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Hello and welcome to the Health Hits podcast.

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I'm your host Tom Fisher and this week's episode doesn't cover the unusual or the bizarre, it covers the truly terrifying. Yes we're talking about the invisible and deadly VX nerve agent. Its been in the news in recent weeks after the horrific attack on a man in Malaysia. We'll talk about how our nervous systems function and how this horrendous agent disrupts that. And also, how on earth scientists came to create a toxin so deadly that half the weight of a grain of sand is enough to kill you.

Some of the descriptions in this weeks episode may be distressing for very young children, but I have not gone out of my way to describe things in a lurid or overly graphic way.

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So the nervous system.

What is the nervous system?

Well it's a collection of nerve cells that take signals from the body to the brain, carry those signals within the spinal column, and then transmit other signals back out again.

Its not necessary to have a nervous system if you're a single celled organism, but if you are made up of multiple, independent cells you need a nervous system in order to be able to coordinate these cells so they all work together towards the common purpose. A very old and very basic nervous system is the net-like web of nerves that spreads out from the mouth of jellyfish. A jellyfish moves in a coordinated, almost hypnotic rhythm, where all the muscle cells have to be able to contract at the same time. The nervous system allows this to happen, it tells the muscle cells when to squeeze, and if it didn't then the jellyfish would just flap about in a disordered way.

Most humans are more complex than a jellyfish, and so our nervous systems are far more complex too.

Nerves can be thought of in basic terms as conducting wires. They are cells like any cell in the body but they have evolved to be long and thin and carry electric signals over long distances. The longest nerve in the human body is the sciatic nerve, stretching from the base of our back, down the back of the legs all the way down to our feet.

The nerves that carry signals from the body, such as pain, temperature or movement are called sensory nerves or sensory neurons. A neuron IS a nerve cell. These signals go up the sensory nerve as far as the spinal cord, and then the signal transfers to a spinal nerve and up to the brain.

If you had two copper wires and you wanted to transmit a signal from one to the other you would just touch them together and the signal would continue, but when moving between two separate nerves cells or neurons, its not quite that simple. The junction between the nerves is called a synapse, from the Greek meaning junction. And to tell the nerve after the synapse, the post synaptic nerve, to fire, the first nerve or pre synaptic nerve releases a chemical neurotransmitter.

You may have noticed a theme here. Almost all of the medical or scientific names for body parts or functions can be traced to either Latin or Greek. Its usually one or the other but a rare example of a combination is ‘neurotransmitter’.

Neuro from the Greek neuron meaning fibre or sinew, and transmitter from the Latin trans meaning across and mittere meaning to send.

The neurotransmitter is a chemical compound and its release from the pre synaptic nerve into the synapse space. In a sensory nerve it is glutamic acid, and it moves into the space and slots into receptors on the new nerve, like a lock in a key, and starts a new signal down the spinal cord. The nerves in the spinal cord, the brain and those that come from our senses – sight, smell, hearing – are called the central nervous system.

You don’t want the spinal nerve to keep firing and keep sending signals up to the brain, you want it to fire once and stop, so the neurotransmitter in the synapse space is broken down by enzymes. Essentially resetting the space between the nerves ready for the next signal.

So that’s signals from the body to the brain.

But what about signals from the brain to the body?

Well when signal come from the brain and spinal cord to the muscles, they leave the spinal nerves across a synapse into what are called motor nerves or motor neurons. As you may guess, these nerves travel to our skeletal muscles and the signals tell our muscles to contract. There are multiple, coordinated signals from the brain to the muscles, and an activity that would seem really simple such as walking would require the coordinated contraction and relaxation of over 40 individual muscles.

When the signal goes down the motor neuron, the nerve from the spine to the muscle, it faces the same problem the sensory nerve has when it reaches the spine. It can’t just plug in to the muscle, like a wire sticking into a piece of plastic explosive. The space or synapse between the nerve and the muscle fibre is called the neuromuscular junction. It works in the same way as a nerve synapse in that a neurotransmitter is released from the end of the nerve and triggers receptors in the muscle. In this case the neurotransmitter is acetylcholine, or ACh for short. It causes the muscle fibre to contract, and then once its done this, the acetylcholine is broken down by and enzyme to switch the signal and the muscle contraction off. Ready for the next instruction.

The VX nerve agent does its cruel work here at the neuromuscular junctions of the muscles on our skeletons.

The organophosphate compound of the nerve agent blocks the action of the enzyme that would normally break down the acetylcholine in the neuromuscular junction. So the muscle normally contracts in response to the acetylcholine from the nerve, then relax once the acetylcholine has been broken down. But when the enzyme that does this is blocked, the acetylcholine stays in the neuromuscular junction, and keeps the muscle in continuous contraction.

The agent gets into our system either directly through our skin or we breath in the gas form into our lungs.

In footage of goats or rabbits exposed to VX during experiments from the 60s, what you initially see is twitching of some muscles, followed by continued prolonged spasm of every muscle. The body is rigid and arched almost as if it is trying to pull itself apart. Its really ghastly to watch.

The muscles that would normally contract and relax in breathing, the diaphragm and rib muscles also go into constant contraction, essentially locking your breathing pattern in the inhale phase. You can’t breathe out and so you slowly asphyxiate. The pain from the muscle spasm and the slow choking sensation as you struggle against the prison that your own body has become must be one of the most awful ways to die.

And die you almost certainly would because unless you are in a military setting where exposure to nerve agent has been anticipated and an antidote is to hand, a moderate exposure to the agent is likely to be fatal within minutes. The man in Malaysia who unfortunately became the first high profile fatality from this agent was taken ill but any doctor treating him would have never been expected to even consider a biological weapon of mass destruction as a differential diagnosis. Its extremely rare for this agent to be used in a targeted assassination like this, but there is pretty conclusive proof that Bashir Al Assad's military has deployed a similar agent, Sarin, in an indiscriminate way in Syria in 2013, reportedly resulting in 1400 fatalities.

When you understand how this agent affects the body you can see how completely unacceptable it is for this type of weapon to be deployed again even military personnel, let alone civilian children.

In fact there is a type of treatment, and some military personnel do carry autoinjectors with a drug called atropine. Atropine is commonly used in medicine to reduced nasal congestion, or by opticians to dilate the pupils. It works by blocking the effect of the acetylcholine on the muscle fibres, so even if you have excess neurotransmitter building up in the synapse, the muscle won't go into spasm, and hopefully you can keep it that way until the nerve agent is out of the system.

The organophosphate nerve agents were developed by British scientists, looking for new and effective pesticides in the 1950s. They were determined too toxic for safe use, but unfortunately the military got hold of samples and got to work on weaponising these compounds.

They were even able to turn it into a binary system where two harmless compounds mix together in the air and become VX. This made storage and transport of these weapons much less dangerous.

In fact it didn't take long for military and political leaders to realise that the agents were beyond morally acceptable as weapons and they have never been used in state vs state open warfare.

In 1997 an international treaty called the Chemical Weapons Convention came into force, and it made production, stockpiling and deploying chemical weapons like VX illegal. Even stockpiling the precursors to the weaponised chemicals is forbidden. I understand that the US and Russia have been able to keep very tiny amounts of VX for research purposes.

So that's enough about the horrific history of nerve agents. It's been a very different and difficult episode to research and far away from my profession where we engineer compounds to treat disease and improve peoples' lives.

It's a reminder that whilst so many people are out there have worked for the embetterment of our world, including those scientists looking for new pesticide, there are a small few who will bastardise their good work and corrupt science for evil purposed.

If you would like to find out more about the things we have discussed in this episode, ask questions, or request topics for future episodes, come and find us at www.HealthHits.info or on Twitter or Facebook @HealthHitsPod.

Thank you so much for listening, and please join me for another, hopefully more upbeat, episode of Health Hits.