemic. Just like the four other coronaviruses that regularly infect people and cause mild colds.

Between five and 30 percent of all colds can be traced back to these four viruses – their scientific names are HKU1, OC43, NL 63 and 229E. These are usually contracted for the first time in pre-school age and almost always take a very mild course. It's quite possible that the pandemic coronavirus SARS-CoV-2 will one day have similarly harmless effects. But if the course of the disease remains more severe or even dangerous following infection, this new virus could be treated just as we treat measles – by vaccinating small children. And if immunity

wears off, the vaccination would simply be refreshed in the form of a booster shot.
This would require a vaccine that is well tolerated by young children, one that combines high efficacy with minimal side effects. It could be one of the current COVID-19 vaccines or perhaps a completely different vaccine. The studies conducted during the current pandemic have yet to produce a result that would allow a vaccine to be approved for use in small children.

From pandemic situation to the new normal

While the endemic state that follows the pandemic will still demand a lot in terms of time, energy and funding, it's a far cry from the state of emergency that began in early 2020 when the COVID-19 pandemic began. We'll enter a new normal, but one that will feel different to the normal we knew before, not least because of the dramatic experiences, situations and scenes to which we've been exposed.
The Indian-American technology philosopher Venkatesh Rao came up with the idea that the coronavirus pandemic can be likened to vaccinating society, in that it's a severe but rarely fatal threat that confronts every individual and every institution with extreme situations. Situations from which, says Rao, we can learn ways to enable us to cope better in more severe crises in the future – crises such as those we could soon be facing as a result of climate change. Although for the moment we're attempting to monitor the immediate and shorter-term side effects of this societal 'vaccination', it will be up to us to determine what the long-term effects will be.

All for one, one for all

Of course, there have also been a number of positive outcomes that have arisen from pandemics. For example, economic historians draw a direct line from the plague in the 14th century to the Renaissance and the emergence of the modern era a century later. The millions of deaths caused a shortage of labour, which in turn led to higher wages and ultimately to the trend towards modest but wide-spread prosperity. In the 19th century, the cholera epidemics in Europe's metropolises brought improved hygiene and more liveable cities.

But still, the dark side of every pandemic remains. They always bring death and destruction, which can sometimes be accompanied by frenzy and terror. In 1348, in many parts of Europe, the Jewish population was blamed for causing the plague; thousands were killed and entire Jewish communities wiped out.

Uniting behind the cause
The strong are often most powerful when they act alone. But in a pandemic, there's strength in numbers – it can be conquered more easily when everyone fights it together.

Just because it doesn't affect us personally or because others are already busy managing the situation, doesn't mean we should sit back and relax while a pandemic rages around us. A pandemic can affect everyone and anyone – old and young, women and men, rich and poor – and has only been defeated when it's been defeated around the world. That means when people everywhere have access to an effective vaccine. If that doesn't happen, the disease can easily flare up and spread again, from the remotest corner of the world to anywhere around the globe. The best way to overcome a pandemic is to unite and work together: one for all, all for one.

GLOSSARY

Antibodies – substances formed by our body's immune system. They trigger a defence reaction against a certain substance. They can make us immune to disease but can also trigger allergies.

Bacteria – small, single-celled organisms – most of them benign – such as the approximately 100 trillion bacteria that live in the intestine of a healthy adult. Some, however, can cause disease, such as coli bacteria, staphylococci, mycobacteria and others.

DNA – the abbreviation for deoxyribonucleic acid and the substance of which genetic material is made. And not only ours – in all living things, DNA is the carrier of hereditary information.

Epidemic – an epidemic is a disease that occurs regularly in an area but with a roughly constant spread. This is the case, for example, with malaria in tropical Africa.

Immune system – the collective term for the body's combined defence systems against microorganisms, foreign substances and other threats. The most important components of the immune system include specialised cells (such as T cells) and antibodies.

mRNA – the abbreviation for messenger ribonucleic acid. It is found in every cell of every living being and provides the blueprint for proteins produced in the cells. The blueprint can be used to produce mRNA vaccines.

Mutations – random changes in the genetic material of humans, animals, plants and viruses. Some viruses, such as influenza or coronaviruses, mutate particularly frequently. A mutation can cause the protection provided by a vaccination to either weaken or disappear.

Pandemic – a new, globally emerging and spreading infectious disease. In the 20th century, the most severe pandemic was the Spanish flu from 1918 to 1920. In the 21st century, the most severe pandemic seen so far is the current COVID-19 pandemic.

Vaccine – derived from the Latin word "vacca" for cow.

Vector vaccines – a relatively new vaccination technology. The actual active substance is packed into a harmless carrier virus (the vector) that enables it to reach the inside the cell. Viruses are relatively short pieces of genetic material surrounded by an envelope or cover. They have no metabolism and are only able to reproduce in the cells of other living organisms. To do so, they penetrate the cells of a host, force them to produce new virus particles and then usually go on to destroy them.

FURTHER INFORMATION

The Vaccination Booklet for Everyone online
The online version of The Vaccination Booklet for Everyone as well as other related information is available at: *www.dasimpfbuch.de*
(available for download in several languages).

Current information from "Zusammen gegen Corona"
The Federal Ministry of Health (BMG), in collaboration with partners, publishes information as part of the "Zusammen gegen Corona" initiative to promote health protection during the pandemic and focuses on COVID-19 and COVID-19 vaccination. Current information, videos, downloads and materials used in the "Deutschland krempelt die #ÄrmelHoch" campaign can be found at: *www.zusammengegencorona.de*, *www.corona-schutzimpfung.de* and also via the BMG's social media channels.

Federal Centre for Health Education (BzgA)
Information having to do with vaccines and vaccination, with various services and downloads for all target groups. See: *www.bzga.de* and *www.infektionsschutz.de*

Specialist information from the Robert Koch Institute
At *www.rki.de/impfen* practitioners and experts can find facts and figures, detailed information and official documentation on the efficacy, safety and monitoring of COVID-19 vaccines and vaccination. There is also a vaccination schedule for the vaccines recommended by Germany's Standing Committee on Vaccination (STIKO, *www.stiko.de*).

Specialist information from the Paul Ehrlich Institute
Specialist information concerning the approval and monitoring, quality, efficacy and safety of vaccines and medicines is available at: *www.pei.de*

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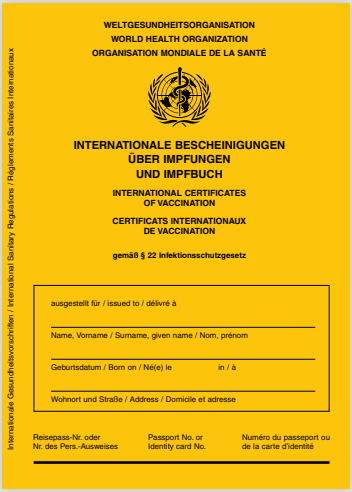
Write your own vaccination booklet

Vaccinations can protect you from a variety of serious diseases. They document the progress of modern medicine and protect us all the way from infancy to old age. The vaccines we approve are both reliable and safe. By deciding to be vaccinated, you protect both yourself and others from avoidable sickness and suffering.

Jens Spahn
Federal Minister of Health



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Some 225 years after the world's first successfully administered vaccination (against smallpox), a new vaccination campaign is underway across the globe. This time the virus being fought is COVID-19. In the same way that the pandemic threatens us all, getting vaccinated provides us with the protection we all need. The vaccine helps the immune system to prepare for a viral attack and be better able to fend off a virus should it attempt to intrude.

This vaccination booklet is designed to help you make up your own mind about the benefits and risks of vaccination. The aim is for you to be able to make an informed decision and feel good about whatever it is that you decide.

"We all have a right to good health. The only thing I should ever infect others with is my sense of humour and good mood." **Eckart von Hirschhausen**

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