[CHAPTER 1 - INTRODUCTION: DEFENDING AGAINST PATHOGENS]
Picture this: you wake up to the blissful sound of birds chirping—because you forgot to set an alarm. You take the quickest shower of your life, throw on some clothes, and… that's the bus. So, you hurry outside with your wet hair, and you hear someone call after you, "Put a hat on! You'll catch a cold!"
Well, it turns out… that's actually a myth. The good news is having wet hair when it's cold outside doesn't cause contagious illness. The only things that do are pathogens, which can be viruses or microorganisms, like bacteria.
The not-so-great news? Potential pathogens are everywhere…and it is true that we're more susceptible to them in cold weather. But thankfully, animals have an Avengers-style team of defenses against pathogens, from snot and oily skin to cells that never forget a face…or, virus.
Hi! I'm Dr. Sammy, your friendly neighborhood entomologist, and this is Crash Course Biology. Now, get ready for some infectious theme music.
[THEME MUSIC]
[CHAPTER 2 - THE INTEGUMENTARY SYSTEM]
When you think about fighting infection, the first thing that comes to mind probably isn't skin. But skin and the things that grow out of it — hair, nails, feathers, and scales — are the first layer of an animal's built-in defense system or its innate defenses. 'Cause you know, awl' of dis isn't just for looks!
We call this outer layer the integumentary system. It's one of the ways the body prevents sickness and injury—basically, it keeps your insides in, and the outside world mostly out.
In general, skin and its associates protect animals from injury and block pathogens that can cause disease. Hair, feathers, and scales can also stop disease-carrying parasites in their tracks. Think about how much harder it'd be for a mosquito to bite you if you were covered in a thick layer of scales! Instead, humans had to invent cargo pants and bug spray.
But although we're basically the naked mole rats of primates, our skin is still a powerful barrier against pathogens. And if you get a paper cut or scratch up your knee, your skin is a pro at regrowing cells and fixing itself up.
And skin isn't just a physical forcefield. The skin of many animals produces an acidic, oily mixture called sebum that helps kill pathogens. Sebum also makes your hair and skin greasy…but hey, at least it's serving a purpose besides making you break out on picture day.
[CHAPTER 3 - INTERNAL DEFENSES]
So, our bodies are great at protecting us from the gnarly stuff outside, whether we remember our hats or not. But what happens when that stuff finds its way inside?
Because most animals have to breathe and eat stuff from their environment, we need openings like mouths and noses that allow stuff into our digestive and respiratory tracts.
But those openings can also sometimes let in harmful things. Like food that's been infected with bacteria or air containing virus particles, like the flu. Thankfully, evolution has prepared us for this.
Any part of an animal's body that's open to the outside world has protective barriers. For those of us with backbones, AKA vertebrates, it's mostly a layer of mucus that contains immune cells and natural antibiotics.
And while snot gets a bad rap, especially when you have to blow your nose in the middle of a perfectly silent classroom, it's doing you a service. That nose goop acts like glue, trapping

pathogens before they can sneak deeper into your body. That's partly why you get so snotty when you're sick: more mucus traps more germs, which means microbes and viruses get blown or coughed out of your body just a little faster.

Still, if you've ever gotten sick…which I assume you have, if you're not a robot. Unless…? No, I'll assume you've caught a cold at some point. And if you have, you've discovered that pathogens can still sneak past this mucus barrier.

But that doesn't mean they're home free. This is where the immune system really steps into high gear, and where things get really cool. Or really sweaty.

When a pathogen goes deeper into the body, an animal's innate defenses attack unwanted cells and make it harder for pathogens to survive and reproduce.

Take scavenger cells, a specific type of white blood cell. A scavenger cell can swoop in, surround a pathogen, and eat it, like Pacman. And then, it spits out what's left of the pathogen so other parts of the immune system can see what had the AUDACITY, the unmitigated gall to sneak into this body.

And then there are natural killer cells. Seriously, that's the scientific name. They can take down microbial infections and cancerous tumors by siccing a sort of poison molecule on them.

Innate defenses also include inflammation, where an area of the body becomes hot and swollen in response to an irritant. Like, when you get stung by a bee, the site of the sting gets red and swells with nutrient-rich blood that's carrying immune cells to fight back against the bee venom.

And when you get a fever, this inflammatory response happens on the whole-body level. It sounds weird, but think about it: pathogens are infecting you — or a vulture, or a whale, or your hamster — because you seem like a pretty sweet apartment. You're warm, you've got running water and energy, and your body seems like a nice place to set up shop and multiply.

When your body detects this new unwelcome tenant, it cranks up the thermostat until it's obnoxiously hot, giving you a fever, and making the pathogens so uncomfy that they grow more slowly or die. Your body would rather have you stuck in bed feeling both sweaty and freezing than have that invader stick around.

That means when we or other animals feel sick, it's often not the pathogen's fault — at least, not directly. The symptoms that specific pathogens cause aren't usually things you can feel — at least not right away. It's how our bodies respond to pathogens that we experience as being "sick."

[CHAPTER 4 - ASYMPTOMATIC INFECTIONS]

Now, on some occasions, pathogens can successfully fly under the radar. They've made it inside and started reproducing, but the body shows no symptoms at all. It might be launching some low-level defenses, but they're minimal enough that the person infected doesn't even realize it. We call this an asymptomatic infection.

These came into the limelight when the COVID-19 pandemic started. You might have heard of people having asymptomatic infections, which meant they could unknowingly infect others with COVID. But you can have an asymptomatic infection of many other illnesses as well. A number of sexually-transmitted infections are a prime example of this.

[CHAPTER 5 - HEALING]

Finally, it's worth noting that innate defenses aren't /just/ for protecting an animal against illness. They're also involved in healing.

For example, inflammation can send a lot of blood to a wounded area, which provides nutrients for cells that need to quickly duplicate. All that blood also carries discs called platelets that are involved in blood clotting — where the body makes a barrier over a wound to stop bleeding. You'll recognize the end result as a scab. Even the pain part of inflammation can be an important part of healing because it makes us protect the injury.

[CHAPTER 6 - ADAPTIVE IMMUNITY & VACCINES]

So yeah, our innate defenses do a lot to keep us safe and healthy. But vertebrates have yet another defensive layer, one with an even sharper eye for the pathogens that could wreak havoc in our bodies: adaptive immunity.

While the gist of innate immunity is "Hey, there's an invader in here, let's get 'em," adaptive immunity is about recognizing and remembering specific pathogens. So, it's not just "an invader," it's "Bob the flu virus is back again; we know how to deal with this guy."

Understanding this system has allowed scientists to develop one of the world's most life-saving technologies: vaccines. Let's head to the Thought Bubble….

Welcome to my adaptive immune system. This is me getting my first COVID-19 vaccine. You got this, buddy!

Now, my body will start making proteins: the same one on the real COVID-19 virus. This protein, called an antigen, is basically a cellular name tag.

Now, here come the super important white blood cells to scope out the situation—hey, T cells. They've never met these proteins before, and they're not fans. They call in other parts of the immune system to wipe them out.

First up: antibodies. These custom-made molecules flag down specific pathogens. They stick themselves to the virus to keep it from causing harm and then, this signals reinforcements.

Next, we've got memory cells — so-called because they sort of "remember" what those proteins look like so they can attack the virus again if needed. They do this by making receptors that fit into just one type of antigen, like one of those two-part friendship necklaces.

This whole process has prepped my body for a potential encounter with the real COVID-19 virus. So, when I'm exposed to it a couple months later, my immune system springs into action more quickly.

Memory cells bind to the antigen and quickly trigger a response. The antibodies then swoop in to smother the virus, and the immune cells get to work, too. Because my body has practiced this exact mission before, it can respond much faster, and I'll be COVID-free in no time.

Thanks, Thought Bubble! In this scenario, you can substitute the COVID-19 virus with basically any bacteria, virus, or other pathogen that could infect an animal. Like, if you've ever gotten chickenpox or strep throat, you likely have antibodies and memory cells for those pathogens in your body right now.

[CHAPTER 7 - THE LYMPHATIC SYSTEM]

But you may be wondering, where exactly /is/ the immune system? Like, if the integumentary part is outside, sort of—on my skin, and in my snot and stuff—where inside me do the other parts happen?

And the answer is… kind of everywhere. Last episode, we talked about the lymphatic system as part of the body's infrastructure — a series of vessels and tubes throughout your body that help keep your fluids balanced.

But, the lymphatic system is also a home base for a lot of adaptive immune cells. They hang out in bean-shaped structures called lymph nodes and screen everything that comes by, like security agents at airports. And if there's a problem with one of your bags, wherever it is, cells from the closest lymph node will sound the alarm.

Unfortunately, though, the immune system is sometimes…a lil extra. It can flag things that are perfectly harmless — like pollen, certain foods, or even the body's own cells. And this is what causes allergies, asthma, and some autoimmune diseases. It's like, immune system, I love you, but chill.

[CHAPTER 8 - REVIEW & CREDITS]

Overall, though, animals' immune systems are wildly impressive, in their ability to fight off pathogens generally and to target specific ones.

From viruses to bacteria and everything in-between, the world is full of organisms trying to survive and reproduce… sometimes at the expense of others. But this is a battle that's been going on since the beginning of animals, millions of years ago. And we are well-prepared, hat or no hat.

Next time, we'll learn how the body governs itself—how it communicates, regulates, and coordinates all the processes that keep us alive. I'll see you then. Peace!!

This series was produced in collaboration with HHMI BioInteractive. If you're an educator, visit BioInteractive.org/Crashcourse for classroom resources and professional development related to the topics covered in this course.

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