[00:00:03] **Narrator:** Globalization, geo-political conflicts, climate change and advancements in technology are making the biological threat landscape more complex than ever before. This is Countermeasures, where we explore health threats impacting communities around the world. Brought to you by Emergent, a leading public health company that delivers protective and life-saving solutions to communities around the world. From Zoonotic disease to bioweapons, orthopoxviruses, and more, we'll explore what it means to protect public health, and how preparedness today can lead to a safer tomorrow.

According to the World Health Organization, vector-borne diseases (VBDs) like malaria, dengue, West Nile virus and Lyme disease cause more than 700,000 deaths a year and account for more than 17 percent of all infectious diseases. These diseases have catastrophic consequences for individuals and communities, and climate change, urbanization, and global travel are contributing to the resurgence and spread of vector-borne diseases. As disease vectors like mosquitoes and ticks adapt to warmer temperatures and expand into new regions, public health systems face mounting pressure to anticipate and respond to outbreaks. This episode explores the evolving landscape of VBDs, the science of vector control, and how we can prepare for future threats. Dr. Matthew Phillips is a physician scientist at Mass General Brigham. He helps break down what vector-borne diseases are and how they spread.

[00:01:04] **Dr. Matthew Phillips** So vector-borne diseases refer to infections that are transmitted between humans and other animals by some other organism. It's what we call a vector. So instead of being spread through the air by coughing or sneezing or on surfaces like some other germs, these are diseases that are spread by insects and other arthropod vectors, like ticks. These vectors are almost always some kind of blood-feeding organism, like a mosquito or tick. And it's an incredibly diverse category of diseases. There's numerous vector-borne diseases, really a worldwide issue. Vector-borne diseases are a tremendous global health concern, mostly because of how widespread they are and how prevalent they are as well. So globally, about three out of every four people live at risk of a vector-borne disease. So that's 6.3 billion people around the world are at risk of getting these diseases. They're punching above their weight in that category. And then in the US alone, there's 20 different species of vector-borne diseases. The number of cases of vector-borne diseases increased. It's doubled in the past couple of decades. Now, it's over 760,000 cases a year based on numbers by the CDC. So even in the USA, it's very diverse, very prevalent category of diseases and poses a really big public health concern.

[00:02:18] **Narrator** Vector-borne diseases pose a threat worldwide and disproportionately affect lower income countries located in climates where vectors thrive. Dr. Pauline Byakika–Kibwika is a Ugandan epidemiologist and a professor of internal medicine and epidemiology. Her focus is largely on malaria.

[00:02:38] **Dr. Pauline Byakika–Kibwika** Vector-borne diseases are persistent challenges in Uganda and in most parts of Africa, mostly because of the tropical climate, because the climate favors survival of the vectors, especially if we look at malaria. Survival of the vectors, the climate is favorable for survival of the vectors, but also survival of the pathogens within the vectors. So it's really about the climate, the tropical climate. But also, we have done a lot in terms of prevention. However, we still have a lot of work to do because not everybody can access the preventative measures that are available to stop

contact with the vectors and therefore to stop transmission. Mostly because of poverty, people are poor, so some cannot afford the preventative measures. And knowing that the diseases are endemic, they occur throughout the year, it's quite costly both for the households and the government to be able to supply the preventative measures for everybody all the time. So mostly the climate and two, of course, the level of poverty at household level, these two fuel transmission diseases.

[00:03:58] **Narrator** Vector-borne diseases impact communities in ways beyond just the health risks and illnesses they present.

[00:04:04] **Dr. Matthew Phillips** Whenever you have a disease that's causing a lot of death and illness, it's gonna have a huge economic impact on that community. So you'll have people not working and you'll have people just the healthcare cost of having all these people ill will affect the community as well. You can actually kind of quantify the economic impact of these diseases by looking at the impact of interventions we've done to help prevent some of these diseases. So there's a kind of a natural experiment done by Malaria No More and Oxford Economics. They went and looked at from between 2003 and 2023, so two decades, the US distributed about 15 billion dollars for malaria control in Africa. And through the through the Global Fund and the President's Malaria Initiative. And it's estimated that this probably prevented about 650 million malaria cases. So when they analyzed this, by averting these malaria cases, the USA contributed to over 90 billion dollars in GDP across these countries. To put another way, for 20 years of US investment in preventing malaria, it generated 5.8 times the economic return for every dollar spent. Another analysis kind of looking forward suggests that if we reduce malaria by 90 percent in Africa, it could increase Africa's GDP by about 126 billion dollars. So by preventing these illnesses, you can really help the economic prospects of that community as well. They also contribute to stigma and discrimination. And then in general, vector-borne diseases also act as a disaster multiplier. So when something is already happening to a community, the vector-borne diseases just make it that much worse. So a great example of this came a couple of years ago in Pakistan in 2022. There was a catastrophic flooding, and this led to a five-fold increase in malaria cases across the country. So typically they would have about 500,000, which is what they had in 2021. In 2022, they had 2.6 million cases. And so it adds to the destruction and disruption of natural disasters.

[00:06:03] **Narrator** As Dr. Byakika–Kibwika mentioned, there is much that can be done to try and prevent vector-borne diseases and their spread. And most of these interventions can be quite straightforward. Mosquito nets are one of the best tools we have for preventing malaria. Rob Mather is founder of the Against Malaria Foundation, the world's third largest funder of nets. AMF has provided 350 million nets over the past 20 years. According to Rob, that's roughly 250,000 deaths prevented and 250 million cases of malaria averted. Although simple, nets have a big impact.

[00:06:42] **Rob Mather** So what makes bed nets such a successful way of preventing malaria are two behavioral aspects of the malaria-carrying mosquito and two fundamental design features of the long lasting insecticidal net. So if we go back to the mosquito, they do two things, got two things on our side. The first is that generally malaria-carrying mosquitoes are nighttime biters. So they bite between ten o'clock at night and two o'clock in the morning. And that means if we can protect people when they sleep at night, we're getting a long way there. The second thing that mosquitoes do is that they land on a net and migrate to a hole if there is a hole in the net. They don't do an aerobatics maneuver through a hole. So if we look at the fundamental nature of a net, which as a mechanical barrier, it protects the person sleeping inside from the malaria-carrying mosquito. The

mosquito lands on the net, picks up insecticide through its feet, through its legs, and that causes a knockdown. And that goes on, even when you have holes and rips and tears in nets, because of that mechanism of movement, if you like, of the mosquito. So putting the humble bed net over a sleeping space, a double bed is covered by a two dollar net, is incredibly effective at keeping the mosquito away from the person sleeping underneath.

[00:08:06] **Narrator** Another key prevention method is education, which can lead to important behavioral changes. These play a vital role in communities where misinformation and misconceptions about how VBDs can present and spread are still real concerns.

[00:08:20] **Dr. Pauline Byakika–Kibwika** In terms of community education, I believe once one, apart from the education that is specific to malaria, the moment one gets attains education in school to a certain level, at least the primary level education, they should be able to prevent malaria. They should be able to understand and be able to do something to prevent malaria. But once somebody hasn't attended school at all, it is very difficult for them to understand some of these issues affecting health. But also there are quite many populations that still have myths within and amongst the populations that will believe that if somebody has a fever, then the cause is either somebody doing some kind of witchcraft or something that is causing them to have a fever, and that will prevent them from seeking treatment. So education usually makes people move away in terms of thinking, think less about things like witchcraft and think more about the actual causes of disease, and therefore they are more likely to reduce their contacts with vectors and also reduce the transmission of malaria and be able to access treatment earlier. Community engagement and community education is one of the methods, the strategies that the Ministry of Health emphasizes for prevention of diseases. And this is in a way to try and cause behavior change, to try and cause behavior change in terms of reducing contact with the vectors, behavior change, household changes around the households and all those, removing all those factors that favor transmission of malaria. For a long time, we preached or we spread vector control measures, trying to, you know, control the vectors, telling educating the population to avoid having stagnant water around their homes, because that's where the vectors breed, the mosquitoes breed. So people to slash and cut down bushes and grass around their homes and remove all areas that could hold stagnant water where the mosquitoes breed. But that is not enough. The other methods include preventing the mosquito bites, that is using repellents, insect repellents, but insect repellents are not that cheap, so not everybody can afford to use those. The other method is use of insecticide treated mosquito nets, which have been distributed by the government of Uganda and distributed to majority of the people in the country. But you know these also have a lifespan. If I give you a mosquito net one mosquito net in a year, it may not necessarily, there is wear and tear and they wash them frequently.

[00:11:23] **Narrator** In communities where the AMF is present, Rob has seen firsthand that education has made a difference.

[00:11:30] **Rob Mather** By now, given that we are many, many cycles into distributing nets, in most countries we're sort of four, five, six cycles in, if you imagine a cycle being three years, there is very widespread knowledge of what a long-lasting insecticidal net is and how it is used. When AMF started twenty years ago, one of the innovative ways that villages would communicate why nets were important, because in many circumstances, malaria is contracted by drinking stagnant water, isn't it? Answer no. But unless you have knowledge of where malaria comes from, that might be the understanding. And so if we go back a number of decades, not today, but go back a number of decades, one of the very amusing but highly effective way of communicating to a village group, you need to use

your nets, and that's how you're going to stop contracting malaria, is they used to groups within villages often used to do a little skit or a little play, where they'd have a couple of people lying down on a mat in the center of the village, and two people flapping their arms, pretending to be mosquitoes, would come next to them and and and sort of dip down and make as though they were biting them, and then fly away and the people would roll around on the ground and not feeling very well. A net would then be put over those two people, and the mosquitoes, the people, mosquitoes would come back and do the same thing, touch the net, roll over on the ground as a dead mosquito with legs and arms in the air waving around, and everybody would be falling over with laughter because it was a very funny scene. Communicating through humor, a very serious message about the use of a net. We're beyond that now. And the education that is done now is much more sophisticated about it does cover things like removing areas of stagnant water where mosquitoes breed, use of the nets, sowing up holes if there are holes in nets, that sort of thing. But broadly, educationally, the knowledge of nets and what they do and how they should be used is pretty well understood.

[00:13:34] **Narrator** Another barrier to prevention and treatment is that for people in rural communities, healthcare can simply be difficult to access.

[00:13:41] **Dr. Pauline Byakika–Kibwika** So, to bring these health centers closer to the communities, but there are still homesteads that are very far from the health facilities. So that is a barrier. Usually, people will have to either walk these long distances or wait for public transport, which public transport also is not very, very accessible. And therefore, that creates a big barrier to access. And that delays diagnosis because people then take several hours to get there. It delays access to diagnostics and therefore delays access to treatment as well. Now, vaccines, we haven't had vaccines for malaria for so for since time immemorial. But recently the WHO approved two vaccines for malaria, and our our government was able to bring in some vaccines, and therefore these have been rolled out for especially for children below five years of age. But regarding access, it's still not highly accessible because the number of doses are still quite few, and therefore, not everybody who needs the vaccine will be able to get the vaccine. So same to the treatments. The treatments are more available than the vaccine. The vaccines are a new modality on the block. The treatments we have had antimalarials for many years, and these are more widely available. But still, some patients will take several hours to get to the health facility, and therefore they may not necessarily get the treatment.

[00:15:25] **Narrator** Not only are vaccines difficult to deploy due to logistics, but it's also been difficult to develop vaccines for many vector-borne diseases in the first place.

[00:15:35] **Dr. Matthew Phillips** Yeah, so there are a variety of reasons why it's been difficult to develop vaccines for vector-borne diseases. Some of the reasons have to do with the disease itself. So, for example, dengue, it's been challenging to make a vaccine because of kind of the underlying biology of the virus. So there are four different types of dengue that are all capable of causing kind of similar clinical syndromes. Once you get infected by one, you are immune to that specific type of dengue, and you have temporary immunity to some of the other ones, but not lifelong. And so when you're developing a vaccine for dengue, you want to make sure that you're covering all four of these strains. Because if for some reason one of the strains isn't covered enough, you could be predisposing people to getting a more serious form of this disease. And so currently, there's only one approved dengue vaccine in the United States. Malaria is another case where the biology of the disease has made it really challenging to find a vaccine. Malaria is not a bacteria or a virus. And so a lot of its underlying machinery, its biological machinery

is similar to ours. We're both eukaryotic organisms. And so it also has other ways of hiding in the body, whether it's hiding in our cells or kind of shifting what it presents to the body on the outside of the parasite. And so it has all these mechanisms that we have to kind of compete with. And so it's been really hard to develop a robust malaria vaccine. That said, in the past couple of years, there has been some progress. There are now two malaria vaccines that are approved by the World Health Organization. The first was approved in October of 2021, specifically for children in sub-Saharan Africa or in areas that have a high risk of transmission, had efficacy of about 50 percent, but it kind of waned over time. Specifically, it was geared towards one type of malaria called falciparum. It had better protections for these kinds of strains. More recently, in the past couple of years, in October 2023, WHO approved a second vaccine for prevention of malaria. Again, this is for children living in areas of moderate to high transmission. This one had a fantastic efficacy. It was over 75 percent. That said, it hasn't been around long enough for us to know how durable this protection is.

[00:17:47] **Rob Mather** If we think about a vaccine, if you could vaccinate against malaria in the way that you know, the classic vaccination program, of course, is polio, hundred percent of the population, a hundred percent effective, one administrative dose, no cold chain logistics. And those first two things, hundred percent effective, a hundred percent of the population talk to how impactful it can be. And the last two, how many administrative doses talk to and cold chain logistics, whether you need to keep the vaccine cool, obviously, refrigerated, and talk to cost. Polio was bullseye. So that was terrific. The work that the scientists in the last well, it's been over a number of decades now have done to come up in recent times with two malaria vaccines has been absolutely fantastic because it's the first time we've ever had a vaccine, now two against a parasite, because there are a number of malaria parasites. But that's been a fantastic breakthrough. But we're not there yet because we don't have that hundred percent, hundred percent. We have a much lower percent, thirty-five, forty, fifty percent, a portion of the population, four administrative doses, cold chain logistics. You get the idea that it's not quite there as a vaccine which costs money and so it's not as cost effective as it we want it to be. But hopefully the scientists will have other scientists stand on their shoulders, metaphorically speaking.

[00:19:11] **Narrator** Over the past few years, there's been increasing worry that climate change is expanding the areas where vectors can live.

[00:19:18] **Dr. Matthew Phillips** So global climate change, driven primarily by greenhouse gasses released into the atmosphere from human activities like burning fossil fuel has a huge impact on all areas of human health, especially infectious diseases. So based on our current understanding and the current literature, over half of all infectious diseases are going to be made worse by climate change. Vector-borne diseases are actually the best studied of these types of infectious diseases just because of how integrated into the environment the transmission of vector-borne diseases is. So these vectors require environment capable of spreading them, the spread of the actual vectors themselves, the range of the animals. You can imagine climate change being this all-encompassing problem, it affects every single aspect of how these diseases are transmitted. And so it's important to remember that arthropod vectors are cold-blooded, and so they don't control their internal temperature. And so the ranges of these organisms is heavily dependent on ambient temperature. And so as the global climate warms, you're seeing a northward expansion of a lot of these vectors, these ticks and mosquitoes that can pass on diseases. You're also seeing them able to get up to a higher altitude as well. It doesn't affect climate change doesn't affect every location in the same way. And so you'll see some areas getting wetter as well, and certain organisms do better in more wet conditions. So you

think about like mosquitoes able to breed in standing water. And so increasing rain, increasing catastrophic flooding and storms in certain areas, will help kind of the breeding of mosquitoes. So you do see this expanding range of vector-borne diseases. Climate change also affects the seasonality of these viruses, of these diseases, vector-borne diseases. So the with warmer weather, you get longer summers and shorter, milder winters. And so it's been estimated that by 2050, the amount of time per year that mosquitoes, like the Aedes mosquito, the one that transmits yellow fever and chikungunya, the range that they'll be able to be active, expands by one or two months by 2050. You're also getting larger populations.

[00:21:18] **Narrator** In Uganda, where malaria is endemic, climate change can make the problem worse. Although the healthcare system is better equipped to deal with these challenges than in many locations that are not used to seeing malaria cases.

[00:21:32] **Dr. Pauline Byakika–Kibwika** The transmission of malaria is favored by the climate in which we live, the tropical climate. And of course, I'm sure you have heard of climate change. Climate change affects so many aspects of life, including health, including the transmission of malaria. So in some months, we get the effects of changes in the climate. And these will have an effect on the transmission of malaria. So some days, some some months we get some years, some years we get outbreaks of malaria. But because we are all very aware with a high index of suspicion for malaria in the environment that we live in, these are usually detected quite fast and interventions are put in place. So our outbreak investigation and control systems as a country are very highly developed and are very very sensitive so that they will be able to detect these and come in timely to try and and and fight the outbreak. But as I said, malaria is transmitted throughout the year here in Uganda with peak seasons during the two rainy seasons. We get two rainy seasons in the year, mid year and towards the end of the year. So usually immediately after the the the rainy season, we have a peak of malaria transmission. And we have to work harder because the the prevention has to be strengthened.

[00:23:10] **Narrator** There are developments on the horizon that show promise in both prevention and treatment.

[00:23:15] **Dr. Pauline Byakika–Kibwika** An individual is given malaria, antimalarials that are meant to treat, but can be used to prevent as well, taken as preventative measures. So chemoprophylaxis is being used for certain populations, especially the high-risk populations, can take chemoprophylaxis to prevent.

[00:23:37] **Rob Mather** When I look at the future for malaria control, I'm absolutely hopeful. I've been at this for twenty years, but I think there are a number of things that make me hopeful, the first is the nature of people. My experience over the last twenty years is that is that I have come across a very, very large number of incredibly generous people who care. And that I think in some ways is sits at the heart of how we make progress with anything. We've got a lot of people who care about something. I think people also care about results, which is really important. And so if you can deliver results, then you can continue to be backed. And so that's a sort of fundamental aspect of why I think in the coming years we're going to make inroads into malaria and drive it further and further down. I think allied to that, and I guess I'm touching on this this point about accountability, or I have touched on this point about accountability and of aid delivery. If we can use data and be ruthlessly true transparent with what you do, and I think that leads to excellence and outstanding behavior that achieves better results. And I think the third thing that makes me hopeful is scientific breakthroughs. You know, we've touched on malaria vaccines and gene drive

technology. Some years away, but not so many years away that we potentially can't see it in in the near to medium term. And I think therefore I would say that bringing malaria under control is a question of when, not if. And if more people were to support interventions with strong track records of impact, and fighting malaria with distributing nets is certainly one of them, we're gonna get there faster.

[00:25:17] **Narrator** Vector-borne diseases remain one of the world's greatest public health challenges, driven by climate change, poverty, and barriers to prevention and treatment. Yet, as we've heard, there is also real progress from bed nets saving millions of lives to education changing behaviors to new vaccines and treatments offering hope for the future. Thank you to our guests for taking the time to share their insights. If you found this episode insightful, please share it with colleagues and friends. And don't forget to subscribe so you don't miss future conversations on global health.