Vilnius University

Faculty of Philology

Department of English Philology

Brigita Bekėžaitė

Multimodal Metaphors in Educational Animated Videos

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Supervisor: Assist. Prof. Dr. Justina Urbonaitė

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Abstract

The rapidly changing perspectives and demands of pupils challenge educators to come up with new ways to explain complex concepts, one of which is the use of animated videos that focus on teaching viewers about those concepts. Studies find that animation stimulates interest in learning and benefits students with autism spectrum disorder. Metaphor is one of the components of these videos that helps portray novel or strange phenomena in a way that would seem more familiar and engaging to the learner. Metaphors have been used in education even in writings of philosophical authors, such as Aristotle, Epicurus, and Lucretius, among others. After researching the topic, it seems that there have been studies conducted on metaphors in education, metaphors in animation and the benefits of using animation in education, however, there have been very few studies on metaphors in educational animations. Hence, the aim of this paper was to analyse animated educational videos from the YouTube channel Kurzgesagt, categorize them into subjects explained in the videos and see how the multimodal metaphors extracted benefit the explanation. Twenty videos from the playlist about medicine and biology were found to have at least one occurrence of multimodal metaphor. Out of the following categories: GMO, animals, health dangers, cancer, intelligence and energy, immunity and health – the most videos were about immunity and health, and out of all the analysed videos the source domain of *war* was found to be the most prevalent. Other source domains occurred much less frequently, mostly only once, suggesting that the metaphors used in the animated videos are very specific and diverse. It was found that multimodal metaphors were only a small contributor to explaining the complex subject matter of the videos and further research would need to be done in order to conclude how the metaphors influence the viewers' understanding of the topics those videos deal with.

1. Introduction

In an era characterized by rapid change, educators encounter the challenge of explaining complex concepts to young learners. This necessitates innovative approaches to teaching, as generational shifts alter perspectives and demands. Educators face an enormous challenge with the change of generations and their perceptions of the world, so the teaching methods and language used has to constantly be updated. The impact of the Covid-19 pandemic is also undeniable, as teachers had to adapt to online lessons and lectures, often trying out new methods of presenting information. Metaphors have been used in education for a very long time (Low 2008), but they are evolving with the times and are being used to explain new concepts as well as old ones. Furthermore, with the internet becoming an indispensable part of humans' lives, attention spans getting shorter (Bradbury 2016), teachers are employing different resources, which may help with different learner types: making quizzes more like a game through Kahoot, which helps the kinaesthetic learners to feel immersed; or showing YouTube videos in class which can be a benefit to auditory and visual learners.

Research finds that the visual medium is useful in education, so as technology advances, educational tools have shifted from text-centric to image-based and even dynamic animation to help with understanding complex concepts (Leung & Pilgrim 2011). Most of the research on the benefits of animation for educational purposes is conducted in classrooms with children and teenagers, but the findings suggest animation stimulates the interest in learning (Xiao 2013) and it has high effectiveness when teaching students with autism spectrum disorder or other special needs (Baglama et al. 2018). Studies also show that the selection of appropriate videos by the teacher is very closely related to the effectiveness of the process of teaching (Ismail et al. 2017). Lowe and Schnotz (2008) found that although animation is greatly helpful in education, animators have little to no guidance on what is most effective for specific fields of education, and quoting that under some circumstances, animations have even had negative effects on learning.

Similar to animation, metaphor is employed to help visualising abstract, invisible and complex concepts, such as space, time or the human body. For example, even in the writings of philosophical authors, such as Aristotle, Epicurus and Lucretius, metaphors are used "to explain meteorological phenomena and expound cosmological ideas (Taub 2012)." Spatial metaphors are very widely researched, because they are a part of everyday speech, and it would be a difficult task to come up with novel metaphors for describing time or movement. As a more recent example, with the Covid-19 pandemic, research has shown that the metaphors used in discourse about coronavirus in the verbal and written modes have been found to be mostly

related to war (Rohela el al. 2020; Marron et al. 2020; Craig 2020), which is to be expected as it is a conventional metaphor used when speaking about illness. These metaphors also mirror the metaphors that were used during the AIDS crisis (Craig 2020) and when dealing with cancer patients (Marron et al. 2020).

From my research I can observe that both animation and metaphor are helpful to educate people. There have been studies done on metaphors in education, metaphors in animation and the benefits of using animation in education; however, there seems to be very little research on metaphors in educational animations. Therefore, the aim of this paper is to examine multimodal metaphors in educational videos and discuss their role in fulfilling educational functions. More specifically, the objectives are as follows: to collect a sample of educational videos from a popular educational YouTube channel that uses primarily animation; to categorize the videos into topics which they discuss; to extract multimodal metaphors from the animations; analyse what types of metaphors can be detected in the selected set of animation videos; and to see how the metaphors used may help the audience understand the complex concepts that the videos deal with. I will be relying on Conceptual Metaphor Theory (CMT) developed by Lakoff and Johnson (2003) to identify the metaphors, and the theoretical framework presented by Charles Forceville (2008) for pictorial and multimodal metaphor analysis.

Lakoff and Johnson (2003: 5) define metaphor in the following way: "the essence of metaphor is understanding and experiencing one kind of thing in terms of another". According to the scholars, a conceptual metaphor consists of two conceptual elements, which are the target and the source domains. The target domain is the complex or vague concept that the metaphor is helping to explain, while the source domain is usually a more concrete concept that most humans would know or experience. Lakoff and Johnson (2003: 36) also define metonymy as "one entity is being used to refer to another". Although metaphor and metonymy differ, they essentially serve a similar purpose (Lakoff and Johnson 2003: 36-37). The theoretical framework proposed by Forceville (2008: 463) is concerned with metaphors that occur in the visual mode of expression, and in his work he distinguishes between monomodal metaphors – which occur when the target and source domains are entirely rendered in one mode; and multimodal metaphors which are – "metaphors in which target, source, and/or mappable features are represented or suggested by at least two different sign systems (one of which may be language) or modes of perception" (Forceville 2008: 463). Using Forceville's suggested method of pictorial metaphor identification, after identifying and distinguishing the two domains, I will explicate the metaphor using mapping – transferring one or more features of the source on to the target.

2. Data and Methods

For this study, a sufficient amount of animated educational videos had to be collected. A decision was made to restrict the research to the YouTube channel Kurzgesagt due to several factors – the channel's main objective is to educate, and 'spark curiosity about science', as they claim in their channel description. Secondly, all videos on the Kurzgesagt channel are animated and are primarily in English, which helps to avoid any grammatical errors from faulty translations if non-English videos were to be analysed. Furthermore, the channel has a global outreach and target a worldwide audience – their videos have closed captions in over 30 languages. The channel currently has 22.2 million subscribers, 2.7 billion views across all videos and average around 10 million views of each video, with the most popular video (*The Coronavirus Explained & What You Should Do*) having 88 million views. Kurzgesagt currently has 221 videos on a variety of topics including space, medicine, futurism and science. For this study, it was decided to focus the playlist created by Kurzgesagt on the topic of medicine and biology, which includes 38 animated educational videos. The specific playlist was chosen taking into considerations the limits of knowledge concerning the other topics, for example, it would be difficult to identify metaphors about space, since the terminology may be unfamiliar and would be incorrectly assumed to be metaphorical. In the process of analysing the videos, it was discovered that 18 of the 38 videos did not have easily identifiable and prominent multimodal metaphors, hence only 20 videos from the playlist were deemed to be suitable for the study. The excluded videos were also highly metaphorical – either pictorial or verbal metaphors were identified in all of them, and there were many cases of metonymy, some videos included direct verbal metaphors, where the source or the target domain was also depicted in the video, however the videos that did not meet the criteria of having at least one example of a multimodal metaphor were not included for the sake of the study.

The analysed playlist has videos that have been uploaded to the channel in the past 9 years, the oldest uploaded on July 1st, 2014, and the latest is from June 18th, 2023. Comparing the oldest videos to the later ones, a clear evolution of animation style and metaphor use can be seen, with more recent videos having more elaborate animations and more multimodal metaphors used. This is most likely due to the popularity that the channel has gained since 2014, which brought on more sponsors, revenue from videos, allowing the channel to invest in equipment, resources and possibly hire more people to work on the videos. The popularity also allows the channel to work with scientists and specialists of their respective fields as advisors on the videos, ensuring the information is accurate, although simplified, as Kurzgesagt creators mention in every video. The total length of the videos examined came to be approximately 185 minutes.

Once the sample selection was complete, the videos were analysed manually. Conceptual metaphor theory outlined by Lakoff and Johnson (1980) and Forceville's (2008) method for multimodal metaphor identification were used to identify the multimodal metaphors used in the videos. Forceville's methodology emerged as particularly advantageous, as it helped identify if the source and target domains were in different modes - for instance, the source was in the pictorial mode, while the target was in the verbal mode, thereby confirming the multimodal nature of the metaphor.

3. Results and Discussion

The paper proceeds with the presentation of the results and their discussion. To effectively overview the analysed data, the section will be divided into further subsections according to the specific topic explored in the videos.

3.1 GMO

There are two videos in the 'Medicine and Biology' playlist on the topic of GMOs that had at least one case of multimodal metaphor use. The videos were both uploaded 7 years ago, and there are few metaphors used in the videos.

The first video, "Are GMOs Good or Bad? Genetic Engineering & Our Food", deals with the topic of genetically modified foods by mostly debunking the main arguments against GMOs and highlighting reasons why it is sometimes necessary to genetically modify certain produce. For example, a genetically modified eggplant was introduced in Bangladesh in 2013 – this eggplant was modified to be resistant to pests which destroyed whole harvests of eggplants. Before the introduction of this modified eggplant, farmers had to rely on pesticides, which made the business expensive and the farmers got sick often. Many plants are also modified to be herbicide resistant, which makes it easier to spray herbicide on whole fields to kill weeds competing for resources, without harming the crops. This is where the use of multimodal metaphor can be seen – the narrator says '[...] glyphosate is much less harmful to humans than any other herbicides', while an image of a mogwai and a gremlin appear.



Figure 1. Mogwai on the right and gremlin on the left.

The understanding of the metaphor in this case also requires some knowledge about pop culture – the 1984 movie "Gremlins", which depicts a strange creature called mogwai (meaning 'devil' in Cantonese) which is well behaved and cute, until one of three rules are broken: no water, no

food after midnight and no bright light. When a rule is broken, the mogwai spawns out gremlins, that are mischievous troublemakers, wreaking havoc upon the town. With this context, two metaphors can be construed: GLYPHOSATE IS MOGWAI and OTHER HERBICIDES ARE GREMLINS. As the source domain – mogwai and gremlin – are in the pictorial mode, while the target domain – glyphosate and other herbicides are in the verbal mode, it can be classified as a multimodal metaphor. Both the mogwai and gremlin are considered the same species, however one is more dangerous than the other; the same can be said about herbicides – glyphosate is much less dangerous to humans than the other herbicides, even though they are the same type of substance.

The second video on the topic is "Genetic Engineering and Diseases – Gene Drive & Malaria", which explains how malaria affects the human body and describes the genetic engineering process to make a mosquito population that does not carry the disease.

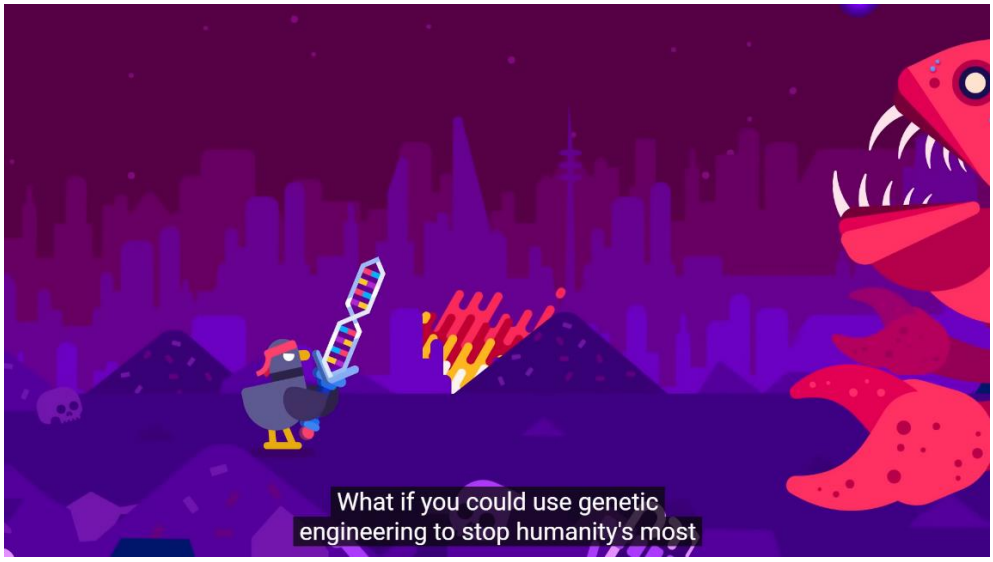


Figure 2. Duck with a DNA sword fighting against a monster.

In Figure 2 it can be seen that the target domain - genetic engineering, mentioned in the verbal mode, is represented in the visual mode as a sword, which also resembles a DNA strand. From this, the multimodal metaphor GENETIC ENGINEERING IS WEAPON can be construed. The metaphor likely stems from the conventional metaphor DEALING WITH A DISEASE IS A BATTLE with medical staff or an ill person being referred to as a soldier and the illness is usually called the enemy. Since malaria is a serious illness, killing thousands of people every year, it is not unusual that the conventional metaphor was used, although in a rather creative way because of the affordances of the medium.

Further in the video, after the narrator explains how genetic engineering would benefit humans, the mosquito's perspective is also shown. As seen in Figure 3, the mosquito is depicted with a ball and chain, with the ball full of parasites. Being chained to the ball is preventing the

mosquito from flying, and the narrator says ‘The mosquitoes […] don't have anything to gain from carrying parasites...’. The metaphor PARASITE IS BALL AND CHAIN can be construed. ‘Ball and chain’ is a phrase commonly used to refer to something that is holding a person back in life, so in this example the heavy ball and chain are representing the mosquito being held back by the parasites spreading malaria.



Figure 3. Mosquito with a ball and chain full of parasites.

3.2 Animals

This sub-section discusses another topic within ‘Medicine and Biology’ section, i.e., – animals. There were multiple videos about animals in the playlist, however only two included instances of multimodal metaphor use.

One of the videos “What Dinosaurs ACTUALLY Looked Like?”, released 2 years ago, explores the progress of discovering what animals in the past looked like from fossils, as most external features, such as pattern, fur or skin color, or soft features, such as bellies, cannot be recovered from the fossil. The video also explains that fossils only form in particular climates and environments, hence it is not possible to know what creatures that lived in jungles looked like, as their bones dissolved in the acidic soil. The topic of animals is quite concrete, so it seems unusual that the videos would need to use metaphor to explain it, however as Kurzgesagt is a channel meant to entertain, as well as educate, the metaphors are also used for the videos to be more interesting to a regular viewer.

As can be seen in Figure 4, when the narrator talks about how many species of eucaryotic cells are now recognized, the duck on screen turns on a flashlight, which shines a light on the number. Discovery of species here is the target domain, expressed in the verbal mode, while the source domain is shining a light, expressed in the pictorial mode. From this, the multimodal metaphor

DISCOVERY IS ENLIGHTENMENT can be construed. The metaphor is not too surprising, since darkness is often associated with the unknown, as what people cannot see, they cannot identify, and when the light is turned on, objects can be recognized. The metaphor is also based on several systematic metaphorical patterns, i.e. UNDERSTANDING IS SEEING, KNOWLEDGE IS LIGHT and REVEALING IS BRINGING TO LIGHT.



Figure 4. Bird shining a flashlight on the number 1.5 million.

Further in the video, the narrator explains that 99 percent of species that have ever existed on earth, have died out, and have become part of the past, something Kurzgesagt call the 'unknown unknown'. While this is said, a fossil emerging from the ground can be seen in the video (Figure 5). The metaphor PAST IS FOSSIL can be construed. This can also be argued to be a case of metonymy, where the fossil metonymically stands for the past through the part for whole relationship.



Figure 5. Fossils emerging from the ground.

The second video specifically on the topic of animals, is “The World War of the Ants – The Army Ant”, which as the title indicates, describes intricacies of the life of army ants. The video title and the name of the species itself suggests that the main metaphor of the video would be ANT LIFE IS WAR, which is proven true by the multiple war metaphors used throughout the video, including the multimodal metaphors. The first case of multimodal metaphor use occurs at the very beginning of the video, where a battlefield is seen, bomb sounds are going off in the background, and an ant emerges from it, while the narrator says ‘Every day, billions of soldiers fight a merciless war on thousands of fronts...’ (Figure 6). While the target domain is in the verbal mode, the source domain is expressed via the pictorial mode and sound. The multimodal metaphor stemming from the overarching ANT LIFE IS WAR metaphor of the whole video is ANT IS SOLDIER. Descriptions of ant life often use metaphors, so naming the ant a soldier is not unusual, especially since the specific type of ant that defends the colony is called the soldier ant in many cases.

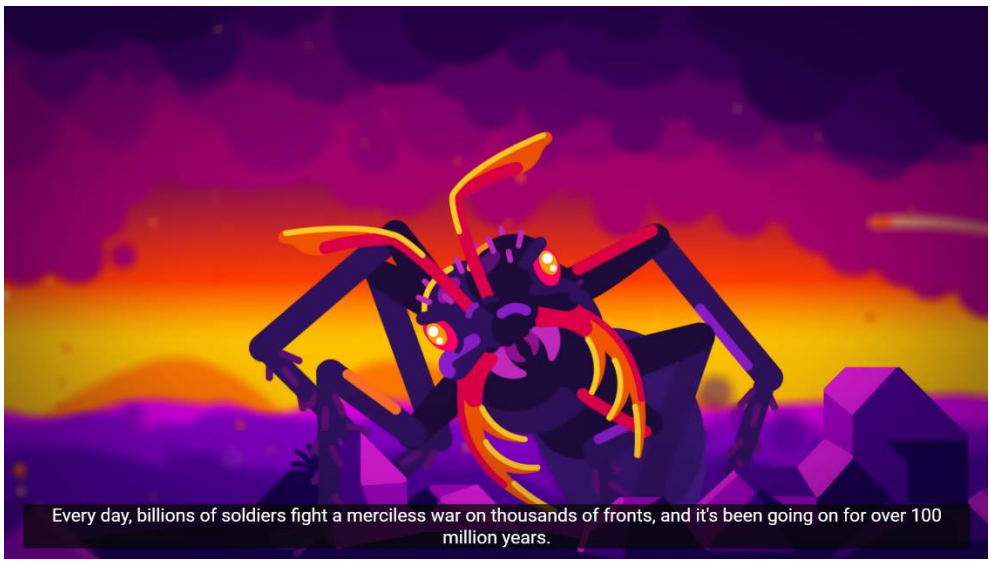


Figure 6. Big ant emerging from the battlefield.

As the video goes on, more war related metaphors are used, however only one of them was found to be multimodal. The video describes how the army ant takes over other ant colonies, in detail describing an example where army ants try to attack leafcutter ants. At the end of the attack, the video shows army ants moving away from the enemy nest, with dead ants laying along the way. The narrator says ‘Regardless who's won the war, thousands lay slain on the battlefield’, meaning the source domain is battlefield – expressed in the verbal mode, while the ant nest, the target domain, is expressed in the visual mode, making the multimodal metaphor ANT NEST IS BATTLEFIELD.



Figure 7. Dead ants laying on the ground near the nest.

3.3 Health dangers

Another topic in the playlist is different types of health dangers to humans, ranging from parasites to man-made dangers such as electromagnetic pollution. A total of three videos are included in this topic, the oldest uploaded to the Kurzgesagt channel 4 years ago, the latest only a year ago, all employ quite different metaphors.

The first video on this topic is “Could Your Phone Hurt You? Electromagnetic Pollution”. The narrator firstly explains what electricity is, different types of electromagnetic waves and how they manifest, and then asks the question: does the constant exposure to electromagnetic radiation affect humans in the long run? Kurzgesagt discuss how the studies on this topic that are quoted most often are actually highly controversial and are based on self-reporting, which means that there is no actual scientific proof that the radiation from phones, TVs, etc., affects humans in the long run. Quite an interesting metaphor is used to portray an electric charge in the video – ELECTRIC CHARGE IS SONIC THE HEDGEHOG.

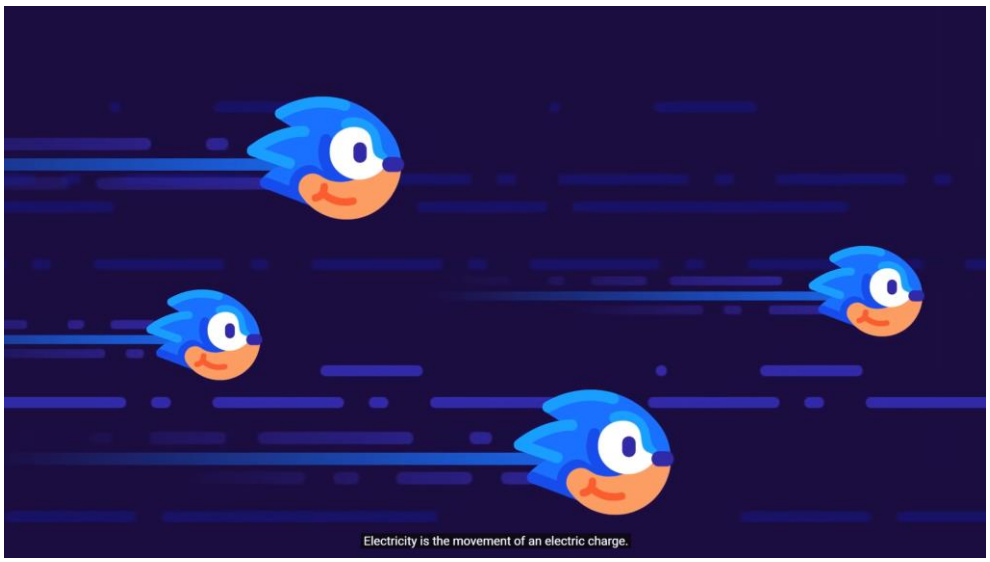


Figure 8. Sonic the Hedgehog heads as electric charge.

Sonic the Hedgehog is a popular video game and cartoon character, an anthropomorphic hedgehog that can run at incredible speeds. As can be seen in Figure 8, the source domain is in the pictorial mode, while the target domain is in the verbal mode. Since electricity travels almost at the speed of light, it is not surprising that a popular character that moves really fast was chosen to represent the electric charge.

A being that is actually dangerous to humans is a parasite called the *naegleria fowleri*, introduced by Kurzgesagt in the video "The Most Horrible Parasite: Brain Eating Amoeba" with the metaphor BRAIN EATING AMOEBA IS MONSTER. The video depicts an amoeba entering a human through his nostril, while the narrator says 'What happens when this monster enters your body?' The source this time is in the verbal mode, while the target is in the pictorial mode. The source domain of monster is not novel, as it is quite commonly used to describe illnesses, and the brain-eating amoeba has several monster-like qualities, and poses huge danger to humans.



Figure 9. Brain eating amoeba entering through a boy's nostril.

The *naegleria fowleri* enters the nasal cavity and the narrator says that it generally flies under the radar of the chemicals that alert immune cells, and it '[…] is not particularly bothered by them and instead calmly checks out the scenery...'. In this case, the source – nose mucus – is in the pictorial mode, while the target domain – scenery – is in the verbal mode, making the metaphor NOSE MUCUS IS SCENERY (Figure 10). Since the brain eating amoeba is not interested in what is happening in the nose, and is just looking for bacteria to feed on, the mucus in the nose is just the surroundings, or the scenery, that the amoeba can see along its way.



Figure 10. Naegleria fowleri surrounded by nose mucus and immunity cells.

Further, the *naegleria fowleri* seen in the video are described as intruders, while the neutrophils are said to be defenders, making the metaphors *NAEGLERIA FOWLERI* IS INTRUDER and NEUTROPHIL IS DEFENDER. The source domain here is in the verbal mode and the target domain is in the pictorial mode. Since the amoeba is a foreign organism that entered the human body without permission and does not benefit humans, it can be defined as an intruder, while the neutrophil is a constant resident in the human body and helps humans function, so it is defending its home.

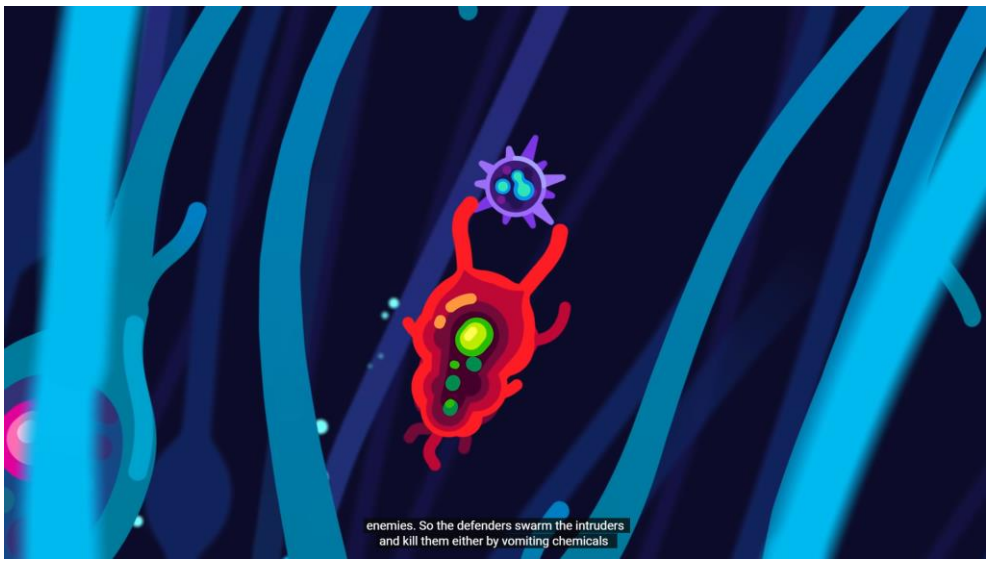


Figure 11. Neutrophil and naegleria fowleri.

The section moves on to metaphors used in another video that deals with a different being that can destroy lives of humans after entering the body, i.e., – the coronavirus. "The Coronavirus Explained & What You Should Do" was uploaded only a week after the global Covid-19 pandemic was declared by the World Health Organization, in March 2020. It is the most popular video on the Kurzgesagt channel, with a total of 88 million views. The video explains how coronavirus spreads, how it impacts the human body and turns the immune system against the human, describes differences between a fast and slow pandemic, and outlines prevention measures. The unconventional use of the metaphor CORONAVIRUS IS WAR can be can be seen when the narrator says 'it […] sends way more soldiers than it should, wasting its resources and causing damage', while the animation on screen shows neutrophil cells and killer T-cells coming into frame. Using mapping, it can be seen that the soldiers stand for the cells that the immunity system sends to fight the virus, resources and damage refer to the infected and non-infected cells that are killed in the process of the immunity system's defence against the virus. Since the conventional metaphor ILLNESS IS WAR is usually used when talking about human beings battling disease, for example, referring to medics or the sick person as a soldier, the source domain of war used in this context is unconventional.

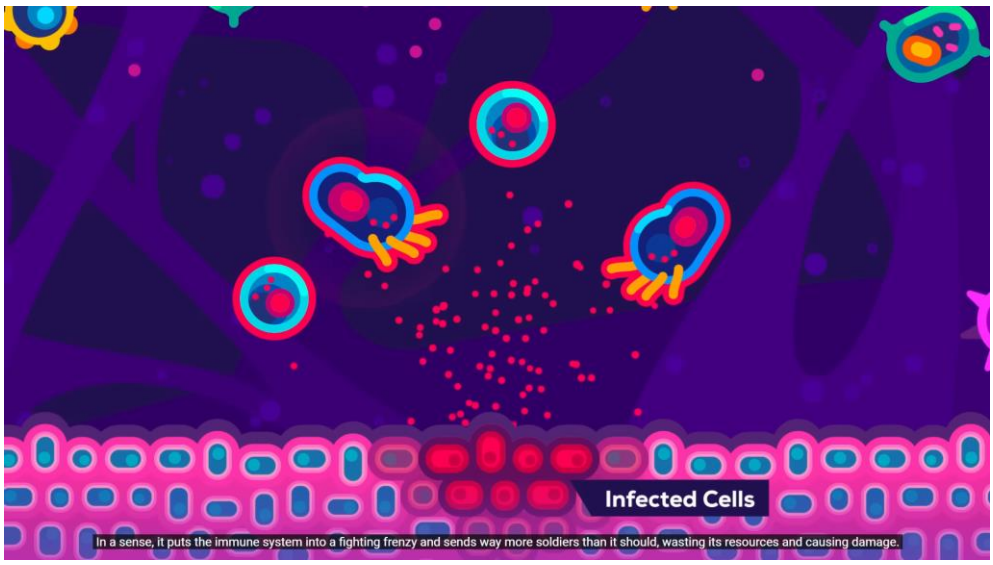


Figure 12. Immune cells getting infected by coronavirus.

Another metaphor prevalent in the video is VIRUS IS A LIVING BEING. In the visual mode the coronavirus is mostly depicted as cells or different coloured dots, but in the linguistic mode the virus is personified and acts as a living being, which would make it a multimodal metaphor. For example, the virus is said to 'hitch a ride' deeper into the body, while in the video the virus particles are moving down a person's throat, it also 'attacks' cells. Personifying the virus may sound more threatening to the viewer, better convincing to adhere to the rules and prevention measures set by the WHO.

3.4 Cancer

A substantial danger to human health, as well as animal health, is cancer, with two more videos in the playlist. When going into the analysis of the videos, there was already an expectation that they would involve metaphors related to war, because it is such a conventional metaphor used to describe illness, however the expectation was proven wrong.

The first video is called "Why Blue Whales Don't Get Cancer - Peto's Paradox", it was uploaded to the Kurzgesagt channel 4 years ago. The video employs multiple metaphors, as it describes the cell processes in the body as machinery, but only one multimodal metaphor instance was found. When the narrator explains hypertumors – tumors that have formed from mutated cancer cells, which start to fight for the same resources and nutrients as the original tumor. As seen in Figure 13, in reference to the hypertumor cells, the narrator says 'Instead of helping, they cut off the blood supply to their former buddies, which will starve and kill the original cancer cells', while in the video a window pops up, that has an image of scissors cutting a wire resembling a blood vessel, and the words 'rewire circuit' beside it. The multimodal metaphor in this case is CUTTING OF BLOOD SUPPLY IS REWIRING CIRCUIT, with the source domain being in the pictorial

mode, and the target in the verbal mode. Since the cells are referred to as robots, and the cell processes are called ‘grandiose machinery’ in the beginning of the video, the blood supply flow being equated to a circuit is not unusual. The term ‘circuit’ can be used in a general sense to refer to any fixed path that electricity, data or a signal can travel through, while in this case it is related to blood flow.



Figure 13. Rewiring circuit window.

The second video is “The Reason Why Cancer is so Hard to Beat”, and it is the latest video that has been added to the playlist, uploaded to the channel ten months ago. From all the reviewed videos, this video is one of the most multimodal metaphor heavy. The video describes the tumor as a rogue town (Figure 14), the source domain – rogue town – is expressed both in the pictorial and verbal mode, while the target domain – tumor – is only in the verbal mode, making the multimodal metaphor TUMOR IS ROGUE TOWN. In relation to that, later in the video, the metaphor HUMAN BODY IS WORLD is used to describe cancer cells exploring the world and building new towns. The source domain in this case occurs in the verbal mode – the world, while the target domain is in the pictorial mode – the human body, metonymically represented by cancer cells mingling in different processes and tissue within the human body, as can be seen in Figure 15.



Figure 14. Rogue town.

Further in the video, multiple multimodal metaphors are used such as TUMOUR CELL CARCASSES ARE CEMENT DEBRIS, MACROPHAGES ARE EXCAVATORS, HEALTHY TISSUE IS BUILDING, in all these cases, the source domains are signalled through the pictorial mode, and the target domain occur in the verbal mode. All of these metaphors are in line with the initial overarching metaphor of the video mentioned before: HUMAN BODY IS WORLD. This is an interesting example, as the world is considerably vaster and more diverse than the human body, so it would seem unusual that a more complex thing at first glance would be used to metaphorically explain a smaller, seemingly simpler thing. However, the processes in the human body are so small that we do not see what is happening exactly, and we have to trust what scientists, such as microbiologists, tell us. So even though the world is big and complex, people can see and understand different processes happening in the world around them much more clearly, which is why the metaphor works.



Figure 15. Cancer cells spreading in different parts of the human body - bloodstream, nervous system, etc.

3.5 Intelligence and energy

This topic includes two videos about quite different concepts however, they are both involved in making a person function. The two videos were uploaded to the channel 3 years ago. One of them, entitled "What Is Intelligence? Where Does it Begin?", employs multiple metaphors, some direct, some implied, but only one was found to be multimodal. The video explains intelligence by depicting a being in a game, where it is levelling up while the narrator explains different features of intelligence. While explaining how beneficial memory is, a floppy disk is shown in the video. The source domain is expressed in the verbal mode, while the target domain is in the pictorial mode, the metaphor MEMORY IS FLOPPY DISK can be construed. The floppy disk is a very commonly used symbol in computer programs such as Microsoft Word, and other apps, to save a document, so it is an established metaphor.

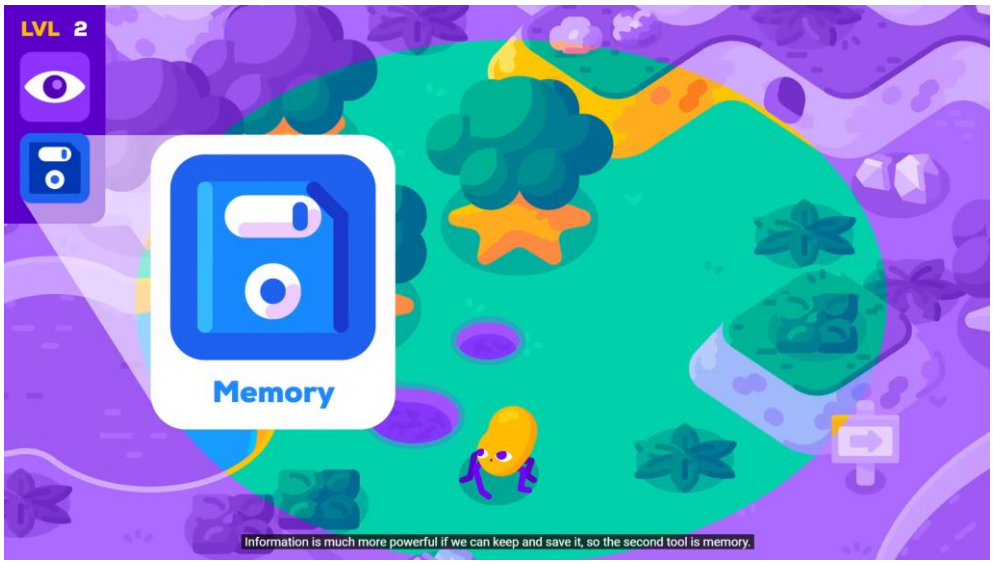


Figure 16. Memory as a floppy disk.

The other video on the topic is called “Why Are You Alive – Life, Energy & ATP”, in which two multimodal metaphors were identified. The video covers how energy in the human body is generated, how photosynthesis works, and explains how mitochondria came to be and how that lead to human life. The metaphor EVOLUTION IS LEVELING UP is used when talking about how the cells kept evolving for many years, the narrator says ‘Evolution did its thing, but overall things stayed pretty much the same for hundreds of millions of years’, while the video shows two cells changing and the phrase ‘Level up!’ is shown above them. In this example, the source domain is in the pictorial mode, while the target domain is in the verbal mode. The metaphor may stem from the broader metaphor LIFE IS GAME, which is even used in the previously discussed video. In a game, levelling up usually comes with new features and skills for the character, similar to evolution, where a being gains different abilities that help them survive in various environments.

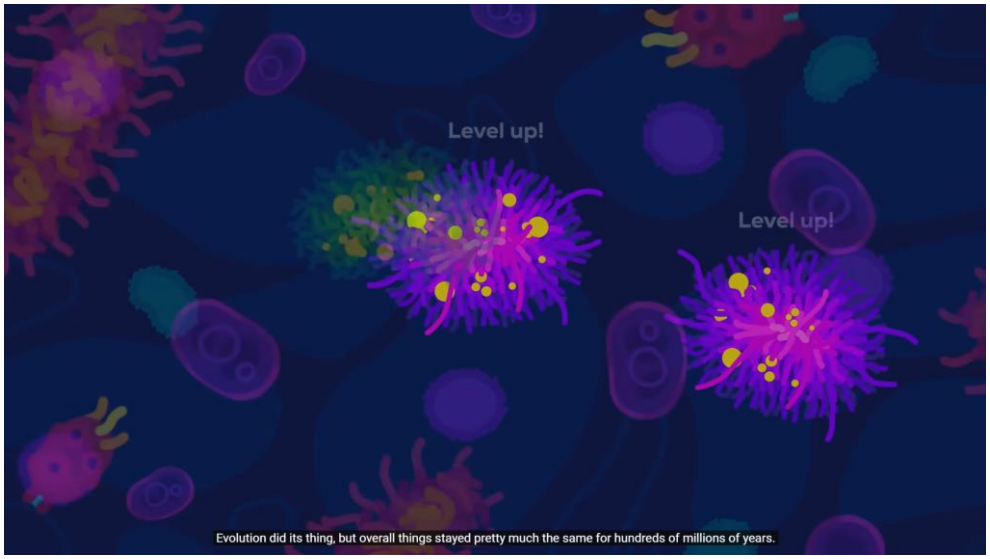


Figure 17. Cells levelling up after consuming sugar.

Later in the video, different types of cells are depicted, while the narrator says ‘[…] you are […] filled with dozens, if not hundreds of little machines that provides you with usable energy to stay alive.’ The metaphor CELL IS MACHINE can be construed, where the source domain is in the verbal mode and the target domain is in the pictorial mode. Every cell has different functions, and they all have to work well in order to keep a human alive, so the machines here are generating energy for the human to function.

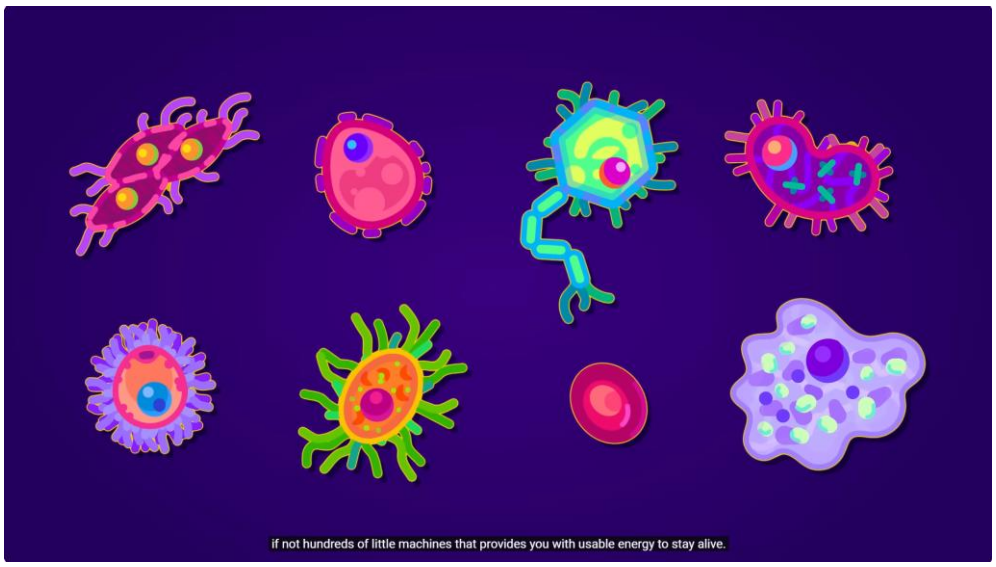


Figure 18. Various types of cells in the human body.

3.6 Immunity and health

The final topic in the playlist 'Medicine and Biology', with eight videos on it, is about the immunity system and health. This topic includes the most videos out of all topics, including the oldest video from the playlist – uploaded to the channel 9 years ago, while the others were uploaded more recently.

The first video is called "Homeopathy Explained – Gentle Healing or Reckless Fraud?", uploaded to the channel 6 years ago. It does not employ many metaphors, and only one case of multimodal metaphor use was identified. The video at first explains how homeopathic medicine is made, how it came to be the most prominent alternative medicine, suggesting that even though it is proven to only work because of a placebo effect, that is a better outcome than hurting a person more. The video further compares homeopathy with modern medicine, using the example of a first consultation: a consultation with a homeopath can take hours and be very personal, while a consultation with a doctor is usually very brief an only focuses on the physical symptoms. While the narrator calls modern medicine a strictly organized system, with tight budgets and says 'Consultations need to be time-efficient, diagnoses made quickly, treatments fast, which can leave patients feeling invisible, scared, and left behind', the video shows patients on a conveyor belt, gears turning in the background. The source domain here, metonymically expressed in the pictorial mode as a conveyor belt, is factory, while the target domain, expressed in the verbal mode, is modern medicine, making the multimodal metaphor MODERN MEDICINE IS FACTORY. The metaphor use here may seem like Kurzgesagt are trying to turn people away from modern medicine towards homeopathy, however the channel does well in explaining how modern medicine is still superior to homeopathy and how it could borrow some aspects of alternative medicine while also being scientifically based.



Figure 19. Patients on a conveyor belt.

One of the videos on the topic of immunity employs a completely different source domain than most of the other videos. It is called "You Are Immune Against Every Disease" and was uploaded to the channel 2 years ago. It explains that the human body is like an ecosystem – 'A perfect place to move into and have a family', evoking the metaphor HUMAN BODY IS HOME. From here, bacteria and virus images appear on screen, with the narrator calling them guests and enemies respectively (Figure 20). Since most bacteria are not harmful to the body, they are said to be welcome guests, while some of the harmful bacteria would be unwelcome. The metaphor that can be construed here – BACTERIA ARE GUESTS. Viruses, in most cases, are harmful to humans, so the metaphor VIRUS IS ENEMY makes more sense than for the virus be called a guest as well.

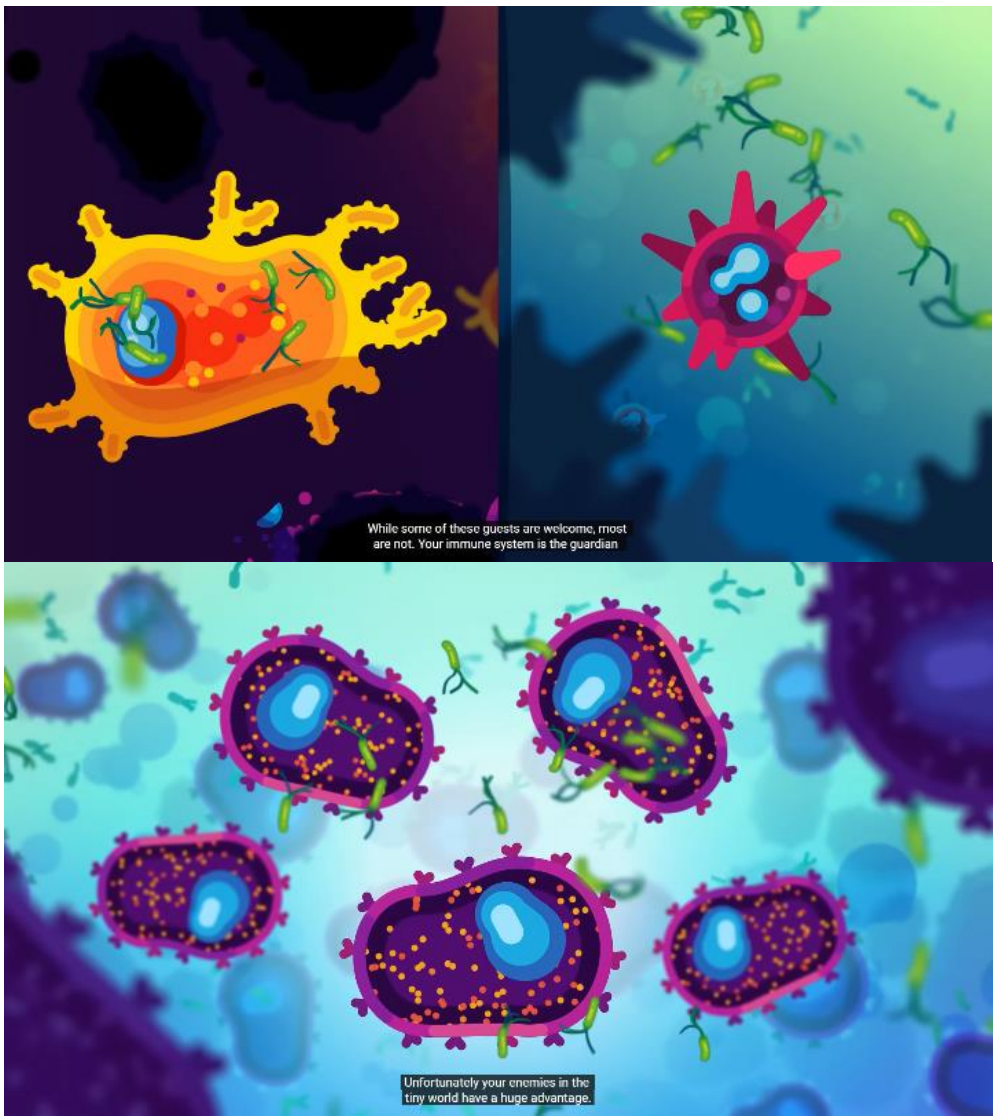


Figure 20. Bacteria and viruses.

The video goes on to detail the functions and processes of the adaptive immune system, explaining that it adapts to defend the body from any harmful protein, however in some rare circumstances, it can start to attack your own cells. Here, Kurzgesagt introduce the thymus, or what they call it – the murder university. The source this time is in the verbal mode, while the target domain is in the pictorial mode, as can be seen in Figure 21, and the metaphor THYMUS IS MURDER UNIVERSITY can be construed. The curriculum, as the narrator says, is represented in the pictorial mode as an obstacle course, and this is where the adaptive immune cells go through training to recognize harmful protein. The multimodal metaphor in this case would be OBSTACLE COURSE IS CURRICULUM (Figure 22).

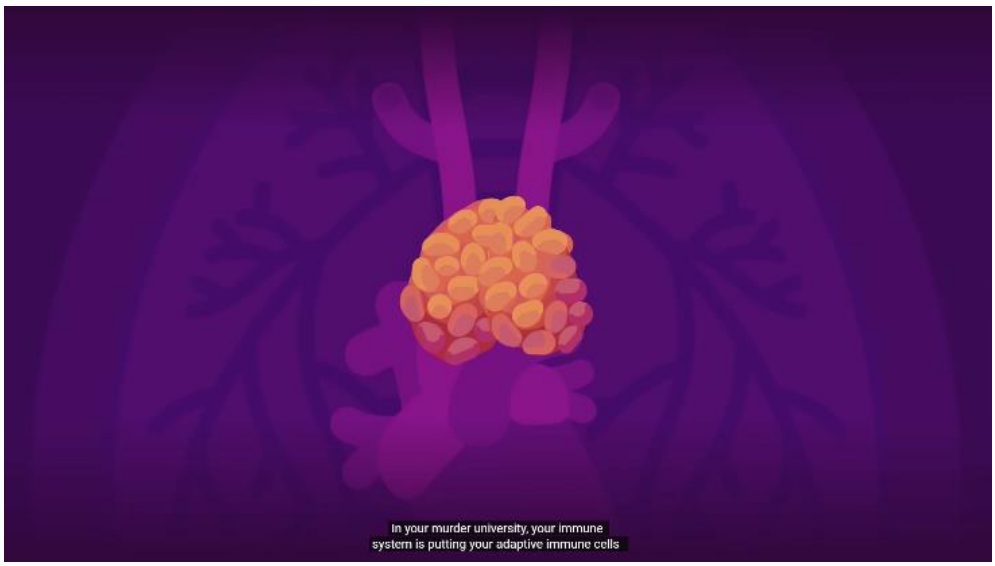


Figure 21. Thymus.

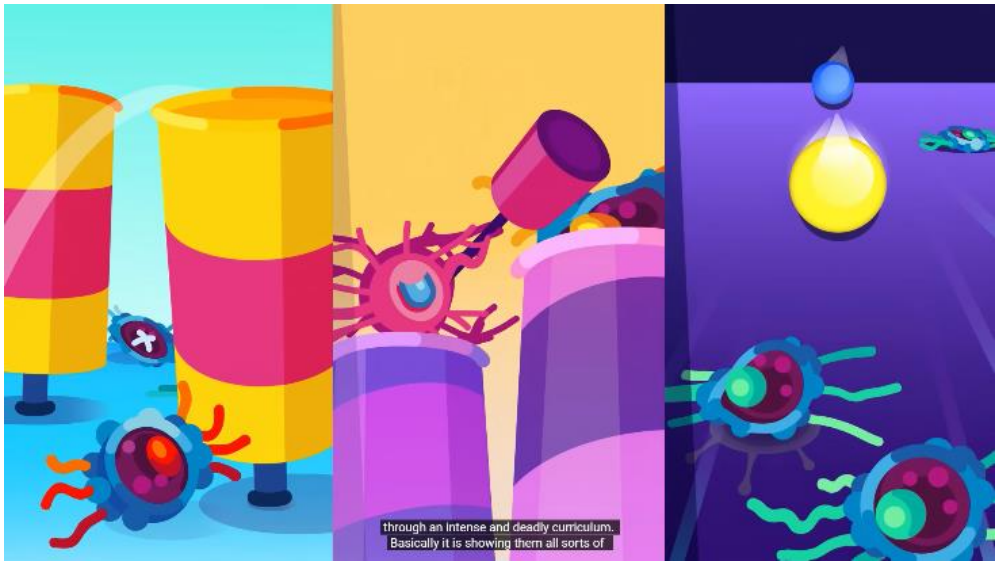


Figure 22. Cells in different obstacle courses.

The oldest video on the topic – "The Immune System Explained I – Bacteria Infection", is quite simple animation wise, and only one multimodal metaphor was found in it. As can be seen in Figure 23, a very simple animation of different types of cells, with exaggerated features that represent their functions – defence, communication, weapons factory, etc. is shown, while the narrator calls it an army. In this case, the source domain is in the verbal mode, while the target is in the pictorial mode, the metaphor that can be construed here is IMMUNITY SYSTEM IS ARMY.

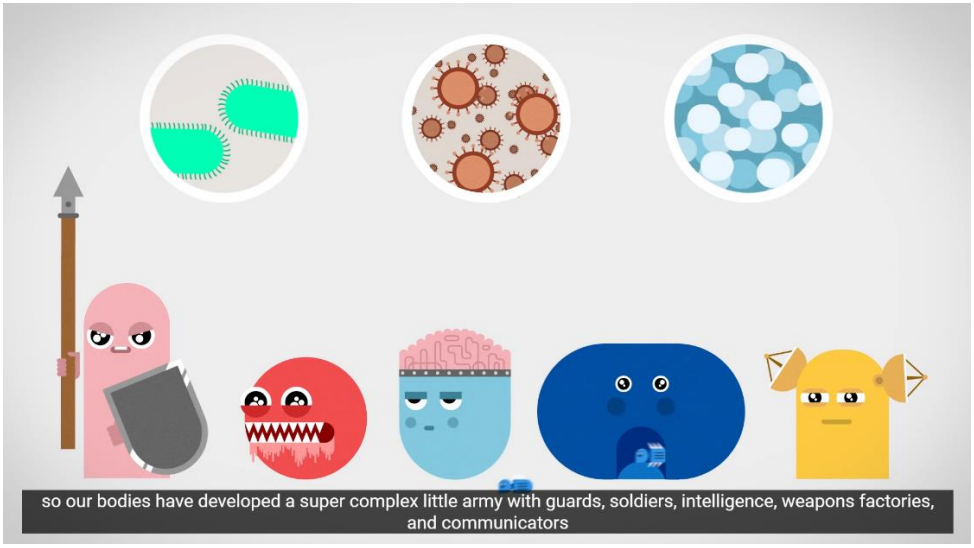


Figure 23. Army of immune system cells.

Most of the other videos on the topic also employ the source domain of war, referring to the immunity system or parts of it as an army. The video "Tiny Bombs in your Blood – The Complement System" refers to the complement system as an army (Figure 24), made up of 30 different proteins, which are depicted in the video. Here as well, the source domain is in the verbal mode and the target domain is in the pictorial mode, making the multimodal metaphor COMPLEMENT SYSTEM IS ARMY. Further on, an antibody is shown in the video, while the narrator says 'Many other parts of the immune system are just tools to activate the Complement System.', then the antibody pulsates and complements show up. From this, the multimodal metaphor ANTIBODY IS TOOL can be constructed. The army metaphor is not surprising in this context, considering the immunity system and all of its components are involved in protecting the human body from disease or infection, much like the purpose of an army is to protect the country.

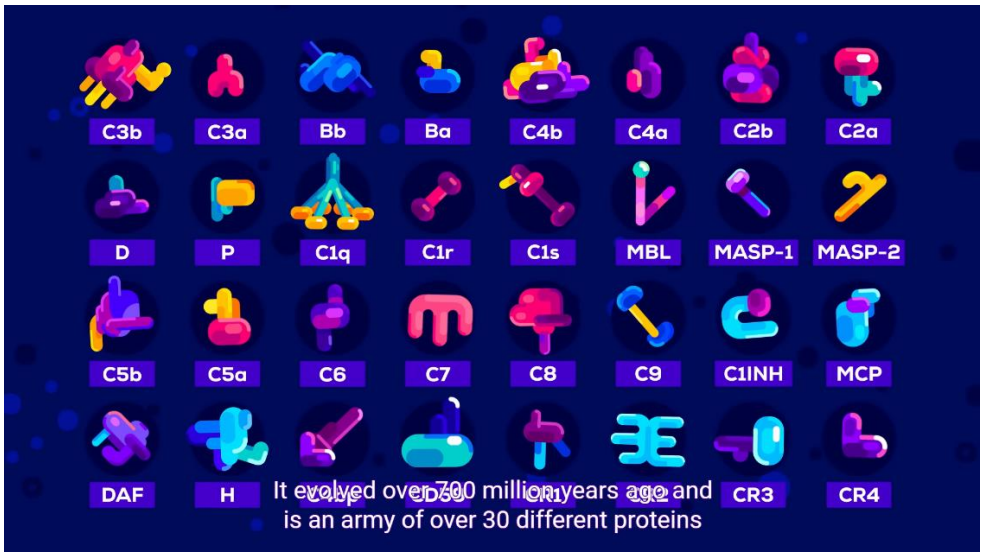


Figure 24. Different types of proteins in the complement system.

Another example of the source domain WAR being used can be found in the video "How The Immune System ACTUALLY Works – IMMUNE", which was uploaded to the Kurzgesagt channel 2 years ago. Not only are antibodies that can be seen in the visual mode referred to as an army in the verbal mode (ANTIBODIES ARE ARMY), the macrophage is said to be a soldier (MACROPHAGE IS SOLDIER) and the infected area is described as a battlefield (INFECTED AREA IS BATTLEFIELD). Once again, different cells in the body are referred to as different types of functions in the army: captains, intelligence officers, heavy weapons, suicide bombers. All these examples signal the source domain through the verbal mode, and the target domain through the pictorial mode, making all the metaphors multimodal. Metaphorizing cells to represent army functions would make the viewer understand the cell types more easily, since a regular viewer most likely does not have the knowledge to recognize different cells on the screen, much less remember their names and functions – Kurzgesagt makes it more convenient for the viewer to understand their roles.

Another video, "The Deadliest Being on Planet Earth – The Bacteriophage," introduces the viewers to the bacteriophage, a virus that kills bacteria, and by doing that, may help humans battle infections that cannot be healed by antibiotics anymore. The video employs war related metaphors as well: as the bacteriophage only targets certain bacteria, they do not affect human health in any negative way, hence the narrator calls the phage a guided missile, while the phage is seen floating through multiple types of bacteria until it finds the type that is its victim (Figure 25). Here, the source domain is expressed via the verbal mode, while the target domain is in the pictorial mode, making the multimodal metaphor BACTERIOPHAGE IS GUIDED MISSILE.

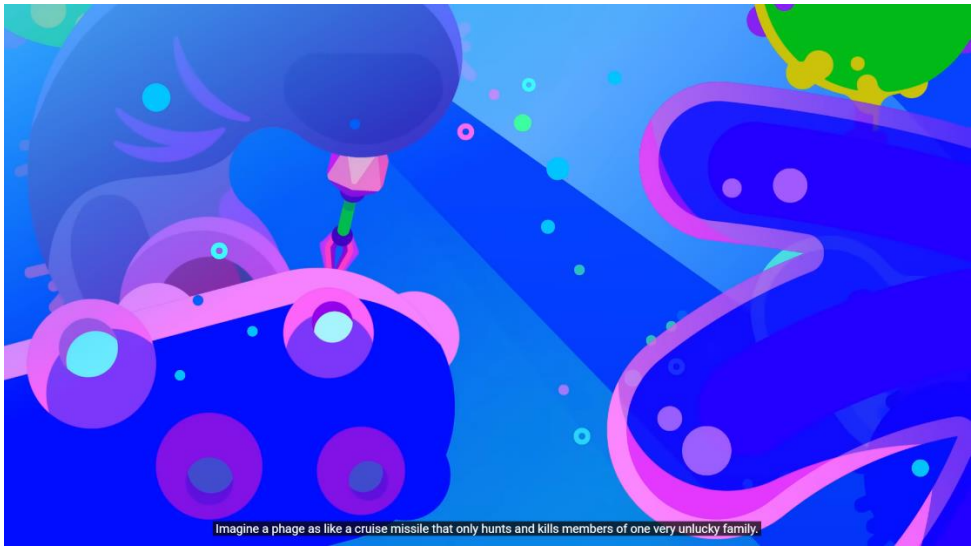


Figure 25. Bacteriophage floating by various bacteria.

The video further explains that even though bacteria keep evolving and may become immune to the bacteriophage, the phage evolves too. This process of constantly evolving to be superior

to the other is called an arms race by the narrator, while the phage and the bacteria is shown to grow various weapons on them, shooting at each other, while shooting sounds are heard in the background. The multimodal metaphor in this case is EVOLUTION IS ARMS RACE, employing the pictorial, verbal and sound modes, with the source domain being in all three, while the target mode is in the pictorial mode only (see Figure 26). With evolution meaning gaining new features that help beings survive, the comparison to an arms race, where two groups are racing to acquire or invent more weapons than the other, and by consequence survive, is fitting. Another interesting detail is that the bacteria are handling quite primitive weapons – a mace, while the phage side is handling guns, likely insinuating that science is on the phage side.

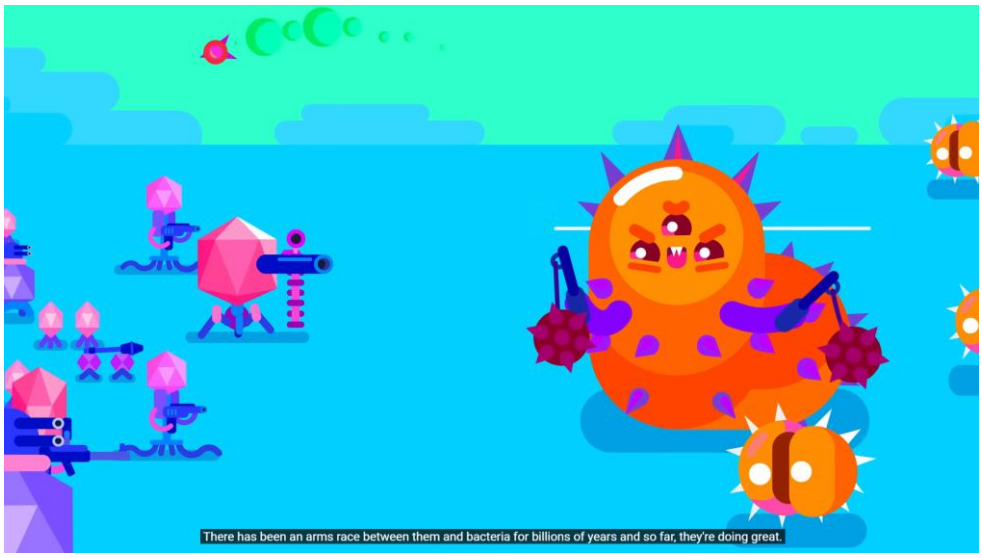


Figure 26. War between bacteriophage and bacteria.

The next video on this topic is "The Side Effects of Vaccines - How High is the Risk?", where Kurzgesagt explain how vaccines work and how severe the potential side effects are. Multiple war-related metaphors are used in the video, once again referring to the immune system as an army (IMMUNE SYSTEM IS ARMY), antibodies as target missiles (ANTIBODY IS TARGET MISSILE), and a dangerous infection as a security breach (INFECTION IS SECURITY BREACH). The source domain in the first example is in the verbal mode and the target domain is in the pictorial mode, while in the other two examples the source is in the pictorial mode and the target domains are in the verbal mode.

One of the most metaphor-heavy videos from the playlist on this topic also employs war metaphors, it is called "What Actually Happens When You Are Sick?". In the introduction of the video there is already one multimodal metaphor used, with a source domain already discussed previously – the human is depicted as a character in a game fighting against pneumococcus bacteria, and winning, while the narrator says '[…] surviving a disease leaves you better off.' From this the metaphor SURVIVING DISEASE IS WINNING A GAME can be

construed, with the source domain being in the pictorial mode, while the target domain is in the verbal mode. Further in the video, getting sick is explained through the metaphor of war, the human body is equated to a country and the immune system activating and defending the body is defined as an army. In Figure 27 it can be seen that a human is metonymically represented as eyes in the middle of a country on a map in the pictorial mode. The narrator describes the scene: 'Think of yourself as a large country, with a sizable army to defend it. You are surrounded by enemies that want to take your land, your energy, your resources' – the two multimodal metaphors identified here are ANTIBODY IS ARMY and VIRUS IS ENEMY, with the source domain in the verbal mode and the target domain in the pictorial mode.



Figure 27. Country being invaded by bacteria and viruses, protected by antibodies.

Following the overarching metaphor of the video HUMAN IS COUNTRY, the narrator warns that an invasion might happen at any moment, while people coughing on the bus and a dog licking a person's face appear on video, disease spreading onto the main human character. Here, the multimodal metaphor DISEASE IS INVASION can be constructed, the source domain appearing in the verbal mode, while the target is in the pictorial mode. The video employs many more war metaphors, however they are mostly direct, depicted in the video and described by the narrator at the same time, not qualifying as multimodal metaphors.

Another video in this topic, "How Bacteria Rule Over Your Body – The Microbiome," also employs the same army metaphor, however it was not found to be multimodal – both the target and source domains occurred in the verbal mode. One multimodal metaphor unrelated to war was found in the video – STIMULATING GUT CELLS IS WATERING PLANTS. As can be seen in Figure 28, while the narrator is talking about how the immune system has motivation to keep the human gut healthy, even stimulating the gut cells to regenerate faster, the video shows a cell pouring water from a watering can onto the ground and a cell grows. Here, the source domain

is in the pictorial mode, while the target domain is in the verbal mode. Just how a human is motivated to grow plants, water them, so they benefit humans in multiple ways, such as producing oxygen and providing a food source, similarly the immunity system keeps the gut healthy, so it can send signals to the brain to recover from injuries or influence the brain and inducing certain cravings.

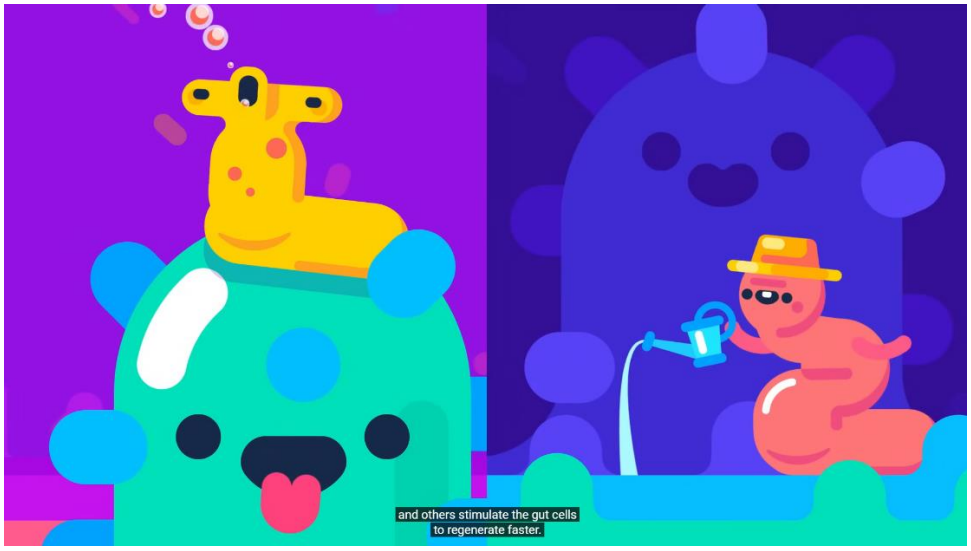


Figure 28. Stimulating gut cells by watering them.

3.7 Discussion of the results

Overall, the videos were found to use many metaphors and metonymies, as well as multimodal metaphors. As the range of topics within the selected playlist was quite varied, most of the metaphors used were unique, and likely employed with the objective to visually stimulate the viewer, making connections to phenomena or characters that are more relatable and well known (e.g. gremlins, university, war). The source domains and target domains occurred approximately the same number of times in the verbal and pictorial mode, with some instances where sound was a part of the multimodal metaphor as well, indicating that no particular mode was preferred to represent either of the domains.

The most commonly used source domain was found to be WAR, which is unsurprising, since the playlist of videos chosen for this paper was medicine and biology, which explored many illness-related issues and the topic including videos about immunity and health had the most videos. As discussed previously, although the ILLNESS IS WAR metaphor is conventional, many of the Kurzgesagt videos employ it in an unconventional way, mostly to describe different parts of the immunity system fighting against the viruses or bacteria. Rodehau-Noack (2001) explains that there are a few ways disease and war are related, and although the article is concerned with the opposite metaphor where war is the target domain, it still helps with the argument that the two concepts are intertwined: similar to disease, war is something that harms society or all of

humanity, it is also suggested that war can be managed through careful planning, similar to public health policies, where a problem can be diagnosed and treated using modern methods. Although the examples in this paper are much more specific, detailing the inner workings of the human body rather than the abstract concept of war and illness, the intertwinedness of the two may explain the substantial usage of the metaphor in Kurzgesagt videos.

Another source domain that can be seen used in a few of the videos is GAME – the videos in multiple occasions depict the human, a cell or an unnamed being as a game character, with a health bar, fighting enemies or exploring the in-game world. Although it may be that such metaphors are only used to make the videos visually interesting, it can also be argued that the game metaphor helps to restructure our view of life, instead of viewing every obstacle negatively, it can be perceived as a challenge in a game, and without it the game becomes dull. Kurzgesagt employing the LIFE IS GAME metaphor aids the viewer in understanding concepts such as evolution, as well as visualize the battles happening inside the human body every day. Metaphors help understand things that are new or strange by making them seem familiar, especially for younger audiences. They also help us explain a problem and suggest a way to solve it.

4. Conclusion

The aim of this paper was to analyse multimodal metaphors found in a selected playlist of videos from a popular educational YouTube channel that uses primarily animation, analyse whether the videos on similar topics employ similar multimodal metaphors and to examine how the metaphors used may help the viewers understand the complex concepts of the videos. Out of the 38 examined videos on the topic of medicine and biology, twenty were found to have multimodal metaphors and were analysed in the Results and Discussion section of this paper.

This study has shown that the most commonly used source domain throughout the videos was WAR, as multiple videos were related to various illnesses such as the coronavirus or the flu, many of them explained the inner workings of the immunity system, where the antibodies were called an army or a macrophage was called a soldier. The ILLNESS IS WAR or DISEASE IS BATTLE metaphor is a conventional metaphor, hence there is no surprise that Kurzgesagt uses a metaphor familiar to the viewer to help understand the functions of the immunity system.

Other metaphors occur through the videos only once or twice, since the topics are varied and deal with subject matter starting from cancer to electromagnetic pollution. Interestingly, from the analysed multimodal metaphors, two used source domains related to pop culture – one referencing the movie 'Gremlins', the other referencing a game and animated character Sonic the Hedgehog. Although these metaphors could only be understood if the viewer already knows the characters, the unusual, but visually interesting source domains bring familiarity to an unfamiliar concept like herbicides.

Another interesting finding was the use of metaphors HUMAN BODY IS WORLD and HUMAN IS COUNTRY: while metaphors are usually used to describe a more complex concept through a simpler, easier to understand concept, these examples seem to be the opposite case upon first impression. Seemingly, the world or a country is large and abstruse, and the human body should be more familiar and easier to understand. However, many of the processes within the human body are so minuscule that we cannot observe them directly and must rely on scientists, like microbiologists, to understand them. Despite the world's complexity, people can more easily see and comprehend the various processes occurring around them, comparing the tangible objects and experiences in the world to microscopic cells and processed, making the metaphor effective.

Due to the limited scope of this research no strong statements can be made about how much the multimodal metaphors in animated educational videos help the viewers grasp complex concepts. Further research could be carried out on a larger variety of topics even within the

Kurzgesagt channel, since only a very small number of the videos uploaded to the channel were analysed. Another possibility would be looking into other channels that create similar content, compare the usage of multimodal metaphors on similar topics across the different creators. Additionally, the videos use not only multimodal metaphors, but also direct metaphors and metonymies expressed in the verbal mode, which are much more varied and would make the scope of research on the animated educational videos significantly broader and may lead to more conclusive findings. Since using animation as an educational tool is starting to be more popular, the potential to explore this field further is unquestionable and may lead to new discoveries in how to aid different types of learners with new teaching and learning strategies.

5. Summary in Lithuanian

Sparčiai besikeičiantys mokinių poreikiai verčia pedagogus ieškoti naujų būdų sudėtingiems reiškiniams paaiškinti. Vienas iš jų – edukaciniais tikslais kuriami animaciniai vaizdo įrašai. Tyrimai rodo, kad animacija skatina susidomėjimą mokymusi ir yra naudinga mokiniams, turintiems autizmo spektro sutrikimų. Metafora yra vienas iš šių vaizdo įrašų komponentų, padedančių naujus ar nepažįstamus reiškinius pavaizduoti taip, kad jie atrodytų lengviau suprantami. Metaforos kaip ugdymo instrumentas buvo naudojamos net filosofijos autorių, tokių kaip Aristotelis, Epikūras, Lukrecijus, raštuose. Išnagrinėjus tyrimus šia tema, matyti, kad buvo atlikta nemažai tyrimų apie metaforas švietime, metaforas animacijoje ir animacijos naudojimo švietime naudą, tačiau nerasta tyrimų, kurie būtų skirti metaforoms edukacinėje animacijoje. Todėl šio baigiamojo darbo tikslas buvo išanalizuoti animuotus mokomuosius vaizdo įrašus iš „YouTube“ kanalo „Kurzgesagt“, suskirstyti juos pagal vaizdo įrašuose aiškinamas temas ir ištirti, kokią naudą aiškinimui teikia įrašuose aptiktos multimodalinės metaforos. Nustatyta, kad dvidešimtyje vaizdo įrašų iš grojaraščio apie mediciną ir biologiją yra bent vienas multimodalinės metaforos atvejis. Iš teminių kategorijų, tokių kaip GMO, gyvūnai, pavojai sveikatai, vėžys, intelektas ir energija, imunitetas ir sveikata, daugiausia vaizdo įrašų buvo apie imunitetą ir sveikatą. Analizuojant visus vaizdo įrašus nustatyta, kad dažniausiai pasitaikanti šaltinio sritis - KARAS. Kitos šaltinio sritys pasitaikė daug rečiau, dažniausiai tik vieną kartą, o tai rodo, kad animaciniuose vaizdo įrašuose naudojamos metaforos yra įvairios. Nustatyta, kad multimodalinės metaforos tik nedaug prisidėjo prie sudėtingų vaizdo įrašų temų paaiškinimo, todėl norint padaryti išvadas apie metaforų įtaką aiškinamų temų supratimui, reikėtų atlikti tolesnius eksperimentinius ar apklausomis grįstus tyrimus. Taip pat būtų pravartu ištirti ir video įrašuose naudojamas monomodalines metaforas ir metonimijas, kurių, kaip buvo pastebėta atliekant šį tyrimą, taip pat tokio pobūdžio įrašuose yra gausu.

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7. Appendix

The investigated multimodal metaphors of every animated educational video analysed in this paper along with the identification of source/target domains and the modes they occur in, as well as transcriptions of the subtitles.

1. “Are GMOs Good or Bad? Genetic Engineering & Our Food”
   Posted: March 30, 2017
   Available online https://www.youtube.com/watch?v=7TmcXYp8xu4, accessed February 28, 2024.
   GMOs are one of the most controversial areas of science. Genetic engineering is used in many fields, but even though medical applications like GM insulin are widely accepted, The debate heats up when it comes to food and agriculture. Why is that? Why is the same thing treated so differently? Let's try to get to the bottom of this and explore the facts, the fears, and the future of GMOs. Humans have been genetically modifing plants and animals for thousands of years. Maybe a few of your crops had very good yields. Maybe one of your wolves was especially loyal. So you did the smart thing, and bred the plants and animals that had traits beneficial to you. Traits suggest an expression of genes. So with each generation, those genes got more pronounced. After thousands of years, almost every single plant and animal around us is vastly different from its pre-domesticated state. If humans have been changing genes for millennia, what makes a so called "Genetically Modified Organism", or GMO, different? Selective breeding is basically hoping for lucky hits. Genetic engineering eliminates this factor. We can choose the traits we want. Make fruit grow bigger, immune to pests, and so on. So, why are people concerned about them? Let's start with one of the most common objections to GMOs. Gene flow, meaning GM crops could mix with traditional crops and introduce unwanted new characteristics into them. There is a method that might guarantee complete prevention, but is a big anti-GMO argument by itself. Terminator seeds. The idea is that they could produce sterile plants, requiring farmers to buy new seeds every year. The very concept of this, however, caused a public outcry, stopping the technology being put to use. This brings us back to the unintentional spreading of engineered DNA. There have been cases of GMOs growing where they weren't planted, and traces of modified genes found in foreign crops. But GM plants can't run wild entirely. Many crops pollinate themselves, and all crops have to be related to mingle. There are also cultural methods like buffer zones, to keep unintentional crossing at a minimum. But if it's possible in principle that a GMO could unintentionally cross with a non-GMO, there's actually a more important question. Is food that comes from GM crops different to food from non-GM crops? This question has been a major concern from the very beginning. GM plants

that are destined to be eaten are checked for possible dangers, and the results are evaluated by multiple agencies. After more than 30 years and thousands of studies, the science is in. Eating GMO plants is no more risky than their non-GMO equivalent. But don't just take it our word for it, the sources for this and other claims are in the video description. But what about plants that have been engineered to be toxic? For example, BT crops. A gene borrowed from the bacterium Bacillus Thuringiensis, lets engineered plants produce a protein that destroys the digestive system of specific insect pests. The plant makes its own pesticide. Insects that eat it die. That sounds alarming! Pesticide sprays could be washed off. While the poison in BT crops is inside the plant. But actually, it's not a big deal. Poison is really just a question of different perspectives. What's harmless to one species, might kill another. Coffee, for example, is a poison that kills insects but is harmless to us. Or take chocolate, it's dangerous for dogs but a pleasure for humans. BT crops produce a protein that is tailored to the specific design of the digestive tract of certain insects; it's completely harmless for us. There's also the opposite approach. Plants that are engineered to be resistant to certain weed killers. This way, farmers can use them widely, killing the other plants competing for resources without harming the crop. Here, we get to the dark underbelly of GMOs. For the pesticide industry, they are big business. Over 90% of all cash crops in the US are herbicide resistant, mostly to glyphosate. As a result, the use of glyphosate has increased greatly. That isn't only bad, glyphosate is much less harmful to humans than many other herbicides. Still, this means famers have a strong incentive to rely on this one method only, casting more balanced ways of managing weeds aside. That's one of the most fundamental problems with the GMO debate. Much of the criticism of this technology is actually criticism of modern agriculture and a business practice of the huge corporations that control our food supply. This criticism is not only valid, it's also important. We need to change agriculture to a more sustainable model. GMOs as a technology are actually an ally and not a enemy in that fight, helping to save and protect nature and minimize our impact on the environment. Let's look at some positive examples. Eggplant is an important crop in Bangladesh but often, whole harvests are destroyed by pests. Farmers had to rely heavily on pesticides. Not only was this very expensive, Farmers also frequently got sick. The introduction of a new GM eggplant in 2013 stopped this. The same BT protein we talked about before, an effective killer of insects but harmless to humans, was engineered into them. This reduced insecticide use on eggplants by more than 80%. The health of farmers improved, and their income rose dramatically. And sometimes, the GM approach is the only option. In the 1990s, the papaya industry in Hawaii was under attack from the ringspot virus which threatened to wipe out Hawaiian papaya. The solution was a papaya genetically modified to be vaccinated against the virus. Without it, the state's papaya industry would have collapsed. All these stories show a

very narrow application. 99% of all GMOs we use right now produce pesticides, or are resistant against them. There is so much more we could do. The scientists are working on GMOs that could improve our diet. Plants that produce more or different nutrients, like fruit with higher antioxidant levels that help to fight diseases or rice with additional vitamins. On a larger scale, we're trying to engineer plants more resilient to climate change, plants that can better adapt to erratic weather and adverse soil conditions, making them resistant to droughts or floods. GMOs could also not only reduce agriculture's impact on the environment, but actively help to protect it. Scientists are working on crops that can draw nitrogen from the air, like microbes. Nitrogen is a common fertilizer, but its build-up pollutes the ground water and speeds up climate change. Plants that collect their own nitrogen could fix two problems at once. The over use of fertilizers in the developed world, as well as the shortage of it in developing countries. We could even modify plants to become super-effective carbon collectors, like the American chestnut tree, to mitigate and actually reverse climate change. With the tools we have today, our imagination is the limit. The world eats 11 million pounds of food every day. A UN estimate suggests we'll need 70% more by 2050. We could grow that food by clearing more and more forests to create fields and pastures and by using more pesticides. Or we find a way to do it on the land we've got right now, with more effective methods like GM crops. Intensifying farming instead of expanding it means GMOs could become the new organic. In a nutshell, GMOs have the potential to not only drastically change agriculture but to also dampen the effects of our own irresponsible behavior. GMOs could be our most powerful weapon to save our biosphere.

Source [mode]	**Target [mode]**	**Time in video**
Gremlin/mogwai [pictoral]	Herbicides [verbal]	04:44

2. “Genetic Engineering and Diseases – Gene Drive & Malaria”

   Posted: September 21, 2016

   Available online https://www.youtube.com/watch?v=TnzcwTyr6cE, accessed February 28, 2024.

   What if you could use genetic engineering to stop humanity's most dangerous predator, the deadliest animal on the planet responsible for the death of billions, the mighty mosquito? Along with other diseases it plays host to Malaria, one of the cruelest parasites on Earth possibly the single biggest killer of humans in history. In 2015 alone hundreds of millions were infected and almost half a million people died. A new technology could help us eradicate Malaria forever, but to do so we need to engineer a whole animal population. This is not a hypothetical problem,

the modified mosquitoes already exist in a lab. Should we use the technology, and is Malaria bad enough to risk it?

Malaria is caused by a group of microorganisms: Plasmodia, very weird microorganisms that consists of just a single-cell, they're parasites that completely rely on mosquitoes. Malaria always starts with an insect bite. In it's salivary glands, thousands of sporozoites wait until the insect penetrates your skin, immediately after invading you they head for the liver where they quietly enter big cells and hide from the immune system. For up to a month they stay here in stealth mode consuming the cells alive and changing into their next form: small drop like merozoites, they multiply generating thousands of themselves and then burst out of the cells. So thousands of parasites head into the bloodstream to look for their next victims, Red blood cells, to stay unnoticed, they wrap themselves in the membranes of the cells they killed. Imagine that! Killing someone from the inside and then taking their skin as camouflage, brutal! They now violently attack red blood cells, multiplying inside them until they burst then finding more red blood cells and this cycle repeats over and over. Pieces of dead cells spread lots of toxic waste material, which activates a powerful immune response causing flu-like symptoms, among the symptoms are high fever, sweats and chills, convulsions, headaches and sometimes vomiting and diarrhea. If malaria breaches the blood-brain barrier it can cause coma, neurological damage or death. The parasites are ready for evacuation now. When another mosquito bites the infected human they get a ride, the cycle can start over. In 2015, the Zika virus, which causes horrible birth defects if it infects pregnant women, spread rapidly into new areas around the globe. It too is carried by a mosquito. The mosquito is the perfect carrier for human diseases they've been around for at least 200 million years. There are trillions of them and a single one can lay up to 300 eggs at a time. They are practically impossible to eradicate and the perfect parasite taxi. But today we have a new revolutionary technology, that could enable us to finally win the war against them; CRISPR. For the first time in human history, we have the tools to make fast, large-scale changes to entire species, changing their genetic information as we please. So instead of attacking isolated groups of insects, why not just change the types that transmit diseases? Using genetic engineering, scientists successfully created a strain of mosquitoes that are immune to the malaria parasite by adding a new antibody gene that specifically targets plasmodium. These mosquitoes will never spread malaria. But just changing genetic information is not enough. The edits would only be inherited by half the offspring because most genes have two versions inside the genome as a fail-safe. So after just two generations, at most only half of the offspring would carry the engineered gene. In a population of billions of mosquitoes they would hardly make a difference. A genetic engineering method called the gene drive solves this problem. It forces the new gene to become

dominant in the following generations overpowering the old gene almost completely. Thanks to this twist, 99.5% of all the engineered mosquitoes offspring will carry the anti-malaria edit. If we were to release enough engineered mosquitoes into the wild to mate with normal mosquitoes, the malaria blocking gene would spread extremely quickly. As the new gene becomes a permanent feature of the mosquito population, Plasmodium would lose its home base. Scientists hope that the change would be so fast that they could not adapt to it quickly enough. Malaria could virtually disappear. If you take into account that maybe half a million children are killed by it every year, about five have died since this video started. Some scientists argue that we should use the technology sooner, rather than later. The mosquitoes themselves would probably only profit from this, they don't have anything to gain from carrying parasites and this might only be the first step Malaria might just be the beginning. Different mosquitoes also carry Dengue fever and Zika, ticks transmit Lyme disease, flies transmit sleeping sickness fleas transmit the plague. We could save millions of lives and prevent suffering on an unbelievable scale. So, why haven't we done this yet? For one, CRISPR editing is barely four years old, so until very recently we just couldn't do it as fast and easily. And there are valid concerns. Never before have humans consciously changed the genetic code of a free-living organism on this scale. Once we do it, there is no going back. So it has to be done right, because there could be unwanted consequences if we set out to edit nature. In this specific case of malaria though, the risk might be acceptable since the genetic modification doesn't make a big change in the overall genome. It only changes a very specific part. The worst-case scenario here, is probably that it might not work or that the parasite adapts in a negative way. There is still much debate. Technology as powerful as gene drive, needs to be handled with a lot of care but at some point we have to ask ourselves: Is it unethical to not use this technology, when every day 1,000 children die. Humanity has to decide how to act on this in the next few years. The public discussion is way behind the technology in this case. What do you think?

Source [mode]	**Target [mode]**	**Time in video**
sword [pictoral]	genetic engineering [verbal]	00:07
ball and chain [pictoral]	carrying parasytes [verbal]	05:05

3. “What Dinosaurs ACTUALLY Looked Like?”

   Posted: October 12, 2021

   Available online https://www.youtube.com/watch?v=xaQJbozY_Is , accessed February 28, 2024.

   The past is a vast and mysterious land that begins at the big bang and ends in the present, expanding with each passing moment. It is the home of everything that came before, the key to

understanding our present. Here we find the most amazing creatures to ever roam our planet, hundreds of millions of species so diverse that our imagination cannot do them justice. Unfortunately the past carefully guards its secrets. While there are a lot of things about the past we know, there are way more things we know we don't know. And worse, there are probably even more things we don't even know that we don't know about. Think of the wonder of life: We now recognize about 1.5 million eukaryotic species but there may be as many as 10 million alive today. And although we are adding some 15,000 new species to our collective knowledge each year, the vast majority of life on earth is still undiscovered. This is just what is around today. An estimated four billion species emerged on our planet in past eons. But at least 99% of them died out, way before humans spoke the first words. The vast majority of all the different species that ever existed are so utterly deleted that they have become part of the "unknown unknown" part of the past, lost to us forever. Or are they? Could we use science and imagination to glimpse a shadow of the unreachable past? Let us start with what we DO know. To learn about creatures of the past we need fossils, any sort of remains preserved from past geological ages – bones or shells, impressions or imprints, things preserved in amber. The totality of all fossils on earth is called the fossil record and it is the most important window on the past we'll ever have. For a dead animal to fossilize a number of things must go just right: The right environment, timing and conditions. And then the fossil needs to survive for millions or hundreds of millions of years and then get back to the surface – and then be discovered before natural processes dissolve it. So it is kind of a miracle that we have what we have and know what we know. Take the dinosaurs since they were one of the largest and most successful groups of animals for some 165 million years – and are also a lot of fun to animate. What were they really like and what are we missing? In the last 200 years we've found tens of thousands of fossils from over 1000 dinosaur species.. Lately we've entered a golden era of discovery and about 50 new dinosaur species are discovered each year, expanding what we know and what we know that we don't know about them, which is amazing. But it also makes us aware of all the things lost to the past forever. Imagine if we took all the animals that lived in the last 50 million years and randomly chose 10000 individuals from 1000 species to fossilize. Think about all the things that would be missed, or that seem too weird to be true. Like the Giraffe, a yellow animal with brown patterns that looks like a horse and an antelope had a baby, with a long neck and two tiny hairy horns. How many "dinosaur giraffes" were there? Animals so weird and selected for ecological niches so specific that evolution molded their bodies very absurdly - today they might seem made up to us.. We know a lot of species are lost forever just because of the environment they lived in. For example, lush jungles basically prevent fossilization as the chances that an animal will be buried here is minimal. Countless scavengers of all sizes

break down freshly deceased animals extremely quickly and the soil is often so acidic that bones are dissolved. And so fossils of dinosaurs from jungles are practically nonexistent. Today half of all known species live in the few remaining rainforests that only cover 2% of earth's landmass. Millions of years ago when dinosaurs roamed earth, jungles covered much more of the planet. So besides some insects and other small animals trapped in amber, there should be millions of species that emerged and vanished, without leaving any trace. Trapped deep inside the unknown, unknown. But just in general biology trips us up. Look at your body. It's mainly squishy, gooey, soft stuff. Which does not preserve well. What remains the longest are the crystalized parts of your bones and so most dinosaur fossils are bones or teeth – usually fragments, not entire skeletons. This means that almost all boneless or shell-less animals are practically wiped from the fossil record. If we take a look at the stunning diversity of weird animals like worms, jellyfish and slugs alive today we can only speculate what we are missing. Although thankfully many mostly soft and gooey species also left us an incredible diversity of shells that tell us an amazing amount about our past, so at least we have that. Still when we think about all the boneless species that may have existed in the last half billion years even our best attempt at imagining them falls short. But it's not like reimagining something based on its bones is straightforward and so the way we envisage what dinosaurs actually looked like has changed a lot in the last few years. In the past many illustrations had a bony, minimalistic look, with a toothy grin to signify fierceness and danger. But if we draw today's animals in a similar way, based on their skeletons, just for the fun of it, we get the most bizarre creatures. Elephants, swans and baboons that look like monsters right out of nightmares. So similar to animals today, we should imagine dinosaurs with much more soft tissue, fat bellies or chests, weird soft parts like skin flaps, lips and gums and just more pronounced features that would make them seem like much more pleasant fellows. Some soft features actually leave distinctive traces on bones that we can look for in the skeletons of extinct animals, which is where today's animals with similar features are really helpful. It's a similar story with color. Because we know what the feathers of living birds look like, modern technology combined with the exceedingly rare fossils with preserved remains of fuzzy feathers give us a glimpse of the real colors of extinct dinosaurs. We know that tiny Sinosauropteryx had a striped tail and its tiny dino buddy Anchiornis huxleyi was white and black with gorgeous red feathers around its head. Still, for the vast majority of really any ancient extinct species we have no real clue what color they were. But we know what modern dinosaurs, birds, look like and here we find the most amazing variety. So some dinosaurs will have tried to blend into the background, while others might have fielded aggressive color schemes to attract mates or to appear dangerous. Some might have had impressive decorations or colorful beaks. Some may have been striped or patterned.

Similarly we don't know that much about dinosaur behaviour, although once again we can draw conclusions from existing animals. For example even apex predators like lions spend a lot of their time lying around and cuddling and licking each other and playing. Why would dinosaurs be so different? When we first found the skull of T. rex with its mighty teeth and probably the strongest bite of any land animal ever, we imagined a fierce and stupid beast. But modern scanning technology has revealed that T.rex had a larger brain-to-body ratio than some earlier giant meat-eaters. And it probably had very sharp hearing, vision and sense of smell and was in all likelihood not a stupid animal. So maybe T.rex was a cuddly fellow that spent a lot of time playing around or impressing potential mates when it was not hungry. Likewise, while their horns and shields might have made ceratopsids appear to be natural born fighters, they were probably much more than that. Based on the behaviour of modern animals and the complex dances some have to go through to mate, maybe their shields were amazingly colorful, maybe it danced for its mates like many birds do today. How intensely amazing these creatures must have been. And what a loss it is to us that we don't get to experience them first hand. What an even greater loss that there is so much we will never know about them and even more tragic, all the absurd and beautiful beings that disappeared without a trace. But such is life – time marches on without any concern for our feelings and the past expands with every moment that passes. Most wild animals alive today will in all likelihood not leave fossils behind and also just disappear forever. We can do something about that though – instead of accelerating the extinction we are witnessing we could become the guardians of life and preserve it where we find it. If possible in the wild, if not then in museums, movies and in our minds. Because as amazing as our imagination is, and as fascinating to think about the animals that are part of the unknown unknown – it is even better to witness them in the present. The land that we actually inhabit, where we get to experience life as it happens.

Source [mode]	**Target [mode]**	**Time in video**
light from flashlight [pictoral]	recognition of species [verbal]	00:53
fossil [pictoral]	past [verbal]	01:36

4. "The World War of the Ants – The Army Ant"
   Posted: August 11, 2019
   Available online https://www.youtube.com/watch?v=7_e0CA_nhaE, accessed February 28, 2024.

Some groups just don't get along. Every day, billions of soldiers fight a merciless war on thousands of fronts, and it's been going on for over 100 million years. The World War of the Ants.

Ants are ancient beings that arose around 160 million years ago and took over a wide variety of ecological niches so successfully that they became one of the dominant animals on planet Earth. Today, they count more than 16,000 different species with over 10,000 trillion individuals. Collectively, ants alone make up 20% of the entire animal biomass on land. Similar to humans, their recipe for success is collaboration. While a single ant is pretty useless, together, they are able to achieve stunning feats. They construct complex colonies, care for livestock, pursue agriculture, or have complex symbiotic relationships. And of course, ants wage war. Even among the same species, a constant state of conflict is pretty common. Skirmishes, raids, and full-on invasions are happening every day, causing millions of casualties. Let's look at some of the most interesting ones in a series of videos. In this one, the army ant, a swarm made for war. The army ant group consists of about 200 different species. Army ants do not build nests; they live a sort of nomadic lifestyle with groups of millions of individuals. On a hunt, some species form large columns up to 100 metres long, killing and immediately dismembering every insect or small vertebrate they encounter. The biggest hunting parties can kill up to 500,000 animals per day. Some army ants specialize in hunting and consuming other social insects, like termites, wasps, and especially other ants. Wasps are fierce and may seem invulnerable, but if a swarm makes its way to their colonies, they don't even stand a chance. The much bigger and stronger wasps might kill a few of them, but they are quickly overwhelmed. Even if their queen survives an attack, the army ants steal the colony's larvae and quickly devour them. There is no recovery from that. When army ants discover another ant colony, they immediately attack. Now you might think this would be a more even battle, but it's not. Because army ants act as a social unit, they are especially dangerous and effective. Most army ants are not particularly impressive individually, but they can overwhelm their victims with sheer numbers before the victim colony can mount an effective defense. And so invasions tend to be won by the attackers, and the prey colony is damaged significantly or is exterminated. Interestingly, army ants don't fight army ants. When two swarms encounter each other in the wild, they either pass through each other, ignoring the other swarm, or both colonies just move away, which makes sense from an evolutionary standpoint. Army ants that fought other army ants probably eradicated themselves millions of years ago. Indeed they're so deadly that other ant species had to specialize to survive their presence. Many species just panic and evacuate their nest when they notice army ant scouts, carrying as many larvae with them as they can, in order to return and rebuild after the attack. Other species have invented living bunkers since fighting is so futile. They have worker

classes that have big square heads. When army ants show up, they use them to block the entrances to their nests, so the attackers have to give up after a while. But not everybody is afraid of army ants. Leafcutter ants form some of the largest and most complex societies of any animal other than humans. They live in extensive nests, many meters deep and across, harboring millions of citizens with a highly sophisticated division of labor. Like huge soldiers, 100 times more massive than a worker. Their sole purpose might be to defend their colonies against army ants. They still have a nemesis though. The diet of the army ant species Nomamyrmex esenbeckii consists mostly of the larvae of other ants. Compared to other army ants, they have a more robust soldier caste. So far, they are the only known species that can successfully attack a mature colony of leafcutters. When they find a leafcutter colony, hundreds of thousands attack in a long column. The moment the leafcutter ants notice the army ant attack, they go into crisis mode and immediately alert their soldiers, who very quickly swarm to the site of attack. A frontline develops that can be a few meters wide and up to a meter deep. The leafcutter soldiers go head-to-head with the army ants, locking on them and trying to cut through their heads. Smaller leaf cutter workers help by grabbing the enemies. Small teams carry out attacks behind the frontline, where they dismember their enemies by ripping their legs from their bodies. The attackers meanwhile try to swarm their victim's soldiers, and sting them to death in a mob. Despite the powerful defense and the determined response, the army ants are still superior in numbers. So without knowing if the battle can be won, the leafcutters prepare for the worst. Workers rush to create barricades and seal off as many entrances to their nest as possible to secure their route. If the leafcutters are not able to repel the invaders, or at least barricade enough of their entrances in time, the army ants swarm the nest, overrunning all opposition. They penetrate deep into the hidden chambers and steal tens of thousands of the leafcutters' brood to eat them. Even if the leaf cutter colony survives, this is a heavy blow. Regardless who's won the war, thousands lay slain on the battlefield. When the army ants attack, death follows them. But there are other species that form much more dangerous ant armies. Species that form supercolonies covering thousands of square kilometers over multiple continents engaging in wars kilometers across. They deserve their own video though. No matter the scale, war is a part of ant existence. Be it between huge colonies, or small groups trying to fend off a raid. In tropical rainforests, but also in the cracks of the concrete we walk over every day. Humans have decided that war is not a thing that they want to do a lot anymore. For ants though, the other ant will always be the enemy. No, some groups just don't get along.

Source [mode]	**Target [mode]**	**Time in video**
soldiers [verbal]	ants [pictoral]	00:09
battlefield [verbal]	ant nest [pictoral]	06:22

5. “Could Your Phone Hurt You? Electromagnetic Pollution”

   Posted: July 7, 2019

   Available online https://www.youtube.com/watch?v=FfgT6zx4k3Q, accessed February 29, 2024.

   Electricity is all around us all the time. It makes our lives easier, safer, more fun, and most of us never think about it. But is there such a thing as too much electricity? Could the thing that is the foundation of the modern world slowly be killing us? Before we dive deeper, let's try to understand what electricity is, and how it affects us. Electricity is the movement of an electric charge. This movement generates Electric and Magnetic Fields that spread out through space and carry energy. We call this phenomenon: Electromagnetic Radiation. Radiation is a word that makes people very nervous. But, to radiate just means, "giving off". Like when the radiator in your house gives off heat in the form of infrared radiation. Different parts of the electromagnetic spectrum correspond to different types of radiation. And, many of them are perfectly harmless. Some of them can be dangerous though. Radiation with very short wavelengths like UV Light, X-Rays, and Gamma Rays are strong enough to rip electrons out of their atoms, which can cause burns and genetic damage. This is what many people have in mind when they hear the term "radiation". The rest of the spectrum covers a large range of longer waves from Visible Light, Infrared, Microwaves, to Radio Waves. This is the kind of radiation that's emitted by all sorts of human technology. Mobile phones, Wi-Fi routers, electric power lines, and household appliances. This radiation doesn't disrupt molecules in our body. However, some kinds of radiation can stimulate muscles and nerves and can also make the hair on your body vibrate, which can sometimes cause a tingly feeling above certain threshold values. Other kinds are useful for making dinner. Microwaves push the water molecules in your food around which warms it up. This happens to us all the time. For example, the pleasant warmth you feel at the beach is your skin heating up from exposure to electromagnetic infrared radiation from the sun. We are surrounded by natural, and generally harmless, sources of electromagnetic radiation all the time and always have been. But, since the Industrial Revolution, we have added a lot of it to our immediate environment. The question of whether this is actually dangerous first got public attention when a 1979 study linked leukemia to living near power lines. This particular study was quickly discredited though. The connection could not be explained and no direct causal link was confirmed. But once this had been proposed, the idea persisted. And the thousands of studies about possible dangers illustrate that it's still seen as a very real threat. A lot of people claim to be sensitive to the radiation coming from our appliances and cell phones. They report symptoms like headaches, nausea, skin reactions,

burning eyes, or exhaustion. But those are just effects reported on a day-to-day basis. A few studies have found much more unsettling results. Like, possible connections between the side of the brain, which people use when they are on their phones, and the appearance of brain tumors. The question that science is trying to answer, is not so much about the acute effects of irradiation. We know, for example, that x-rays cause immediate damage to the DNA in your cells but that the same doesn't happen with radio waves. The question is rather: Is the sort of weak electromagnetic radiation we are constantly surrounded by harmful in the long run as a result of some as-yet-unknown mechanism? Answering this question was much harder than we first thought. There are thousands of primary sources, reports, and statements by an onslaught of different organizations. So, we read a lot for this video. You can take a look at our research in the video description. What we found is that this debate is a good example of how science should be communicated and how it shouldn't. Many of the much-cited studies that spread panic about electromagnetic radiation are highly controversial. For example, a series of population studies based on surveys and self-reporting. What this means is, for example, asking brain tumor patients how much they think they used their phone in the last few years. The problem is that people are unreliable. We tend to misremember things or can be influenced easily. On top of this, studies or media reports may be cherry picking, the findings that best suit their opinion, or make for the most exciting headline. For example, a study looking for cancer in rats and mice from cell phone radiation. The results seemed to show a connection. But, for some reason, only in male rats. And, none at all in mice. But it was reported as if this study did prove that mobile phone radiation causes cancer. Unfortunately, this is the case for studies with both positive and negative findings on the issue. Another aspect, is that the WHO did officially classify radio frequency fields as possibly carcinogenic. But what this actually means is that there are some hints that they might cause cancer, but we can't prove it, and that we will keep an eye out. So, if we zoom out a bit, what's the big picture? On the whole, there was no consistent evidence in human studies that electromagnetic radiation below exposure value limits causes health problems. There are some statistical associations but they're mostly weak and inconsistent. If there were any definite cause-effect relations we would know by now because of all the data we have. So, based on the current state of science, should you worry about the radiation from your laptop, or cell phone, or TV? The answer is no. You shouldn't. But what about the people who say it is harming them? Research show they could be experiencing what's known as the Nocebo Effect. If you have a headache and happen to start feeling better right when you switch off your laptop, you might see a connection between those two things. Once you get this suspicion, the idea alone that weak radiation might harm you could be the very thing harming you. It's easy to belittle these people; most of them feel they're not being taken seriously, which

makes the situation even worse for them. They should get support. But, it's important to be aware that, so far, we have no robust evidence that electricity below safety limits has any negative effect on humans. In the attention economy we live in, talking about unproven dangers can make us neglect things that we know for sure are bad for us. Just one example: Outdoor air pollution is linked to 4.2 million premature deaths each year, and is definitely something we could have a real impact on today. Still, to make people feel safe, and just to make sure, there are several long-term studies ongoing already. For example, the Cosmos study that will look at the possible health impacts of cell phone use by exactly measuring frequency and duration of phone calls. But while we wait for the conclusion of these long-term studies, there are a lot more pressing problems to focus on.

Source [mode]	**Target [mode]**	**Time in video**
Sonic the Headgehog [pictoral]	Electric charge [verbal]	00:36

6. "The Most Horrible Parasite: Brain Eating Amoeba"

   Posted: May 3, 2022

   Available online https://www.youtube.com/watch?v=7OPg-ksxZ4Y, accessed February 29, 2024.

   A war has been going on for billions of years that breeds well armed monsters, who struggle with other monsters for survival. Having no particular interest in us, most of them are relatively harmless, as our immune systems deal with their weapons easily. But there are exceptions. Naegleria fowleri is an amoeba that has not only developed a deadly taste for human brains but is also a match for our defences and stars in dramatic headlines. What happens when this monster enters your body? Naegleria fowleri is an amoeba, a microbe with a nucleus, one of the smallest lifeforms on earth. It is a voracious hunter of bacteria and other critters that it devours whole and rips into pieces. Like many amoebea it is able to transform into different stages that help it survive, but most of the time Naegleria fowleri is in its trophozoite stage, during which it looks like a squishy blob with tiny arms and hunts, divides and thrives. Its natural home is in fresh water: ponds, rivers, lakes and hot springs. But unfortunately it also feels happy in pipes, swimming pools, fountains or spas when they are not properly treated. The warmer the water, the more it thrives and multiplies. So in the summer, when humans seek to cool off and enjoy themselves, the chances are highest that both species will interact. Because this makes it hard to avoid, millions of people regularly have contact with the amoeba, especially in warmer climates, and many people even seem to have antibodies against it. And

this is mostly ok, you can even swallow it without consequences. Things turn bad when people dive or swim in water contaminated with the amoeba and water splashes high up into their noses. In a single drop of lake water there are millions of viruses, bacteria and amoebea and that isn't really a big deal. But Naegleria fowleri is different. Let us zoom into the nose of an unsuspecting victim enjoying a great summer day and see what happens. First of all, the amoeba doesn't really want to be inside your nose as it is not really looking for trouble, it just wants to eat a few bacteria. Instead it is greeted by your natural defenses. Unfortunately for humans, Naegleria fowleri happens to be exceptionally good at generally flying under the radar of your immune system. For example, the inside of your nose is covered by mucosa, a slime filled with chemicals that kill or stun possible invaders or alert immune cells. But Naegleria fowleri is not particularly bothered by them and instead calmly checks out the scenery, mildly annoyed about the whole ordeal. Now, if you are unlucky, the tiny critter stumbles over something that actually sparks its interest: Nerve cells. Your nose is filled with a large network of olfactory nerve cells that pick up molecules from the outside and transmit their information to your olfactory bulb, the center of smell in your brain. To do their job these cells talk to each other by releasing various messenger chemicals and recognizing them via specific receptors. One of the most important of these chemicals is acetylcholine. Through sheer evolutionary bad luck, Naegleria fowleri happens to have receptors that recognize acetylcholine. And it seems to attract them irresistibly, a little like moths that are attracted by light. So as your olfactory nerve cells do their job, using plenty of acetylcholine to talk to the brain, Naegleria fowleri enters your tissue. It seems to follow the chemical signals upstream. Neutrophils, crazy suicide warriors begin to attack the amoebae. Individually they have no chance against them as the invaders are large and pretty buff fighters, used to dealing with tough enemies. So the defenders swarm the intruders and kill them either by vomiting chemicals that punch holes into them or by literally ripping parts of them off and devouring them. But the Naegleria fowleri train is still on track and while the Neutrophil attacks slow them down, they continue to follow the olfactory nerves to their final destination: Your brain. This process can take between one and nine days and you'll probably not notice anything during that time. Until the amoebae reach the olfactory bulb, the center of smell and entrance to your brain. Your brain cells are nothing more than helpless victims and they all release that wonderful acetylcholine. Naegleria fowleri initiates a massacre and releases an onslaught of various attack molecules. Some of them are basically little bombs that rip holes into your cells on contact so their pieces can be eagerly consumed. But Naegleria fowleri is now multiplying - and it's also becoming really creepy. In a feeding frenzy it can develop up to a dozen suckers called food cups, that look like giant eerie mouths. The amoebae engage your brain cells, suck them in and rip large "bites" out of them while they are still alive.

Now things escalate quickly and the disease that will kill you sets in. Alerted by the massacre, millions of immune cells, Neutrophils, Eosinophils and microglias invade the infected tissue. Which is a problem: your immune system is dangerous and not exactly a careful fighter. It's like burning down a forest to kill the wolves inside it. A really bad idea in the brain. They waste no time and attack the amoeba, using all the weapons available to them, from chemicals to trying to eat them alive. Neutrophils explode themselves to erect barriers spiked with deadly chemicals. A fierce battle ensues. Naegleria fowleri can actually fight back, itself attacking and killing many immune cells. The immune system now throws everything it has at the invader but in vain. The complement system, tiny protein bombs that can kill intruders on their own, are easily disabled. Antibodies, usually one of your superweapons, are just destroyed or swallowed. A high fever that usually slows enemies down does nothing, as the amoeba actually thrives in the heat. All the while the amoebae continue to multiply, fight and devour your brain cells. A disastrous chain reaction is taking place. One major thing your immune cells do when they fight is to cause inflammation. Which directs large amounts of fluid from your bloodstream into the site of an infection. So as the battle rages on without a clear winner, more and more fluid enters the brain. At this point the human will feel symptoms that quickly escalate. It all begins pretty vaguely, a headache, fever, nausea and vomiting. As the battle spreads rapidly through the brain serious symptoms appear, from confusion, inability to concentrate to fatigue, seizures and hallucinations. The brain swells up massively but can’t expand due to the bones surrounding it. So it compresses and disables the brainstem that controls things like breathing. Usually within a week the patient dies. Up to 97% of patients infected by the amoeba share this fate. In almost all cases, by the time an infection by Naegleria fowleri is recognized the disastrous battle for the brain is already so far along that there is almost nothing to be done. Not only do we currently not have effective treatments, there are also an abundance of open questions about how an amoeba that usually enjoys its life in open water, is able to overcome our immune system so effectively. So how worried do you need to be about this horrifying killer amoeba? Well, not very. While the Naegleria fowleri is clearly extremely deadly and the infection truly horrible, there have only been a few hundred cases in the last few decades. You are way more likely to drown in a pool than to get infected. Not only does the amoeba need to be flushed high up your nose, it also needs to get a good grip and it also has to make its way through the first lines of your defences. Ultimately Naegleria fowleri is neither evil nor a huge public health risk. But every year some unlucky people have to deal with it. We still have so much to learn about it and until we find a way to treat it, Naegleria fowleri will continue to be this vague and horrifying thing, hunting in puddles and lakes and sometimes pools. Usually for bacteria. And very occasionally, for people.

Source [mode]	Target [mode]	Time in video
monster [verbal]	amoeba [verbal/pictorial]	00:36
scenery [verbal]	mucus inside the nose [pictoral]	02:52
defenders [verbal]	neutrophils [pictoral]	04:09
intruders [verbal]	amoeba [pictoral]	04:09

7. “The Coronavirus Explained & What You Should Do”

   Posted: May 3, 2022

   Available online https://www.youtube.com/watch?v=BtN-goy9VOY, accessed February 29, 2024.

   In December 2019, the Chinese authorities notified the world that a virus was spreading through their communities. In the following months, it spread to other countries, with cases doubling within days. This virus is the Severe Acute Respiratory Syndrome-Related Coronavirus 2 that causes the disease called COVID-19, which everyone simply calls coronavirus. What actually happens when it infects a human, and what should we all do? A virus is really just a hull around genetic material and a few proteins, arguably not even a living thing. It can only make more of itself by entering a living cell. Corona may spread via surfaces, but it's still uncertain how long it can survive on them. Its main way of spreading seems to be droplet infection when people cough or if you touch someone who's ill and then your face, say rubbing your eyes or nose. The virus starts its journey here and then hitches a ride as a stowaway deeper into the body. Its destinations are the intestines, the spleen, or the lungs, where it can have the most dramatic effect. Even just a few coronaviruses can cause quite a dramatic situation. The lungs are lined with billions of epithelial cells. These are the border cells of your body, lining your organs and mucosa, waiting to be infected. Corona connects to a specific receptor on its victim's membranes to inject its genetic material. The cell, ignorant of what's happening, executes the new instructions, which are pretty simple: copy and reassemble. It fills up with more and more copies of the original virus until it reaches a critical point and receives one final order: self-destruct. The cell sort of melts away, releasing new corona particles ready to attack more cells. The number of infected cells grows exponentially. After about 10 days, millions of body cells are infected, and billions of viruses swarm the lungs. The virus has not caused too much damage yet, but corona is now going to release a real beast on you: your own immune system. The immune system, while there to protect you, can actually be pretty dangerous to yourself and needs tight regulation. As immune cells pour into the lungs to fight the virus, corona infects

some of them and creates confusion. Cells have neither ears nor eyes. They communicate mostly via tiny information proteins called cytokines. Nearly every important immune reaction is controlled by them. Corona causes infected immune cells to overreact and yell bloody murder. In a sense, it puts the immune system into a fighting frenzy and sends way more soldiers than it should, wasting its resources and causing damage. Two kinds of cells in particular wreak havoc. First, neutrophils, which are great at killing stuff, including our cells. As they arrive in their thousands, they start pumping out enzymes that destroy as many friends as enemies. The other important type of cell that goes into a frenzy is killer T-cells, which usually order infected cells to commit controlled suicide. Confused as they are, they start ordering healthy cells to kill themselves too. The more immune cells arrive, the more damage they do, and the more healthy lung tissue they kill. This might get so bad that it can cause permanent irreversible damage that leads to lifelong disabilities. In most cases, the immune system slowly regains control. It kills the infected cells, intercepts the viruses trying to infect new ones, and cleans up the battlefield. Recovery begins. The majority of people infected by corona will get through it with relatively mild symptoms. But many cases become severe or even critical. We don't know the percentage because not all cases have been identified, but it's safe to say that there is a lot more than with the flu. In more severe cases, millions of epithelial cells have died, and with them, the lungs' protective lining is gone. That means the alveoli—tiny air sacs via which breathing occurs—can be infected by bacteria that aren't usually a big problem. Patients get pneumonia. Respiration becomes hard or even fails, and patients need ventilators to survive. The immune system has fought at full capacity for weeks and made millions of antiviral weapons. As thousands of bacteria rapidly multiply, it is overwhelmed. They enter the blood and overrun the body; if this happens, death is very likely. The coronavirus is often compared to the flu, but actually, it's much more dangerous. While the exact death rate is hard to pin down during an ongoing pandemic, we know for sure that it's much more contagious and spreads faster than the flu. There are two futures for a pandemic like corona: fast and slow. Which future we will see depends on how we all react to it in the early days of the outbreak. A fast pandemic will be horrible and cost many lives; a slow pandemic will not be remembered by the history books. The worst-case scenario for a fast pandemic begins with a very rapid rate of infection because there are no countermeasures in place to slow it down. Why is this so bad? In a fast pandemic, many people get sick at the same time. If the numbers get too large, health care systems become unable to handle it. There aren't enough resources, like medical staff or equipment such as ventilators, left to help everybody. People will die untreated. As more health care workers get sick themselves, the capacity of health care systems falls even further. If this becomes the case, then horrible decisions will have to be made about who gets to live and who doesn't. The number

of deaths rises significantly in such a scenario. To avoid this, the world—all of us—needs to do what it can to turn this into a slow pandemic. A pandemic is slowed down by the right responses, especially in the early phase, so that everyone who gets sick can get treatment and there's no crunch point with overwhelmed hospitals. Since we don't have a vaccine for corona, we have to socially engineer our behavior to act like a social vaccine. This simply means two things: 1. Not getting infected; and 2. Not infecting others. Although it sounds trivial, the very best thing you can do is to wash your hands. Soap is actually a powerful tool. The coronavirus is encased in what is basically a layer of fat; soap breaks that fat apart and leaves it unable to infect you. It also makes your hands slippery, and with the mechanical motions of washing, viruses are ripped away. To do it properly, wash your hands as if you've just cut up some jalapeños and want to put in your contact lenses next. The next thing is social distancing, which is not a nice experience but a nice thing to do. This means no hugging, no handshakes. If you can stay at home, stay at home to protect those who need to be out for society to function: from doctors to cashiers to police officers. You depend on all of them; they all depend on you to not get sick. On a larger level, there are quarantines, which can mean different things, from travel restrictions to actual orders to stay at home. Quarantines are not great to experience and certainly not popular. But they buy us—and especially the researchers working on medication and vaccinations—crucial time. So if you are put under quarantine, you should understand why and respect it. None of this is fun. But looking at the big picture, it is a really small price to pay. The question of how pandemics end depends on how they start; if they start fast with a steep slope, they end badly. If they start slow, with a not-so-steep slope, they end okay-ish. In this day and age, it really is in all of our hands, literally and figuratively.

Source [mode]	**Target [mode]**	**Time in video**
hitch a ride [verbal]	travelling inside the body [pictorial]	01:01
soldiers [verbal]	immunity cells [pictorial]	02:45

8. “Why Blue Whales Don't Get Cancer - Peto's Paradox”

   Posted: March 1, 2020

   Available online https://www.youtube.com/watch?v=1AElONvi9WQ, accessed February 29, 2024.

   Cancer is a creepy and mysterious thing. In the process of trying to understand it and get better at killing it, we discovered a biological paradox that remains unsolved to this day: large animals seem to be immune to cancer, which doesn't make any sense. The bigger a being, the more

cancer it should have. To understand why, we first need to take a look at the nature of cancer itself. Our cells are protein robots made out of hundreds of millions of parts. Guided only by chemical reactions, they create and dismantle structures, sustain a metabolism to gain energy, or make almost perfect copies of themselves. We call these complex chemical reactions pathways. They are biochemical networks upon networks, intertwined and stacked on top of each other. Most of them can barely be comprehended by a single human mind, and yet they functioned perfectly... until they don't. With billions of trillions of reactions happening in thousands of networks over many years, the question is not if something will go wrong, but when. Tiny mistakes add up until the grandiose machinery gets corrupted. To prevent this from getting out of hand, our cells have kill switches that make them commit suicide. But these kill switches are not infallible. If they fail, a cell can turn into a cancer cell. Most of them are slain by the immune system very quickly. But this is a numbers game. Given enough time, a cell would accrue enough mistakes, slip by unnoticed, and begin making more of itself. All animals have to deal with this problem. In general, the cells of different animals are the same size. The cells of a mouse aren't smaller than yours; it just has fewer cells in total and a shorter lifespan. Fewer cells and a short life mean a lower chance of things going wrong or cells mutating, or at least it should mean that. Humans live about 50 times longer and have 3,000 times more cells than mice, yet the rate of cancer is basically the same in humans and in mice. Even stranger, blue whales, with about 3,000 times more cells than humans, don't seem to get cancer at all. This is Peto's Paradox: the baffling realization that large animals have much less cancer than they should. Scientists think there are two main ways of explaining the paradox: evolution and hypertumors. Solution one: evolve or become a blob of cancer. As multicellular beings developed 600 million years ago, animals became bigger and bigger, which added more and more cells and hence more and more chances that cells could be corrupted. So the collective had to invest in better and better cancer defenses. The ones that did not died out. But cancer doesn't just happen. It's a process that involves many individual mistakes and mutations in several specific genes within the same cell. These genes are called proto-oncogenes, and when they mutate, it's bad news. For example, with the right mutation, a cell will lose its ability to kill itself. Another mutation, and it will develop the ability to hide. Another, and it will send out calls for resources. Another one, and it will multiply quickly. These oncogenes have an antagonist, though: tumor suppressor genes. They prevent these critical mutations from happening or order the cell to kill itself if they decide it's beyond repair. It turns out that large animals have an increased number of them. Because of this, elephant cells require more mutations than mice cells to develop a tumor. They are not immune but more resilient. This adaptation probably comes with a cost in some form, but researchers still aren't sure what it is.

Maybe tumor suppressors make elephants age quicker later in life or slow down how quickly injuries heal. We don't know yet. But the solution to the paradox may actually be something different: hypertumors. Hypertumors are named after hyperparasites: the parasites of parasites. Hypertumors are the tumors of tumors. Cancer can be thought of as a breakdown in cooperation. Normally, cells work together to form structures like organs, tissue, or elements of the immune system. But cancer cells are selfish and only work for their own short-term benefit. If they're successful, they form tumors, huge cancer collectives that can be very hard to kill. Making a tumor is hard work, though. Millions or billions of cancer cells multiply rapidly, which requires a lot of resources and energy. The amount of nutrients they can steal from the body becomes the limiting factor for growth. So the tumor cells trick the body to build new blood vessels directly to the tumor, to feed the thing killing it. And here, the nature of cancer cells may become their own undoing. Cancer cells are inherently unstable and can continue to mutate, some of them faster than their buddies. If they do this for a while, at some point, one of the copies of the copies of the original cancer cell might suddenly think of itself as an individual again and stop cooperating. Which means, just like the body, the original tumor suddenly becomes an enemy, fighting for the same scarce nutrients and resources. So the newly mutated cells can create a hypertumor. Instead of helping, they cut off the blood supply to their former buddies, which will starve and kill the original cancer cells. Cancer is killing cancer. This process can repeat over and over, and this may prevent cancer from becoming a problem for a large organism. It is possible that large animals have more of these hypertumors than we realize; they might just not become big enough to notice. Which makes sense—a two-gram tumor is 10% of a mouse's body weight, while it's less than 0.002% of a human and 0.000002% of a blue whale. All three tumors require the same number of cell divisions and have the same number of cells. So an old blue whale might be filled with tiny cancers and just not care. There are other proposed solutions to Peto's paradox, such as different metabolic rates or different cellular architecture. But right now, we just don't know. Scientists are working on the problem. Figuring out how large animals are so resilient to one of the most deadly diseases we know could open the path to new therapies and treatments. Cancer has always been a challenge. Today, we are finally beginning to understand it, and by doing so, one day we might finally overcome it.

Source [mode]	**Target [mode]**	**Time in video**
rewire circuit [pictoral]	cut off blood supply [verbal]	05:49

9. “The Reason Why Cancer is so Hard to Beat”

Posted: June 18, 2023

Available online https://www.youtube.com/watch?v=uoJwt9l-XhQ, accessed February 29, 2024.

An undead city under siege, soldiers and police ruthlessly shooting down waves of zombies that flood from infected streets, trying to escape and infect more cities. This is what happens when your body fights cancer, more exciting than any movie. How does this battle for survival unfold? It all begins with a single corrupted cell. It is no longer able to repair its genetic code, it can't kill itself anymore, and it is beginning to multiply rapidly. At this point, things are not great, not terrible – this cell is not yet dangerous, but if nothing happens, it soon will be. Over a few weeks, the corrupted cell keeps making copies of itself. One cell turns into dozens, hundreds, thousands. Because the original was broken, its copies are breaking and mutating even more. They turn into different genetic lineages, clans that are working together and competing. Some mutate in a way that makes them weaker, others' mutations don't change anything, while a few become fitter and better at survival. Together, they now form a tiny, tiny tumor. Not cancer yet, but getting there. The growing tumor needs a lot of resources. If the cells don't get food and oxygen, they will die, and the problem just solves itself. Unfortunately, a few corrupted cells unlock a new mutation that saves them: the ability to order the growth of new blood vessels. And so your body provides the supply they need to survive. But as the tumor continues to grow, it starts causing damage – neighboring healthy cells begin to starve and die, which attracts attention. In a sense, this tiny tumor is like a rogue town. Imagine a group of rebels in Brooklyn decided that they were no longer part of New York but started a new settlement called Tumor Town, which happens to occupy the same space. The new city wants to grow, so it orders tons of steel beams, cement, and drywall. New buildings follow no logic, are badly planned, ugly, and dangerously crooked. They are built right in the middle of streets, on top of playgrounds, and on existing infrastructure. The old neighborhood is torn down or overbuilt to make room for new stuff. Many of the former residents are trapped in the middle of it and begin to starve. This goes on for a while until the smell of death finally attracts attention. Building inspectors and police show up. In your body, attracted by the stench of dead cells, your immune system is activated. First responder immune cells invade the tumor: Macrophages and Natural Killer Cells, police forces that go right to work, killing and eating tumor cells. They release chemical signals that let the whole immune system know that there is cancer to be eradicated. Dendritic Cells, the intelligence officers of your immune system, collect samples of dead tumor cells and begin activating your heavy weapons: Helper and Killer T Cells. We explained these specialized super weapons in another video, but all you really need to know is that they have a library listing every bad thing that could come into your body. While

each cancer is unique, there are genetic corruptions that they can't hide. And your T Cells know what to look for. They are the deadliest cancer killers you have. By the time they arrive, the tumor has grown to hundreds of thousands of cells, but this is about to change. T Cells block the growth of new blood vessels, which starves thousands of tumor cells and puts an end to their growth. Imagine the building inspectors, switching off electricity and water and putting up roadblocks to Tumor Town so no more food and materials can be delivered. With no way to hide from the carnage unfolding, the tumor collapses as hundreds of thousands of tumor cells are massacred. Their carcasses are cleaned up and consumed by Macrophages that then order healthy tissue to regenerate. Your body has crushed the illegal Tumor Town without mercy. You will never know about this fight or how many times this has happened inside your body. Except… in this case, something did not go as planned. Unfortunately, natural selection spoils your victory. By doing its best to destroy the tumor, your immune system accidentally selects the fittest tumor cells. Remember, the tumor consists of different lineages that keep growing and keep mutating. Most of these are eradicated. But just a few are more resilient. One cell survives – it comes from the fittest tumor lineage and was just a bit better at surviving the massacre than anyone else. It decides to do it all over again. But better this time. This tumor cell is much stronger than any of the thousands that were killed. Maybe it is better at hiding, or fighting back. Maybe it grows faster or is better at stealing resources. Maybe it can survive with much less oxygen. And so it all begins again. It's like the surviving rebels that started Tumor Town have learned their lessons. Now they know the law better and how to break it, what permits help them, how to avoid the police. And so the surviving tumor cell makes thousands of copies that mutate and form new lineages, until once again a tumor has grown, made up from more resilient cells. The immune system does not care though, and this time it even has experience - instead of starting with police, swat teams go right in to tear Tumor Town down, killing its inhabitants without mercy. But once again they don't get everyone. One of them survives: a fitter tumor cell from an already fitter lineage. This time it gets a cheap suit and studies the building code, pretending to be a lawyer to start Tumor Town all over again. This struggle now repeats a few times, each time the rebels learn a bit more about how to avoid the law. If at any point, the immune system gets all of the tumor cells, the story ends. But in this case, it doesn't. Finally, a tumor cell changes in a way that makes it properly dangerous, cancer. The type that kills people. How? Immune cells have an off switch that deactivates them before they can attack – which in principle is a good idea. The immune system is extremely dangerous and in many cases, it needs to be shut down, like around your central nervous system. But this off switch can be exploited. The mutated tumor cell finds a way to switch the immune system off by targeting inhibitor receptors on anti-cancer cells. Inhibitor receptors stop immune cells

from, well, killing. This cell is the now powerful founder of a new lineage of cancer cells and mass produces thousands of new copies that once again change and mutate further, building yet another Tumor Town. The new cancer cells have become immune to the immune system and everything is different this time. Tumor Town has been rebuilt, even uglier and stranger than before, but now the cancer city council has forged all sorts of permits. As building inspectors come to shut down construction, they get confused. Stunned, they wander off, unable to order the destruction of the sprawling buildings. Police try to enter the illegal city to arrest the builders and execute inhabitants – but this time Tumor Town has erected its own roadblocks that keep the law from entering. Confused officers stand around helplessly. As Tumor Town slowly envelops the former Brooklyn and more and more civilians die, T Cell swat teams arrive to end this travesty. But things got worse – new lineages of Tumor Town officials have started to forge court documents that order police to shoot at the swat teams. What the cancer cells are doing at this point is actively shutting down immune defenses by sending corrupt signals. The now malignant tumor is no longer a pushover and has begun creating the Cancer Microenvironment. A sort of borderland that is hard to cross. All avenues of attack have been shut down and uncontrollable growth is the consequence. This is a dangerous tumor. Cells that are strong and able to fight push your immune system back and expand further. If more mutations happen, then some of the cancer cells will begin to explore the world and expand into other tissues, to build new towns. And this is exactly what makes cancer so harmful: it is taking up space and stealing so many nutrients that your true self has no room to function anymore. If this goes on for too long, organs will shut down. But this tactic is a dead end. The more successful cancer gets, the more damage it does to its world. When the body dies, the cancer dies too. It truly is a game without winners. Except, humanity is planning to win this game. At this moment, hundreds of thousands of scientists are working on new and better ways of killing cancer, to destroy and burn down Tumor Towns for good. In recent years, immunotherapy has made enormous progress – it is a relatively new therapy in which your own immune cells are modified to kill cancer better than any medicine can do. It's like giving your building inspectors machine guns and flamethrowers. But this is a story for another time – For now, cancer is a battleground – but if human ingenuity is to be trusted, then one day, maybe in the not too distant future, we will eradicate it once and for all.

Source [mode]	**Target [mode]**	**Time in video**
rogue town [verbal and pictoral]	tumor [verbal]	01:58
building inspectors and police [verbal and pictoral]	immune system [verbal]	02:47

intelligence officers [verbal]	dendritic cells [verbal and pictoral]	03:01
cement debris [pictoral]	tumor cell carcasses [verbal]	04:05
excavators [pictoral]	macrophages [verbal]	04:06
buildings [pictoral]	healthy tissue [verbal]	04:10
the world [verbal]	the human body [pictoral]	08:31
battleground [verbal and pictoral]	cancer [verbal]	09:32

10. “What Is Intelligence? Where Does it Begin?”

    Posted: July 12, 2020

    Available online https://www.youtube.com/watch?v=ck4RGeoHFko, accessed February 29, 2024.

    Humans are proud of many achievements, from particle accelerators to poetry to Pokémon. These accomplishments are possible because of something we value highly: intelligence. Intelligence is often thought of as a trait like height or strength, but defining it gets complicated. In essence, intelligence is a mechanism to solve problems, especially those related to survival, such as finding food and shelter, fighting rivals, or escaping predators. It's not a single entity; it includes the ability to gather knowledge, learn, be creative, form strategies, and think critically. It manifests in various behaviors, from instinctual reactions to learned actions and awareness. However, not all scientists agree on where intelligence begins or what should be considered as such. Moreover, intelligence is connected to consciousness, which helps with problem-solving, but we'll explore that in other videos. Instead of thinking of intelligence as a clear-cut trait, we can view it as a flexible set of skills or a toolbox. Basic Tools. The most basic tools in the intelligence toolbox are the ability to gather information, save it, and use it to learn. Information is gathered through senses like vision, sound, smell, touch, and taste, helping living beings navigate and react to the world. Additionally, they need to monitor their own body's state, such as hunger and fatigue. Information forms the basis for action, allowing appropriate and flexible reactions. Memory, the ability to save and recall information, prevents starting from scratch with each new relevant perception. Memories can be about events, places, associations, and behaviors like hunting or foraging, which often require repetition to master. This process is called learning, the sequence of repeatable behaviors that can be adapted. These tools enable even seemingly simple creatures to act intelligently. For instance, the acellular slime mold, a single slimy cell, displays behavior akin to that of an animal with a simple brain.

In a maze, it marks paths with slime trails to avoid dead ends, demonstrating adaptive behavior that some scientists argue could be considered intelligent. Bees exhibit more adaptive smart behavior. Scientists trained bumblebees to move a colored ball into a goal for a sugar reward. The bees improved over time, choosing the nearest ball to the goal, even if it was a different color from the training ball. Fancier Tools. More complex animals build on these basic tools to solve a wider range of problems, memorizing associations, connections, and mechanical tricks. We call this the "Library of Knowledge." For example, raccoons, known for their love of human food, use theoretical and practical skills to open windows or pick locks. In a study, they quickly learned to open boxes secured with various locks and remembered how to do so a year later. Beyond associations and skills, the most impressive tool is creativity, which allows making new and valuable connections. In another study, raccoons dropped pebbles into a water tank to raise the water level and reach a marshmallow, with one raccoon simply tipping the tub over for an easier solution. Creativity also involves applying new resources to tasks, like primates using sticks to fish for termites or octopuses using coconut shells as portable armor. Collecting materials for later use is linked to planning, an advanced problem-solving dimension. Planning involves considering activities required for a goal and putting them into a plan, adapting to unforeseen circumstances and new possibilities. Squirrels, for instance, hoard food, examining nuts to decide which to eat or store and using advanced thinking to distract rivals with fake caches. Human Intelligence. Humans have developed an unusually diverse intelligence toolkit, which has allowed us to shape the planet and create complex societies. Our added set of tools, culture, enables us to work together and share knowledge across generations, achieving feats beyond any single individual's ability. This has led to remarkable achievements but also new challenges like climate change and antibiotic resistance. To solve these, we'll need to look beyond short-term survival and consider the distant future, using our extensive toolbox wisely.

Source [mode]	**Target [mode]**	**Time in video**
floppy disk [pictoral]	memory [verbal/pictoral]	02:06

11. “Why Are You Alive – Life, Energy & ATP”

    Posted: May 10, 2020

    Available online https://www.youtube.com/watch?v=QImCld9YubE, accessed February 29, 2024.

    At this very second, you are on a narrow ledge between life and death. You probably don't feel it, but there's an incredible amount of activity going on inside you, and this activity can never stop. Picture yourself as a Slinky falling down an escalator moving upwards. The falling part represents the self-replicating processes of your cells. The escalator represents the laws of

physics driving you forwards. To be alive is to be in motion but never arriving anywhere. If you reach the top of the escalator, there's no more falling possible, and you are dead forever. Somewhat unsettlingly, the universe wants you to reach the top. How do you avoid that? And why are you alive? All Life is Based on the Cell. A cell is a piece of the dead universe that separated itself from the rest so it could do its own thing for a while. When this separation breaks down, it dies and joins the rest of the dead universe again. Unfortunately, the universe would like for life to be done with doing its own thing. For some reason, it's not a fan of exciting things and tries to be as boring as possible. We call this principle "entropy," a fundamental rule of our universe. It's pretty complicated and counterintuitive, so we'll explain it in detail in another video. For now, all you need to know is living things are inherently exciting. A cell is filled with millions of proteins and millions more simpler molecules like water. Thousands of complex, self-replicating processes are happening up to hundreds of thousands of times every second. To stay alive and exciting, it has to constantly work to keep itself from achieving entropy and becoming boring and dead. The cell has to maintain a separation from the rest of the universe by keeping the concentration of certain molecules different on the inside and the outside, actively pumping out excess molecules. Energy: The Lifeline of Cells. To do this, a cell needs energy. Energy is the ability of things in the universe to do work; to move or manipulate a thing; to create change. This ability cannot be created or destroyed. The set amount of energy in the universe will never change. We don't know why; it just is that way. So, billions of years ago, one of the most crucial challenges for the first living beings was to get usable energy. We don't know a lot about the first cells, except that they got their energy from simple chemical reactions. They found the ultimate energy transfer system: the energetic building block of life, Adenosine Triphosphate, or ATP. Its structure makes it uniquely good at accepting and releasing energy. When a cell needs energy, for example, to pump out molecules or repair a broken micro machine, it can break down ATP and use the chemical energy to do work and create change. This is why living beings are able to do stuff. We don't know when or how exactly the first ATP molecule was made on Earth. But every living thing we know uses ATP, or something very similar, to keep its internal machinery running. It's crucial for almost every process. Without ATP, no life on Earth. Harnessing the Sun's Energy. While breaking down chemicals for energy is nice and all, early life missed out on the greatest available source of energy: the Sun. The Sun merges atoms and radiates photons away that carry energy into the solar system. But this energy is raw and indigestible. It needs to be refined. After hundreds of millions of years of evolution, a cell finally figured out how to eat the Sun. It absorbed radiation and converted much of it into neat little chemical packages that it could use to stay alive. We call this process photosynthesis. In photosynthesis, cells take photons that are wobbly with

electromagnetic energy and use a part of this energy to merge and combine different molecules. The electromagnetic energy is converted into chemical energy stored in the ATP molecule. This process improved as some cells learned to create better chemical packages: glucose, or sugar. Easy to break down, high in energy, and pretty tasty. Some cells decided that instead of doing all that pesky photosynthesis work themselves, they would just swallow other cells that did, and take their glucose and ATP. This is considered one of the biggest betrayals in evolutionary history. The Powerhouse of the Cell. Photosynthesizing cells could mostly harness energy at their surfaces, which limited their maximum energy production and evolutionary possibilities. Time passed, and some cells made sugar, others ate them. Evolution continued, but things stayed relatively the same for hundreds of millions of years. Until one day, a cell ate another and did not kill it. Instead, they became one cell. This merging of two living beings is crucial because it allowed the inner cell to stop trying to survive and concentrate on making ATP, becoming the mitochondria, the powerhouse of the cell. The host cell's job was to ensure survival in the dangerous world and provide the mitochondria with food. Mitochondria reverse photosynthesis by taking sugar molecules, combusting them with oxygen, and making new, energy-rich ATP molecules. This process works like a tiny furnace, producing waste products like CO2, water, and a bit of kinetic energy that we experience as body heat. This division of labor meant the new cell had much more energy available, enabling more complex cells to evolve. These cells eventually formed small groups, leading to multicellular life, and finally, to you. The Fragility of Life. Today, you are a pile of trillions of cells, each filled with dozens, if not hundreds of little machines that provide you with usable energy to stay alive. If this process is interrupted, even for a few minutes, you die. Life's fragility raises the question: why don't we store ATP like we store sugar in fat cells to avoid dying if we stop breathing for a while? Even simple bacteria like E. Coli produce about 50 times their body weight in ATP for every cell division. Your trillions of cells need a lot of ATP to keep you alive. Every day, your body produces and converts about 90 million, billion, billion molecules of ATP, about your body weight. You need a whole person's worth of ATP just to make it through a single day. Storing enough ATP to last even a few minutes is impossible. An ATP molecule is excellent for shifting energy around quickly but terrible for storage, as it has only one percent of a glucose molecule's energy at three times its mass. So ATP is constantly produced and used up quickly. Conclusion. This was the short and simplified story of the molecule that allows you to be different from the dead universe and to be the Slinky on the escalator. It is a weird story. There is this molecule you need to survive at all times. You need it to keep moving, because even a short break brings your Slinky to a stop. And you need to make it yourself. It's like driving a car at full speed while producing fuel in the trunk with junk that you pick up from the side of the road. As far as we

know, this all began billions of years ago, when tiny parts of the dead universe came together and became something else for a moment. It could keep itself going. It could grow. That moment set the Slinky in motion, and it's been going ever since. From the very first cells to you watching this now. At some point, you will merge with the rest of the dead universe again. Maybe you'll tell it stories about your adventures. Maybe not. But before you find out, you get to do what life does best: making a dead universe much more interesting.

Source [mode]	**Target [mode]**	**Time in video**
level up [pictoral]	evolution [verbal]	05:34
machine [verbal]	cell [pictoral]	07:35

12. “Homeopathy Explained – Gentle Healing or Reckless Fraud?”

    Posted: February 22, 2018

    Available online https://www.youtube.com/watch?v=8HslUzw35mc, accessed February 29, 2024.

    Homeopathy may be the most controversial but also the most popular alternative medicine. While some argue against it, others swear by its great power and effectiveness. How does homeopathy work? How did it become what it is today, and what can modern medicine learn from it? The first principle of homeopathy is "like cures like." Remedies use ingredients that cause the symptoms you want to cure. In practice, that means that remedies against fever could, for example, be made from belladonna, which also causes fever. A mixture based from bee venom is used to treat itchy swellings, and so on. The second principle is the special method of preparation called potentization. The idea is that diluting and agitating the ingredients activates their curative powers and enhances their effect. To do this, the ingredient is dissolved in alcohol or distilled water. Homeopaths take one part of the solution and mix it with nine parts of water, diluting it down to one tenth of its original concentration, and shaking it. What you have now is a 1X potency---one part ingredient and nine parts solvent---named after the Roman numeral X, for 10. one-part ingredient and nine parts solvent, named after the Roman numeral X, for 10. Now, this process is repeated. Take one part, mix it with nine parts of pure water and shake it vigorously. Now you have 2X. You do this again and again until you reach the desired grade of potency. The finished remedy is then taken orally, or sometimes it's applied as little sugar pellets that are sold as globuli. A 20X potency, for example, is like dissolving one aspirin pill in the water volume of the whole Atlantic. But many are much more extreme, like 30C, for example. C means that the mixture has one part ingredient and 99 parts water. So the commonly sold 30C mixture means one part ingredient and.one million billion billion billion billion billion BILLION If we wanted a globuli pill with a single atom of the original ingredient, then our pill

would be the diameter of the distance between the Earth and the Sun. 150,000,000 kilometers A pill so massive, that it would collapse into a black hole under its own mass. Because of this, potentization is one of the biggest criticisms of homeopathy. The extreme dilution is supposed to make the ingredients more potent, but on a physical level, this doesn't really make sense. Most homeopathic remedies are diluted so much that not a single atom of the active ingredient is left in them. The explanation of why the mixtures still work is that shaking the mixture after every dilution leaves behind a spirit-like essence of the ingredient. Basically, the idea is that water remembers what was put into it. But if this were true, then every substance that ever met a drop of water would leave an essence behind and lead to unpredictable effects when it was accidentally ingested. Think of all the stuff that lives and floats in the oceans. Every sip of water would be a supercharged homeopathic cocktail. So how did homeopathy become the most successful alternative medicine? In the 18th century, medicine was very different from today. Treatments like bloodletting left the patient worse off than before. So German physician Samuel Hahnemann wanted a non-invasive, natural way of healing and developed homeopathy. And, in fact, homeopathic hospitals were soon successful because doing no harm beats doing harm. Hahnemann imposed very strict rules on his patients. First you had to avoid coffee, tea, alcohol, spicy food, sweet food. No old cheese, no onions, no meat. No clothes made from sheep's wool, but also no sedentary work, no sitting inside in stuffy air, no warm rooms, no riding horses, no napping, no playing games, no masturbation, and of course, no reading pornographic texts, and many more. Then, and only then, would his remedies work, according to the inventor of homeopathy. Of course, all of these instructions are ignored and not talked about today. Of course, all of these instructions are ignored and not talked about today. Medicine has changed a lot in the last 150 years. Never before in human history have we enjoyed a comparable level of health. Never have we lived as long, and this is largely due to the new tools we've developed. Never have we lived as long, and this is largely due to the new tools we've developed. Modern diagnostics, double-blinded studies, and scientific evaluation to check and prove which stuff works. Thanks to these tools, after countless studies and reviews, we know beyond a shadow of a doubt that homeopathy does not have any effect beyond placebo. But even so, who cares why it works if it helps people? Maybe you tried it and felt better, or you know someone that got over a horrible disease while using homeopathic remedies, and there are plenty of reports of it working for children and animals. What do we make of these experiences? The Placebo Effect is very real and not imaginary. No matter how smart you are, you're not immune to it. If people believe that something will help them feel better, their trust alone has the desired effect. And it's been proven that the Placebo Effect can be transferred. Children and animals rely on their parents or keepers and are in tune to their emotions. If a parent has a lot of trust in a

treatment and eases up, this can help a child relax and help relieve symptoms. This could also be observed with animals who react strongly to the body language cues of the people caring for them. but the most powerful tool of homeopathy is time. Our bodies are survival machines. Infections pass on their own after a few days. But if you take some remedy when you already feel sick, and then start getting better, it feels like it did indeed cure you, when actually, it would have happened anyway. The homeopathy industry likes to play the gentle alternative to Big Pharma. But the homeopathic industry IS Big Pharma. Billions of dollars are made with extreme profit margins. The homeopathy industry has its own lobby organizations and fights its enemies as hard as it can. A lot of money is on the line. Globally, the market is expected to reach over 17 billion by 2024. Some critics even argue that the homeopathic industry is bad for public health because it creates distrust in proven medicine. The belief in homeopathy correlates with skepticism about vaccinations. This can discourage people to seek the help they need when their lives or the lives of their children are on the line. But there is actually a key to the success of homeopathy that we could, and should, copy. The first consultation with a homeopath can take hours and is very personal. For a patient who's already been on a pilgrimage from doctor to doctor, this level of attention and empathy can make a huge difference to their well-being, even if the conversation was not the point of the therapy. Modern medicine is efficient. It saves millions of lives each year. But it's also a strictly organized system. Tight budgets force doctors and nurses to deal with lots of patients. Consultations need to be time-efficient, diagnoses made quickly, treatments fast, which can leave patients feeling invisible, scared, and left behind. This is what modern medicine can learn from homeopathy. It meets a human need that has been left unfulfilled. We need to make time for the individual again. See people, not numbers. But as important as empathy is, it's not a substitute for actual treatment. Faith can move mountains, but sugar water can't cure cancer. After a short break of a few years, Kurzgesagt is back in German. Thanks to the support of Funk, we have relaunched the German channel and are beginning to upload a video every 1-2 weeks. Besides redoing our favorite videos, there'll be a number of videos that will not exist in English for a while. Check out the channel here, tell us what you think, and subscribe and watch a few. If the channel goes well, the German videos might become a regular thing for years, and we might even do more languages.

Source [mode]	**Target [mode]**	**Time in video**
factory [pictoral]	conventional medicine [verbal]	07:12

13. “You Are Immune Against Every Disease”

    Posted: November 2, 2021

Available online https://www.youtube.com/watch?v=LmpuerlbJu0, accessed March 1, 2024.

You are not a person, you are a planet, made of roughly 40 trillion cells. There is so much of you that if your cells were human-sized, you would be as big as 20 Mount Everests. For your creepy-crawly inhabitants, this makes your body an ecosystem, rich in resources and warmth and space. A perfect place to move into and have a family. While some of these guests are welcome, most are not. Your immune system is the guardian of this planet, the force tasked with protecting yourself against the constant danger of invasion. Unfortunately, your enemies in the tiny world have a huge advantage. Consider the effort it takes to make a single copy of yourself and your trillions of cells. First, you need to find someone who thinks you are cute, date and be awkward, and if things work out in a complicated dance, two of your cells merge together. Then you need to wait for months while the cell multiplies over and over until it is released into the world as a human being. And even then, you only have a mini copy that needs years to become remotely useful. A bacterium consists of one cell. It can make a fully grown copy in about half an hour. A virus can turn into hundreds within hours and billions within days. Your enemies multiply orders of magnitude faster than you. Even worse, for a bacterium or virus, your body is a hostile ecosystem applying selective pressure. Because they go through so many generations so quickly, eventually, by pure chance, there will be an individual that mutates and adapts in just the right way to resist your defenses and then multiply quickly again. In other words, you are facing a sheer endless variety of different enemies and you're too slow to keep up with their evolution. This is bad. Luckily, your immune system is just about the most amazing thing ever. The second most complex biological system known to us, after the human brain, and so sophisticated that we still haven't discovered all its secrets. Since it is so complicated, we have to simplify and focus on one thing at a time. If you want the full story, wait for the announcement at the end of the video! Ok, so why are we not all killed by some new bacteria or virus? In a nutshell, you actually have two immune systems, the innate and the adaptive immune system. The innate immune system was ready when you were born. It mostly consists of general-purpose soldiers, we introduced them in the last immune video. The adaptive immune system carries two types of cells T Cells and B Cells that are your super weapons and are incredibly effective and deadly for your enemies. These cells are complicated to produce and take a lot of time to deploy but once they are ready, they pack a real punch.

What makes your adaptive immune system so powerful is that it has the largest library in the universe. It has an answer to everything. You have at least one of these super weapon cells inside you to fight the black death, the coronavirus, and the first deadly bacteria that will emerge in a city on Mars in one hundred years. This makes it possible for you to counter the ability of bacteria and viruses to change so rapidly. How is this possible? To understand what is going on

here, we need to take one step back. All organisms on earth are made from the same basic parts, mostly proteins. Proteins are the building blocks of life and can have billions of different shapes - you can imagine them as 3D puzzle pieces. There are billions of different puzzle pieces your enemies can use to construct their bodies. Why is this important? Because proteins are in a way the “language” of the microworld. Cells don’t have eyes or ears, so to tell friend from foe, they have to touch them and recognize if their protein is part of a friend or part of an enemy. Recognizing means that cells have countless tiny devices called receptors, that are able to connect with a specific protein puzzle piece. So your cells have tiny puzzle pieces on their outsides that are able to click together or recognize other protein puzzle pieces. When a cell connects together with a protein and recognizes it as “enemy”, it knows that it has to attack. Only if your cells can make this distinction between friend or foe is your immune system able to fight an invader. But since there are billions of possible protein puzzle pieces, this means there are billions of possible enemy puzzle pieces. This is also one of the reasons we still have to deal with diseases like the flu each year – the influenza virus mutates very rapidly and so the proteins that make up its hull constantly change a tiny bit. The soldiers of your innate immune system have a large number of the puzzle pieces for common bacteria and viruses memorized, that’s why they are your all-purpose weapons. But they are ineffective against many billions of mutations and adaptations that your enemies can develop. So the reason you are still alive is that your adaptive immune system is able to recognize between one billion and ten billion different enemy protein puzzle pieces, which is enough to be prepared for every possible enemy. But how is this possible? How could your immune system possibly have this much of a variety to be prepared for every possible protein puzzle piece? Well, the cells of your adaptive immune system found a cheat code: mixing and matching their own genetic code to create this stunning variety of receptors. The details are way too complicated for this video but in a nutshell, your adaptive immune cells have official permission to take a tiny part of their own genetic code and mix it in random ways to create billions of different receptors. A good way to explain this is by asking you to imagine an army of cooks, with each of them wanting their own special recipe. They have 100 different ingredients to choose from. Each ingredient stands for one tiny piece of genetic code in this metaphor. So each cook takes a few random ingredients and randomly mixes them together. Maybe Tomato, Chicken, Rice, and half an onion as an entree, Marshmallow, Pepper, Strawberries, and a quarter banana as a dessert. Or Cucumber, Beef, Potatoes, and two carrots, and blueberries, chocolate, and cream with a pinch of cinnamon. Even with slight variation and with only 100 ingredients, there are billions of possible recipes. And likewise, with just a small selection of gene fragments, your cells create billions of receptors. The details of this are so cool that they should get their own video – or their own

chapter in a book. In any case, by mixing up gene fragments, you get up to ten billion different combinations. So in the end, you get billions of immune cells, and each of them has one specific and unique receptor – the dish from our metaphor – that is able to recognize one specific protein puzzle piece. In total, you end up with at least one cell for every enemy that could possibly exist. But here we run into a pretty dangerous problem – if your adaptive immune system is making weapons that can attack every possible protein puzzle piece in the universe… wouldn't it also make some that can attack your own cells? Yes, it happens all the time. This is so fundamentally dangerous to your survival that you have a whole organ that does nothing but work on preventing this: The Murder University of your Thymus. Your Thymus is a chicken wing-sized organ above your heart and you've probably never heard of it. Interestingly, your thymus is one of the reasons why your immune system weakens as you age because it is in a constant state of decline once you reach puberty. But what does the Thymus do? In your murder university, your immune system is putting your adaptive immune cells through an intense and deadly curriculum. Basically, it is showing them all sorts of protein puzzle pieces that are used by your own cells to see how they react. When a young cell recognizes a body puzzle piece and wants to attack it, the teacher cells order them to kill themselves and they are eaten up and recycled. The immune system is so particular about this process that around 98% of your adaptive immune cells that enter murder university die there. 2% graduate and get to do their job of protecting you for real. If this process goes wrong and cells escape that can recognize your own protein puzzle pieces, this can lead to autoimmune disease, where your immune system attacks your own body from the inside. And this, again is another story for another time. Ok, let us summarize. Your immune system has two parts, one that defends you right after birth and one that carries the largest library of superweapons in the universe but needs to boot up first. To create billions of different superweapons, your adaptive immune cells recombine a part of their genetic code to create a breathtaking variety of attack weapons. Then they enter a murder university that only 2% survive to make sure they do not attack you. And then you end up with billions of different cells, that in total are able to protect you against every possible enemy in the universe. Now wait a second. If this is all true, why do we get sick at all? Why was a new disease like Covid-19 able to kill millions of people? Well, everything we just learned about is just a tiny, tiny window into the amazing struggle for life and death that plays out every day inside your body and there are so many amazing details and questions here: How does your body actually find the right cell in time to protect you? How do your enemies fight back and overcome your immune system anyway? And what about all the things that did not fit in this video?

Source [mode]	Target [mode]	Time in video
guest [verbal]	bacteria [pictoral]	00:30
enemy [verbal]	virus [pictoral]	00:47
Cheat code [verbal]	genes [pictoral]	05:49
university [verbal]	thymus [pictoral]	08:15
obstacle course [pictoral]	curriculum [verbal]	08:20

14. “The Immune System Explained I – Bacteria Infection”

    Posted: July 1, 2014

    Available online https://www.youtube.com/watch?v=zQGOcOUBi6s, accessed March 1, 2024. Every second of your life, you are under attack. Billions of bacteria, viruses, and fungi are trying to make you their home, so our bodies have developed a super complex little army with guards, soldiers, intelligence, weapons factories, and communicators to protect you from... well... dying. For this video, let's assume the immune system has 12 different jobs. For example, kill enemies, communicate, etc. And it has 21 different cells and 2 protein forces. These cells have up to 4 different jobs. Let's assign them. Here are the interactions. Now, let's make this understandable. First of all, let's add colors to the jobs. Now, let's illustrate the cells. The central color represents the main job of the cell, while the surrounding ones represent secondary duties. Now the immune system looks like this. Now the interactions. Isn't this complexity just awesome? For this video, we will only talk about these cells and ignore the rest. So, what happens in the case of an infection? It's a beautiful day when suddenly, a wild rusty nail appears, and you cut yourself. The first barrier of the immune system is breached: your skin. Nearby bacteria seize the opportunity and enter your wound. They start using up the body's resources and double their numbers about every 20 minutes. At first, they fly under the radar, but when a certain bacteria population is reached, they change their behavior and start to damage the body by altering the environment around them. The immune system has to stop them as fast as possible. First of all, your guard cells, known as macrophages, intervene. They are huge cells that guard every border region of the body. Most of the time, they alone can suffocate an attack because they can devour up to 100 intruders each. They swallow the intruder whole and trap it inside a membrane. Then the enemy gets broken down by enzymes and is killed. On top of that, they cause inflammation by ordering the blood vessels to release water into the battlefield so fighting becomes easier. You notice this as a very mild swelling. When the macrophages fight for too long, they call in heavy backup by releasing messenger proteins that communicate location and urgency. Neutrophils leave their patrol routes in the blood and move to the

battlefield. The neutrophils fight so furiously that they kill healthy cells in the process. On top of that, they generate barriers that trap and kill the bacteria. They are, indeed, so deadly that they evolved to commit suicide after five days to prevent them from causing too much damage. If this is not enough to stop the invasion, the brain of the immune system kicks in. The dendritic cell gets active. It reacts to the signals of the soldiers and starts collecting samples from the enemies. They rip them into pieces and present the parts on their outer layer. Now, the dendritic cell makes a crucial decision. Should they call for anti-virus forces that eradicate infected body cells or an army of bacteria killers? In this case, anti-bacteria forces are necessary. It then travels to the closest lymph node in about a day. Here, billions of helper and killer T cells are waiting to be activated. When T cells are born, they go through a difficult and complicated training process, and only a quarter survives. The surviving cells are equipped with a specific set-up. The dendritic cell is on its way looking for a helper T cell with the set-up that's just right. It's looking for a helper T cell that can bind the parts of the intruders that the dendritic cell has presented on its membrane. When it finally finds one, a chain reaction takes place. The helper T cell is activated. It quickly duplicates thousands of times. Some become memory T cells that stay in the lymph node and will make you practically immune against this enemy. Some travel to the field of battle to help out. The third group goes on to travel to the center of the lymph node to activate a very powerful weapons factory. Like the T cells, B cells are born with a specific set-up, and when a B cell and a T cell with the same set-up meet, hell breaks loose. The B cell duplicates rapidly and starts producing millions of little weapons. They work so hard that they would literally die from exhaustion very fast. Here, helper T cells play another important role; they stimulate the hard-working factories and tell them: "Don't die yet, we still need you, keep going!" This also ensures that the factories die if the infection is over so the body doesn't waste energy or hurt itself. But what is produced by the B cells? You've heard of them, of course, antibodies. Little proteins that are engineered to bind to the surface of the specific intruder. There are even different kinds of antibodies that have slightly different jobs. The helper T cells tell the plasma cells which type is needed the most in this particular invasion. Millions of them flood the blood and saturate the body. Meanwhile, at the site of infection, the situation is getting dire. The intruders have multiplied in number and start hurting the body. Guard and attack cells fight hard but also die in the process. Helper T cells support them by ordering them to be more aggressive and to stay alive longer. But without help, they can't overwhelm the bacteria. But now, the second line of defense arrives. Billions of antibodies flood the battlefield and disable lots of the intruders, rendering them helpless or killing them in the process. They also stun the bacteria and make them an easy target. Their back is built to connect to killer cells, so they can connect and kill the enemy more easily. Macrophages are

especially good at nomming up the bacteria to which antibodies have attached. Now the balance shifts. In a team effort, the infection is wiped out. At this point, millions of body cells have already died. No big deal, the losses are quickly replenished. Most immune cells are now useless and without the constant signals they commit suicide, so as not to waste any resources. But some stay behind: the memory cells. If this enemy is encountered ever again in the future, they will be ready for it and probably kill it before you even notice. This was a very, very simplified explanation of parts of the immune system at work. Can you imagine how complex this system is, even at this level, when we ignore so many players and all the chemistry? Life is awfully complicated, but if we take the time to understand it, we'll encounter endless wonders and great beauty.

Source [mode]	**Target [mode]**	**Time in video**
army [verbal]	immunity system [pictoral/verbal]	00:12

15. “Tiny Bombs in your Blood - The Complement System”

    Posted: July 28, 2019

    Available online https://www.youtube.com/watch?v=BSypUV6QUNw, accessed March 1, 2024.

    Every living being needs to fight off other living beings that want to feast on them. So as multicellular life evolved over billions of years, it came up with ways to defend itself. Today humans have a sophisticated defense network like physical barriers, defense cells, and weapons factories. But one of the most important defenses of our body is largely unknown: The Complement System. It evolved over 700 million years ago and is an army of over 30 different proteins that work together in a complex and elegant dance to stop intruders. All in all, about 15 quintillion of them are saturating every fluid in your body right now. Guided by nothing but chemistry, these proteins are one of the most effective weapons we have against invaders. Many other parts of the immune system are just tools to activate the Complement System. But it's also really dangerous. Imagine having trillions of little bombs inside your blood that could go off at any moment. So our cells use numerous mechanisms to prevent complement from accidentally attacking them. Okay, what exactly does it do and what makes it so dangerous? In a nutshell, The Complement System does three things: it cripples enemies, it activates the immune system, and it rips holes in things until they die. But, how? After all, these are mindless proteins randomly drifting around without will or direction. Well, this is actually part of the strategy. Complement proteins float around in a sort-of passive mode. They do nothing, until they get activated and change their shape. In the world of proteins, your shape determines what you can

and cannot do. Because shape determines what you can interact with and in what way. For example, in your passive shape you might do nothing. In your active shape, however, you might, for example, change the shape of other proteins activating them so they can activate others. Mechanisms like this one can start cascades that spread very quickly. Imagine the complement proteins as being like millions of matches very close together. Once one catches fire, it ignites the ones around it. They ignite more and suddenly you have a big fire. To show the actual mechanisms of The Complement System is a tad complicated and overwhelming. So, we'll simplify here. Now, let's imagine you cut yourself and a bunch of bacteria enter the wound and make it into the surrounding tissue. Our complement attack begins with C3. C3 is the first match, the initial spark that will start our fire. And to do that, C3 needs to switch from passive to active. How this happens is complex, but let's just say it can happen randomly through other complement proteins that bind to enemies or through antibodies. All you really need to know is that C3 breaks into two smaller proteins, C3a and C3b, that are now activated. One of these parts, the C3b protein, is like a seeker missile specialized in bacteria, fungi, and viruses. It has a fraction of a second to find a victim or it will be neutralized by water molecules. If C3b does find a target, it anchors itself very tightly to its surface and doesn't let go. By doing so, the protein changes its shape again. In its new shape, it's now able to grab other proteins and start a small cascade, changing its shape multiple times, adding other complement proteins to itself. Finally, it transforms itself into a recruiting platform known as C3 Convertase. This platform is an expert at activating more C3 proteins that start the whole cycle anew. An amplification loop begins. Soon, thousands of proteins cover the bacteria. For the bacteria, this is very bad. It can cripple the bacteria and make them helpless, or slow them down. But, there's more. Do you remember the other part of C3—the C3a protein? C3a is like a distress beacon. Thousands of them flood away from the site of battle screaming for attention. Passive immune cells notice the C3a proteins, and awaken from their slumber to follow the protein tracks to the site of infection. The more alarm proteins they encounter, the more aggressive they get. This way, complement guides reinforcements exactly to the place where they're needed the most. So far, the complement has slowed down the invaders and called for help. Now, it's beginning to actively help to kill the enemy. The first immune cells to arrive at the battlefield are phagocytes. Which means, cells that swallow you whole, trap you in a tiny prison, and then kill you with acid. But, to swallow an enemy, they need to grab it first. Which is not easy because bacteria prefer not to be grabbed and are sort-of slippery. But now, the complement that has anchored itself to the bacteria acts as a sort-of glue that makes it easy for the immune cells to catch their victims. But it gets even better. Imagine being covered in flies again. Now, imagine them turning into wasps. Another cascade is about to begin. On the surface of a bacteria, the C3

recruitment platform changes its shape again and begins to recruit new proteins. Together, they begin the construction of a bigger structure: a Membrane Attack Complex. Piece-by-piece, new proteins shaped like long spears anchor themselves deep into the bacteria's membranes, until they rip a hole into them that can't be closed again. Fluids rush into the bacteria and their insides spill out. They bleed to death. The remaining bacteria are maimed and distracted by the complement, and quickly taken care of by the arriving immune cells. The invasion has been nipped in the bud before it had the opportunity to become dangerous. You probably didn't even notice it. But while bacteria are not happy about complement, the enemies it might be the most useful against are actually viruses. Viruses have one problem: they need to travel from cell to cell. Outside of cells, they're basically hoping to randomly bump against a cell to infect by pure chance. Here, they're completely defenseless. And here, complement is able to intercept and cripple them, so they become harmless and guide the immune system to devour them. Without complement, virus infections would be a lot more deadly. But wait, if we have such an effective weapon, why do we ever get sick? The problem is that in a war, both sides adapt. For example, when the vaccinia virus infects a cell, it forces it to produce a protein that shuts complement activation down. This way, the virus creates safe zones around the cells it infects. When it kills them, and tries to infect more, it has a higher chance of being successful. Or some bacteria, for example, can grab certain molecules from the blood that keep the complement system calm and make themselves invisible. So the complement system, while being extremely important, is only one player in the complex and beautiful organization that is our immune system. A beautiful example of how many mindless things can do smart things together.

Source [mode]	**Target [mode]**	**Time in video**
army [verbal]	proteins [pictoral/verbal]	00:33
tools [verbal]	antibody [pictoral]	00:54

16. “How The Immune System ACTUALLY Works – IMMUNE”

    Posted: August 10, 2021

    Available online https://www.youtube.com/watch?v=lXfEK8G8CUI, accessed March 1, 2024.

    The human immune system is the most complex biological system we know, after the human brain, and yet most of us never learn how it works. Or, what it is. Your immune system consists of hundreds of tiny—and two large—organs. It has its own transport network spread throughout your body. Every day, it makes hundreds of billions of fresh cells organized like an army. With soldiers, captains, intelligence officers, heavy weapons, and crazy suicide bombers. It's not some sort of abstract entity. Your immune system is you. Your biology protecting you from the

billions of microorganisms that want to consume you, and from your own perverted cells that turn into cancer. It's so manifold that it's impossible to cover in one video, so we'll make a series looking at different aspects of it. Today: What happens when your body is invaded and your first lines of defenses are engaged in a fight for life and death. It's been a normal day, when suddenly the world explodes and an asteroid rips the sky open. Countless alien life forms invade, ready to destroy cities and infrastructure, and eat civilians... Or, this is what your cells experience. You look at your bleeding thumb that you just cut on a dirty twig in the park. How annoying! But inside the wound, a horrible catastrophe has happened. There are dead cells, and blood and dirt everywhere. Even worse, countless bacteria invade the warm caverns between your helpless cells to explore their new home, steal your resources, and poop everywhere. Immediately, the first stage of your defense kicks in. The cells that survive the impact, or are hurt or dying, scream in panic releasing an onslaught of chemical alarm signals that awaken your immune system. The first cells to show up are macrophages. If an average cell were the size of a human, a macrophage would be the size of a black rhino. A stoic cell in principle but you wouldn't want to annoy it. Bacteria -do- annoy them. Within seconds, the large cells attack and begin killing them without mercy. They stretch out parts like the arms of an octopus, and grab the bacteria to swallow them whole and digest them alive. A macrophage can eat 100 bacteria before it's exhausted. But there are too many enemies, so the macrophages call for reinforcements. In your blood, hundreds of thousands of neutrophils pick up their signals and move to the battlefield. Neutrophils are intense suicide warriors that only live to kill. They're so enthusiastic about killing that they kill themselves a few days after birth, so they don't have time to accidentally destroy your body from the inside. As soon as neutrophils arrive, they begin vomiting deadly chemicals at bacteria, or devour them. They are so careless in their attacks that they are causing real damage to your own cells. But collateral damage is not their concern now, or ever. Some neutrophils go so far to push their suicide button and explode, casting a wide and toxic net made from their own DNA filled with deadly chemicals that trap and kill bacteria. Sometimes, they can continue fighting after that, even though they're sort of dead already. This is how much fun they have killing! While the battle rages, your blood vessels let fluid stream into the battlefield like a dam opening up towards a valley. You notice this as inflammation. Your thumb swells up a little and gets red and warm. The fluid brings a silent killer into the battle zone, millions of complement proteins. A sort of automated liquid weapon that stuns and kills bacteria by ripping holes into them. We made a whole video explaining them in detail. We are reaching a crossroad now. If things go well, your first line of defense kills the invaders quickly. But sometimes, the enemies are too strong and would overwhelm your defenses eventually, which means certain death for you, the human. This is the hour of the dendritic cell,

your immune system's intelligence officer. While your soldiers were bashing in heads, it was collecting samples by ripping bacteria into tiny parts and covering itself in it. Like a soldier decorating itself in the guts of a dead enemy. The cell leaves the battlefield and enters the superhighway of your immune system that connects all your tissues with your immune headquarters. Your lymph nodes. The dendritic cell coming from the battlefield is looking for a helper T cell, which is a sort of all-purpose commander cell within your immune army. But not any helper T cell. One that happens to have just the right weapon for the bacteria that infected your wound. So it goes around and rubs itself, still covered in bacteria parts, against every helper T cell it meets. Most T cells are a bit disgusted and not interested. But after a few hours, something clicks. A helper T cell recognizes the bacteria parts. This cell is the weapon that's needed right now. The dendritic cell is overjoyed and activates the helper T cell. Okay, wait. How come your immune system has a cell that has a weapon against the specific bacteria that infected you? Well, your immune system has a perfect weapon against every possible disease in the universe. Against the Black Death, the Coronavirus, or an infection that will emerge in 100 years on Mars. We'll talk about this a bit more in the next video because it's very complex. So, for now, just know that you have billions of unique helper T cells that each have weapons against every possible enemy. After the right T cell is activated, your second line of defense awakes and rises like a teenager that needs to get up on a school day... Very slowly. Your heavy weapons are incredibly effective but they're not fast. The activated helper T cell begins to clone itself over and over again. One becomes two, two become four, until there are thousands of them. Now, they split into two groups. The first group quickly moves to help out your soldiers. At the battlefield, things are getting out of hand. A tired macrophage is ready to give up. After fighting for days, it just wants to go to sleep like many of its buddies have done already. But now the helper T cells arrive. One of them comes to the tired macrophage and whispers something using special chemical signals. In a heartbeat, the demoralized soldier feels fresh again. But there's something else. A hot white anger. The macrophage knows what it needs to do... Kill. Invigorated, it throws itself against the enemies once again. All over the battlefield, this begins to happen. Meanwhile, the second group of helper T cells was working on activating another line of defense: B cells, your antibody factories. Antibodies are protein super weapons that look like tiny crabs with two pincers to grab enemies. Just like the helper T cells, there are B cells in your body that are able to make just the right antibodies for every possible enemy. And the helper T cell is looking for exactly these B cells. After a day or two, the right B cell is found, and begins to clone itself. As soon as enough clones have been made, each B cell begins pumping out up to 2,000 antibodies per second! About a week after you injured yourself and bacteria invaded, your second line of defense finally arrives in full force. The tiny army begins

to saturate the battlefield, pinching and stunning desperate bacteria. The antibodies clump them together and make them unable to move or fight, while your soldiers massacre the defenseless victims. The tide is turning fast. As the last enemies are cleaned up, your soldiers realize they are no longer needed, and begin to kill themselves to save resources. But not all of them. A few helper T cells remain and turn into memory cells. They will guard the tissue for years, making sure the same bacteria will never again gain a foothold here. Similarly, a few B cells will stay alive and keep producing a low amount of antibodies, making you immune against this bacteria, maybe for the rest of your life. One day you wake up and notice that the wound has grown over and left nothing but a faint red mark. You were completely unaware of the drama your cells had to deal with. For you, the whole ordeal was a slight annoyance. While for millions of cells, it was a desperate fight for life and death.

Source [mode]	**Target [mode]**	**Time in video**
battlefield [verbal]	infected area [pictoral]	06:41
soldier [verbal]	macrophage [pictoral]	07:01
army [verbal]	antibodies [pictoral]	08:09

17. “The Deadliest Being on Planet Earth – The Bacteriophage”

    Posted: May 13, 2018

    Available online https://www.youtube.com/watch?v=YI3tsmFsrOg, accessed March 1, 2024.

    A war has been raging for billions of years, killing trillions every single day, while we don't even notice. The war is fought by the single deadliest entity on our planet: the bacteriophage or 'phage' for short. A phage is a virus; not quite alive, not quite dead. Also, they look as if someone made them up. Their head is an icosahedron, a sort of dice with 20 faces and 30 edges. It contains the genetic material of the virus and often sits on a long tail that has leg-like fibers. There are more phages on earth than every other organism combined, including bacteria. And they are probably everywhere living things exist. Billions are on your hands, in your intestines and your eyelids right now. Which might make you nervous since phages are responsible for the majority of deaths on earth but you're lucky. While they do commit genocide for breakfast, they only kill bacteria. Up to 40% of all bacteria in the oceans are killed by them every single day. But phages also have major flaws. Like any other virus, phages need a host to survive and reproduce. They're not much more than genetic material in a hull and they specialize. Usually, a phage has chosen one specific bacteria and maybe some of its very close relatives. These are

its prey. Imagine a phage as like a cruise missile that only hunts and kills members of one very unlucky family. When a phage finds its victim, it connects its tail fibers with receptors and uses a sort of syringe to puncture a surface. In a weird motion, the phage squeezes its tail and injects its genetic information. Within minutes, the bacteria is taken over. It's now forced to manufacture all the parts of new phages. They only stop when the bacteria is filled up with brand-new phages. In the final step, they produce 'endolysin', a powerful enzyme that punches a hole in the bacteria. The pressure is so high that the bacteria sort of vomits out all of its insides and dies. New phages are released and begin the cycle anew. In the last few years, bacteriophages have enjoyed the attention of the second deadliest beings on earth: humans. Recently, we've started looking into injecting millions of them into our bodies because we're sort of getting desperate; we screwed up. In the past a single cut or a sip from the wrong puddle could kill you. Bacteria were our phages. Tiny monsters that hunted us mercilessly. But then, about 100 years ago, we found a solution in nature. By accident, we found fungi that produced compounds that killed bacteria: antibiotics. Suddenly, we had a powerful super weapon. Antibiotics were so effective that we stopped thinking of bacteria as monsters. Only the old and the weakest among us were killed by them. We used antibiotics more and more for less and less serious causes. We lost respect for the monsters and the weapon But bacteria are living things that evolve and one by one they started to become immune against our weapons. This continued until we had created what are called 'superbugs', bacteria immune to almost everything we have. This immunity is spreading across the world as we speak. By 2050, superbugs could kill more humans a year than cancer. The days when a cut or bladder infection or a cough could kill you or your loved ones are coming back. In the US alone, more than 23,000 people die from resistant bacteria each year. But it turns out that phages, our tiny killer virus robots, could save us. We can inject them into our bodies to help cure infections. Hold on, how could injecting millions of viruses into an infection be a good idea? Phages are very very specialized killers of bacteria. So specialized, in fact, that humans are completely immune to them; we are too different. We encounter billions of phages every day and we just politely ignore each other. Antibiotics are like carpet bombing, killing everything even the good bacteria in our intestines that we don't want to harm Phages are like guided missiles that only attack what they're supposed to Wait a minute, if we use phages to kill bacteria, won't bacteria develop ways of defending themselves? Well, it's more complex than that; phages evolved too. There has been an arms race between them and bacteria for billions of years and so far, they're doing great. This makes phages smart weapons that are constantly getting better at killing. But even if bacteria were to become immune against our phage, we still might be able to win. It turns out that in order to become resistant to even just a few species of phages, bacteria have to give up their resistance to

antibiotics. We might be able to trap them in a catch-22. This has already been successfully tested with a patient who had no other hope left The bacteria 'Pseudomonas Aeruginosa', one of the most feared bacteria, infected the man's chest cavity. They are naturally resistant to most antibiotics and can even survive an alcoholic hand gel. After years of suffering, a few thousand phages were directly inserted into his chest cavity together with antibiotics the bacteria were immune to. After a few weeks, the infections had completely disappeared. Unfortunately, this treatment is still experimental and pharma companies are still reluctant to invest the necessary billions in a treatment that has no official approval yet. But things are finally changing. In 2016, the largest phage clinical trial to date began and phages are getting more and more attention. and we better get used to it because the era in which antibiotics have been our super weapon is drawing to a close. It might be a weird concept but injecting the deadliest being on planet Earth directly into our bodies could save millions of lives.

Source [mode]	**Target [mode]**	**Time in video**
enemy [pictoral]	bacteria [verbal/pictoral]	01:14
guided missiles [verbal/pictoral]	phages [verbal/pictoral]	01:44
arms race [verbal/pictoral]	evolution [verbal]	05:05

18. “The Side Effects of Vaccines - How High is the Risk?”

    Posted: May 12, 2019

    Available online https://www.youtube.com/watch?v=zBkVCpbNnkU, accessed March 2, 2024.

    Vaccines are celebrated for their part in fighting disease. But, a growing group of people seem to believe that they endanger our health, instead of protecting it. The Internet is full of stories about allergic reactions, the onset of disabilities, and even death following vaccination appointments. And, it's true vaccines can have side effects. Let's look at how they work, and how dangerous they really are. Your immune system is a complex army of billions of cells. Soldiers, intelligence cells, and weapons factories. Every day, you're attacked countless times, but your immune soldiers alone usually deal with that, so you don't even notice. If an infection becomes serious though, our intelligence cells gather intel about the attackers and activate our weapons factories. You know the weapon: antibodies. They're like targeted missiles produced specifically to combat the invader. Unfortunately, this process takes several days to complete. That gives intruders a lot of time to do damage. Contrary to popular wisdom, what doesn't kill

you doesn't make you stronger. Our bodies really don't want to fight serious wars over and over, so our immune system came up with an ingenious way to get stronger and stronger over time. If we fight an enemy that is dangerous enough to trigger our heavy weapons, our immune system automatically creates memory cells. Memory cells remain in our body for years, in a deep sleep. They do nothing but remember. When an enemy attacks for a second time, the slumbering memory cells awaken, and order coordinated attacks and the production of antibodies. This is so fast and effective, that many infections you beat once will never make you sick again. You might even be immune against them forever. Which is also why little kids are constantly ill; they don't have enough memory cells yet. And this beautiful natural mechanism is what we build on when we use vaccines. How Vaccines Work As great as memory cells are, obtaining them through an infection is unpleasant and sometimes dangerous. Vaccines are a way of tricking our bodies into making memory cells, and becoming immune to a disease. They pretend to be a dangerous infection. One way of doing this is to inject invaders that can't do harm. For example, by killing them, or by ripping them into pieces. Our immune systems deal with these kinds of vaccines pretty easily. Sometimes, it's necessary to make our immune system work harder though, to produce even more memory cells. Live vaccines are the real deal. An enemy that can punch back is a bigger challenge than a dead one. But this also sounds like a sort-of horrible idea. What if the germs win? To avoid that, we breed a sort-of weak cousin of the real germ in the lab. Just powerful enough to annoy the immune system, and create enough memory cells. Okay, so these are the basic principles of vaccine use. They provoke a natural reaction in our bodies that makes us become immune against very dangerous diseases. Some, like the flu virus, mutate so often that we need a new vaccine every year, but most vaccines protect us for years, or even a lifetime. But, there's a catch. Like everything in life, vaccines have another side: Side effects. What are they, and what happens if your child develops one? The Risks of Vaccines It's complicated to directly compare the side effects of vaccines with the effects of diseases. For example, hundreds of millions of people are vaccinated against measles in the West, but there were only 83,000 cases in Europe in 2018. So, with numbers that different, even mild side effects can seem scary compared to the bad effects of a disease that we don't see as much anymore. Before the measles vaccine became available in 1963, virtually every single child on Earth contracted measles at some point. An estimated 135 million cases in the 1950s. Every single year. But are measles really that dangerous in the year 2019? With our advanced healthcare and new technologies, are they worth the risk of vaccine side effects? Let's do a thought experiment based on real numbers. Imagine a developed country in a parallel world. It has good healthcare but people stop vaccinating. In this scenario, let's say ten million children caught measles. What happens? Nine

million eight hundred thousand, or 98%, will get a high fever and a very unpleasant rash. Up to 800,000 of them, or 8%, will suffer from dangerous diarrhea. 700,000, or 7%, will suffer from an ear infection, which can lead to permanent hearing loss. 600,000 kids, or 6%, will suffer from pneumonia -- the most dangerous effect of measles. It, alone, will kill 12,000 children. Up to 10,000 children, or 0.1%, will get encephalitis. 2,500 kids, or 0.025%, will contract SSPE, a disease where the measles virus lingers in their brain and kills them a few years later. Taken together, around 2.5 million children will suffer from somewhat serious effects from measles. And, about 20,000 children will be killed by measles. It doesn't stop here though. The kids who beat measles are left with a severely damaged immune system that needs a lot of time to regenerate. Time for other diseases to do further damage. Aside from that, what's almost guaranteed is that your kids will have a really bad time for about two weeks. Okay, but what about vaccines? It's only fair to look at these risks, too. So, let's repeat our thought experiment. But, this time, we vaccinate ten million children with MMR. What would theoretically happen here? After being vaccinated, of our 10 million kids, around ten percent get a fever. 500,000, or 5%, will get a mild rash. Up to 100, or 0.001%, might have a serious allergic reaction and will have to be treated. Up to ten boys, or 0.0001%, might might get inflammation of the genitalia. And up to ten kids in total, or 0.0001%, might get the most serious side effect: encephalitis. So, we vaccinated ten million kids. In total, around one hundred and twenty had side effects that were somewhat serious. Thanks to good medical treatment in developed regions, almost all of them will be fine. What about autism? The connection of autism and vaccines stems from one source that has been disproven countless times. We'll link to further reading and videos in the description. But, in 2019, it's fair to say that vaccines do not cause autism. All right, but what about deaths? It's really hard to say if even a single one of our 10 million vaccinated kids would die. We really did look hard and talked to a lot of different experts. If we ignore self-reporting, we could only come up with a tiny handful of documented cases for all the hundreds of millions of children who received the MMR vaccine since 1971. Measles are many, many thousands of times more dangerous for your child than even the absolute worst case of vaccine side effects. You have to search for lethal vaccine side effects with a huge magnifying glass and, even then, it's very hard to find confirmed cases. While, deaths from measles are real and easy to find. In 2017 alone, 110,000 people died from measles worldwide. Statistically, today, 300 children will die of measles. One since this video started. You can compare vaccines to seatbelts. Are there weird freak accidents where someone gets killed by their seatbelt? Well, yes. But, do you personally think it's safer to not put a seatbelt on your kid? Wait a second! What if your kid is actually allergic? What if none of the things we've said applies to your specific situation? In this case, you need to become the greatest vaccination

promoter of all. Because if your children can't be vaccinated, only the collective can protect them. This is called herd immunity, and it's the only thing that can protect your unvaccinated child. Herd immunity means that enough people are immune to a disease, that it can't spread, and dies before it reaches its victims. But to accomplish this for measles alone, 95% of the people around you need to be vaccinated. Conclusion The problem with the debate about vaccines is that it's not fought on a level playing field. While the pro-vaccine side argues with studies and statistics, the arguments against them are usually a wild mixture of gut feeling, anecdotes, and misinformation. And feelings are often immune to facts. We'll not convince anybody by screaming at them. But we can't hide from the reality of what anti-vaccine conspiracies do. They kill babies too young to be vaccinated. They kill healthy children that are just unlucky. They bring serious diseases back from the verge of extinction. And, the biggest side effect of vaccines is fewer dead children. Vaccines are one of the most powerful tools we have to eradicate the monsters that most of us have already forgotten. Let's not bring the beasts back.

Source [mode]	**Target [mode]**	**Time in video**
army [verbal]	immune system [verbal/pictoral]	00:40
soldiers [verbal]	immune system cells [verbal/pictorial]	00:49
target missiles [verbal/pictoral]	antibodies [verbal]	01:06
security breach [pictoral/audio]	dangerous infection [verbal]	02:36
losing game [pictoral/verbal]	germ infection [pictoral]	03:07

19. “What Actually Happens When You Are Sick?”

    Posted: February 28, 2023

    Available online https://www.youtube.com/watch?v=M-K7mxdN62M, accessed March 1, 2024.

    There is this idea floating around that what doesn’t kill you, makes you stronger. That surviving a disease leaves you better off. And it seems to make sense because we have all experienced this. When you go through hardship, often you come out more resilient, more ready to face a difficult situation in the future. But it turns out that sometimes, what doesn’t kill you makes you weaker. So, what happens when you get sick? The Machinery of War Think of yourself as a large country, with a sizable army to defend it. You are surrounded by enemies that want to take your land, your energy, your resources. This is a matter of life and death, so your body

evolved to be sensitive to damage and to the presence of enemies. Because this means that an invasion might happen at any moment and that it has to act fast. Let us start an invasion and see what happens. The moment your cells notice that something is off, they release an onslaught of signal proteins called cytokines. They are like air raid sirens that activate all sorts of immune cells, that then themselves release many more cytokines, amplifying the alarm. Soon you are flooded with signals that trigger precautions and counter-measures. Mobilization is under way. Your brain activates sickness behavior and reorganizes your body's priorities to defense. The first thing you notice is that your energy level drops and you get sleepy. You feel apathetic, often anxious or down and you lose your appetite. Your sensitivity to pain is heightened and you seek out rest. All of this serves to save your energy and reroute it into your immune response. You become a country under attack switching into a war economy, because properly activating your immune system is intensely disruptive and draining. Just like war is expensive for a country as industry switches to building tanks, your immune system demands huge amounts of energy, amino acids and micro elements to build its weapons. Take fever: it speeds up your metabolism and makes your cells work harder and faster, while creating heat that is pretty stressful for many invaders – but it uses up a lot of calories to maintain. Then your immune system begins to clone millions of specialized immune cells to respond specifically to the enemy infecting you. B Cells produce millions of antibodies every second, each requiring hundreds of amino acids to construct. Billions or even trillions of proteins need to be made to refresh the complement system, a minefield inside your blood. Cytokines, the mobilisation and information signals, also need constant refreshing. Usually you acquire your resources by eating. But when you are sick, your body slows down your digestion because it needs a lot of energy you can’t spare. So it reaches for the easiest source of amino acids and starts breaking down your muscles. All that muscle that you worked so hard for is sacrificed to keep you alive. If you are young and healthy and fit, you will make up for that quickly once you are better. But if you are old or very young, weak or suffer from chronic illness, this may be way too draining. Your body is literally consuming itself to keep the defense going. If your whole system is already strained, when you get sick, just keeping your immune responses going can overwhelm your capacities. Your Immune System is a Jerk. Our enemies too. Your immune system is as dangerous to you as it is to enemies. There is a very fragile balance between the damage caused by an infection and the collateral damage caused by immune cells. One of your first responders are Neutrophils – imagine crazy aggressive chimps with machine guns. If a Neutrophil encounters enemies it showers them with chemicals that cut them open but can also damage civilian cells, especially if the patient is already compromised, for example by smoking. On top of that the microorganisms that invade you often release chemicals and toxins that can cause

significant damage and cell death. So a serious infection often causes many tiny wounds, literally holes in your organs. As you can imagine it is not great to have holes and wounds in your organs, and your body rushes to close them. Your Neutrophils and Macrophages help by releasing chemicals that signal the body to start repairs, and most of the damage is quickly filled up with regrowing cells. But others are filled with collagen, a sort of fix-all organic cement that gives your gooey tissue structural integrity. You have seen the result on your skin as scars. A scar is different from the original tissue. It has no functioning cells in it, it is like a sloppily applied cement patch. It can't do what the original tissue was doing. A scar on your heart makes it beat a tiny bit weaker. A scar on the lungs no longer captures oxygen. A scar on your liver makes it a worse filter. And so, as you go through life and survive serious disease after serious disease, the functionality of your organs may decrease. This damage is usually small enough not to affect your quality of life – but can be permanent. Ok, this sounds depressing, but there is actually something you can do to avoid a lot of this damage and train your immune system! The best way to train your Immune System Your immune system is unique. Everyone has a slightly different immune system that's stronger against some enemies and weaker against others. Which makes evolutionary sense, as this protects our species from being Our species from being wiped out by a single infection. Collectively, the immune system of the human species is a spectrum: most people respond well enough to an infection, a few are super-responders and a few don't respond well and die. Some people survived the black death, are more resistant to HIV or Corona virus or even resistant against Ebola. Others are killed easily by the flu or highly vulnerable to certain bacterial infections. Where you are on this spectrum is impossible to predict. And you also respond differently to every possible infection. This is why seemingly very healthy young people died from Covid while for some elderly people it was more like a mild flu. The idea that you can weather all sorts of diseases if you never get a cold is wrong. You never know what your immune system is good at until it is tested. Getting sick is a gamble in life's casino with your health on the line. Always. But there is something you can do: hacking one of the best features of your immune system. When you survive a disease, usually you have better defenses against it afterwards – you gain memory cells that are very good at killing the specific enemy you fought that day. So you either don't get the disease again or the next infection is much milder. And you can use an incredible achievement of human ingenuity that taps into this mechanism to prevent damage from disease and train your immune system: Vaccines. Vaccines basically pretend to be a disease and train your defenses to be ready if it ever shows up for real. The goal is to create the same memory cells that you would get after surviving an infection. But if you can feel some side effects, why should you still do it? Nature Vs Vaccine Dojo You have two options to train your immune system: Vaccine Dojo and nature

dojo. In vaccine dojo you train with paper weapons and learn to defend yourself. Sure, you might get a black eye or a bruise. Sometimes after a vaccine, you get sick for a few days, but that's generally it. No scars, no permanent damage. We discussed vaccine side effects in detail in another video if you want to learn more. On the other hand, getting a disease to become immune means going to a nature dojo. In nature dojo, you train with real weapons, sharp knives and swords. Things might still work out, but with way more cuts and wounds. But from time to time someone will die, be it a kid from measles or an adult from influenza. Nature dojo is just way more risky. On top of that, the immunity you get from a vaccine is often better than the natural resistance, because they are engineered to engage your immune system in a more productive way. Of course vaccines are not magic and sometimes they do not protect us as well as we'd like them to. Maybe because an enemy mutates too quickly, like the Omicron coronavirus, or because your specific immune system does not respond well to the vaccine and builds less of a defense. Still, being vaccinated is one of the best tools to train your natural defenses. In the end, if we look at the stunning progress humanity has made in the last century, eventually we may overcome disease for good. But until then we can do our best to take care of ourselves and others - your body and your older self will be grateful to you.

Source [mode]	**Target [mode]**	**Time in video**
winning a game [pictoral]	surviving disease [verbal]	00:07
Country [verbal/pictoral]	Human [verbal/pictoral through metonymy]	00:41
Army [verbal]	Antibodies [pictoral]	00:42
Enemies [verbal]	Viruses [pictoral]	00:42
Invasion [verbal]	Sickness [pictoral]	00:56
Gambling [pictoral/verbal]	Sickness [verbal]	06:29

20. "How Bacteria Rule Over Your Body – The Microbiome"

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    Available online https://www.youtube.com/watch?v=VzPD009qTN4, accessed March 2, 2024. Microbes are everywhere, on your phone, in your water bottle, on your hands before you wash them, on your hands after you wash them, and literally everywhere else on top of you too. Microbes are omnipresent at any moment, and there is nothing we can do about it So, millions of years ago we made a pact, we give them shelter and food, and in turn they work for us. But the more we learn about this partnership, the more it looks like a cold war Inside our mother's womb, humans start out sterile When we are born and traveling through the birth canal, billions

of our mother's bacteria cover every single part of our bodies. This is an essential part of human health. Children born via C-section have a higher rate of asthma, immune diseases and even leukemia. So our bodies do not only accept the invasion of microorganisms, they welcome it. Over millions of years, we co-evolved to make the best of our relationship. Mother's milk for example, contains special sugars that are meant to feed and support certain groups of microbes, work as a decoy for others, and help to modulate the immune system. It takes up to two years, until a healthy microbe community has formed. Every human has their own unique microbiome, made up of bacteria, viruses, fungi and other organisms. We have three categories of guests, on and in our bodies. One: Quiet passengers that do their own thing, and are politely ignored. By being there, they take up space and keep more aggressive intruders in check. Two: Guests that harm us, But with whom we've learned to live, for example, bacteria that literally create acid that melts our teeth, if we don't brush enough. They want to take up as much space as they can, and we don't want them to. But, we can't get rid of them entirely. Three: Friendly fellows that our bodies want to have around, most of them are a community of 380,000 billion bacteria, from up to 5,000 different species, that live in our gut. These gut microorganisms help us digest food, and pull additional calories from things that we can't digest ourselves. Unfortunately, our gut is also the perfect point of attack for intruders, so it's guarded by an aggressive army, our immune system. To survive here, our microbiome co-evolved with us to be able to communicate with our body. The most important part of that is to ask the immune system to not kill them. But, they also have a real motivation to keep our gut healthy, so some of them produce a messenger substances, that help to educate the immune system, and others stimulate the gut cells to regenerate faster. But, over the last few years. Evidence has emerged that the influence of our gut microbiome, goes much much further. It might even talk directly to our brain. We've observed a few curious things, 90% of our body's serotonin, an important messenger substance for nerve cells, is produced in the gut. Some scientists think the microbiome does this, to communicate with the vagus nerve. The information highway of our nervous system. Other examples are bacteria that stimulate immune cells in the gut, so they send a kind of alarm signal to the brain. Here, it activates immune cells that help the brain recover from injuries. Since the brain decides what we eat, the microbiome is interested in a healthy brain. A new field of science is opening up here, and we're just on the verge of understanding how these complex systems inside our bodies interact. But we are starting to see how much our microbiome actually influences us and our behavior. Take depression for example, Healthy rats fed microbes from the guts of depressed people, began showing anxiety-like behavior, and symptoms that look like depression. And in early 2017, a study linked the microbiome to intelligence, by connecting a certain set up of bacteria in newborns, with better motor and language skills. But it might also

influence our daily lives. Tests with fruit flies, showed that their microbiome, influenced what kinds of food they craved. This could mean your microbes are able to tell your brain, which food it should get them. Although, this is not a one-way street The seed for our microbiome comes from our mother, but how it develops and changes, is determined by what we eat. the organisms in our gut feed on different things, some like fibers and leafy greens, others go for sugars and starches, and some love greasy fries and butter. Our gut is like a garden in which be constantly decide, what will grow and blossom. If we eat healthily, we breed bacteria that like healthy food. If we eat a lot of fast food, then we breed fast food loving bacteria. Life is hard, so we can get trapped in a vicious circle. You have a stressful time, and eat lots of burgers and fries and pizza. This is awesome for fast food bacteria, they multiply and multiply, and take up space from vegetable loving bacteria. But even worse, they send signals to the brain to continue what it's doing. this makes you want more fast food. Which breeds more fast food bacteria, which makes you crave fast food, and so on. This kind of self-reinforcing cycle, could play a huge role in obesity. But, it's important to stress that you can fight this process, and reverse it, by eating healthily and breeding more good bacteria. Beyond weight gain, our microbiome has also been linked to other serious diseases like autism, schizophrenia, and cancer. One of the earliest symptoms of Parkinson's, is actually gut problems. If your body is overrun with bacteria that harm you, there is often only one solution. You bring in an army of good guys. That's very easy, You just transplant some healthy poop. You do that by literally transferring poop, from a healthy person, into your gut. This method is already used, to cure diarrhea that's caused when C. difficile bacteria, take over a gut microbiome. But we just don't know enough about the complex interplay at work here yet. For example, a transplant from an overweight donor cured a woman's diarrhea, but contributed to her obesity down the line. This caused some ways and another study tried to reverse the effect. Poop transplants from slim people to obese ones, gave them a more diverse microbiome, and made them less sensitive to insulin. Both things that also happen when people lose weight We need to do a lot more science, to really understand how our microbes make us healthy or sick. But, whether we like it or not. We need our microbiome, and it needs us. We'll never have our bodies to ourselves. But we have gained a powerful ally, if we can just keep the peace.

Source [mode]	**Target [mode]**	**Time in video**
army [verbal/pictorial]	immune system [verbal/pictorial]	02:38
watering plant [pictoral]	stimulate gut cells [verbal]	02:59