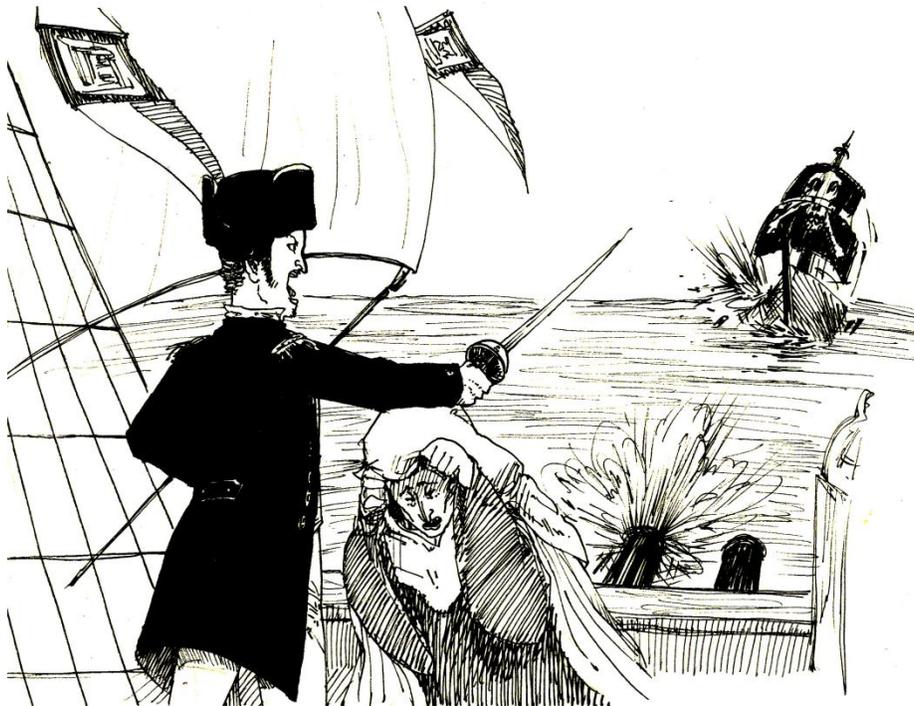


## Osmosis and Osmotic Pressure: Pirates Big and Small

### Story 1: Ready The Cannons!

*The year is 1710 and in the Caribbean it is the golden age of piracy. To sail these waters with anything of value is to take your life into your own hands. This was a fact that Captain Bartholomew Rackham knew all too well. He could feel his pulse quicken as his ship drifted further into pirate infested waters. His grip on the ship's steering wheel was so tight that the wood creaked beneath his fingers. His crew had the fiercest reputation in the Royal Navy and*



*had survived many pirate attacks in the past but this mission was more dangerous than most and they were all beginning to crack under the tension. Out of the corner of his eye he could see his first mate, Nigel, a giant of a man whose body was a map of scars, nervously sharpening his cutlass.*

*Captain Rackham called out to him, "Nigel my friend, if I didn't know you better I'd think you were afraid."*

*Nigel gave a hushed response, "Sorry Captain Rackham, but I*

*don't like the situation we're in. Transporting these monks and their religious artifacts to the island of Hispaniola is a fool's errand. Every rum-soaked pirate in the Caribbean knows we have a 50 pound cross on our ship made of solid gold. Look at those monks! Not one of them is as big as my forearm and they are always reading their filthy books. They aren't going to be much help if we get attacked unless they want to read one of those filthy dogs a bed time story."*

*Captain Rackham furrowed his brow as he scanned the horizon with his spyglass, "I have some bad news my friend. There is a pirate ship closing in on us fast from the east! Have the men ready the cannons. It might be bad news for us but it will be a lot worse for those pirates!"*

*The deck of Rackham's ship was alive with activity as the crew loaded the giant cannons. As the Pirate vessel drew closer Captain Rackham gave the order to open fire. The explosive sound of the cannons was closely followed by the crunches of splintering wood as the cannonballs blew many giant holes in the hull of the pirate ship. The pirates that weren't killed by the initial barrage panicked as seawater began to rush into their ship through the holes. Some of the pirates desperately tried to press their backs against the holes in an effort to stop the water from rushing in. Unfortunately for them, the force of the water was too strong and the black-hearted buccaneers were quickly swept inside the ship to drown. The water continued to rush into the pirate ship causing it to sink. It was not long before the entire vessel slipped beneath the*

ocean's waves. The amount of water that filled the pirate ship was so great that it put enough pressure on the hull to cause the ship to explode under the water. As planks of wood floated to the surface the surviving pirates desperately tried to grab onto them for support as they swam away.

Captain Rackham laughed victoriously, "Ha! Look at the cowardly pirate scum turn tail and run. Leave them to the sharks and continue our course to Hispaniola! See Nigel, I told you, nothing to worry about.....Nigel?"

Nigel groaned, "Over here Captain. During the chaos I took a musket ball to the shoulder, it was just a flesh wound but it knocked me to the floor. Not to worry, I'll be fine. One of the monks put this poultice on my wound and it feels better already. Wound care is important and those monks seemed to know what they were doing. I have seen even mild cuts turn fatal if a fever sets in. Maybe there is something in all those books after all. Are you sure that it is a good idea to let the other pirates get away? They are no longer a threat but the only good pirate is a dead one."

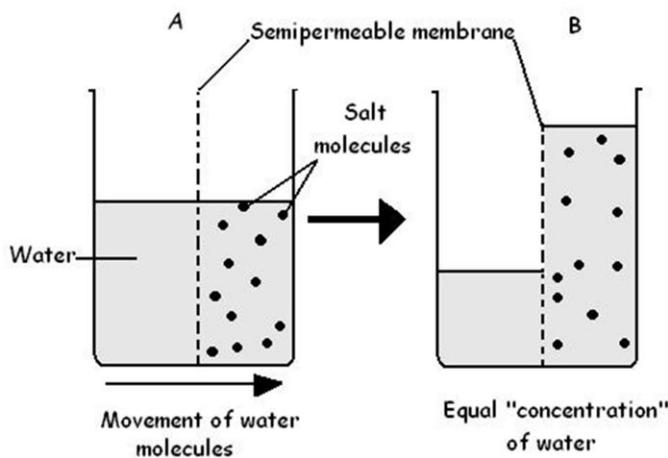
Captain Rackham patted Nigel on his good shoulder, "Not to worry my friend, just get better. If those worthless scoundrels ever return they will get another taste of our guns."

### Scientific Explanation:

Why did the pirate ship explode after the cannons blew holes in it? The answer is because of **osmosis**. **Osmosis** is defined as the net movement of water molecules through a partially

permeable membrane towards an area of higher solute concentration. Water does this because entropy (the force of disorder) drives it to equalize solute concentrations on both sides of the membrane. Though the definition of osmosis sounds very technical it basically means that water likes to travel from where it is to where it isn't. The term "partially permeable membrane" refers to a barrier that water can easily move through but some solutes cannot.

Figure 1. Osmosis Diagram



The wooden hull of a pirate ship is an impermeable membrane. Water cannot flow through wood which is one reason why wooden ships are able to float. When Captain Rackham's cannons blew giant holes in the pirate ship's hull it became a partially permeable membrane. Water flowed in through the holes and filled up the ship. Water went from an area of lower

solute concentration(the ocean) to an area of higher solute concentration(the dry interior of the ship) in an effort to equalize the concentrations on both sides of the wooden hull. So much water flowed into the ship as a result of this that it put pressure on the hull and the hull splintered and broke. This phenomenon is not an exaggeration and wooden ships exploded quite frequently when they started to sink.

You might notice in this story that some pirates tried to press their backs against the holes in the hull in an effort to plug them and prevent water from flowing in. The minimum amount of force necessary to stop the flow of water is the **osmotic pressure**. The force that the pirates' bodies generated was well below the value in this case and they ended up getting pushed out of the way by the water and swept to their deaths.

The term **tonicity** refers to the relative concentrations of solutes on either side of a semi-permeable membrane. Usually this term is made from the perspective of the membrane's exterior. If the solute concentrations are the same on both sides of a partially permeable membrane then the solution is **isotonic** and there is no flow of water across the membrane. This was obviously not the case in terms of the sinking pirate ship. The ship's interior was dry so you can sort of think of it as having infinite solute concentration while ocean water is much less concentrated. The ocean water is a **hypotonic** solution compared to the ship interior. As a result as soon as cannon balls made the hull semi permeable, water rushed in and filled the ship to the point that it exploded.

A less obvious feature of osmosis in this story was the **poultice** used to treat Nigel's wound. A **Poultice** is typically a damp mass that has a very high solute concentration. It is usually made of damp mashed herbs but the bottom line is that it is **hypertonic** compared to the wet surface it is placed on, like the fluids in Nigel's open shoulder wound. The purpose of the poultice is to make water flow out of the wound and into the poultice. The flowing water removes bacteria and dirt, cleans the wound and reduces swelling and inflammation. Flesh wounds are no joke. **A dirty wound is a home for bacteria and bacterial infections can kill a young healthy person very quickly.**

Bacteria themselves are sort of like very small pirates. Don't let their size fool you, bacteria have killed more people than all the pirates in the world combined. The cells in your body are surrounded by a nutrient rich fluid that is an endless source of energy for them. Bacteria have to struggle and kill each other for sources of nutrition so that they can grow and survive. The fluid that surrounds your cells is like treasure to bacteria. They want to get inside of you and raid your body for nutrients just like the pirates in this story raid ships for gold and valuables. Just like actual pirates, when bacteria start to raid your body death and destruction quickly follows. Your skin is a natural barrier to bacterial invasion, if you get a cut then that is the same as a hole in your defenses. Wounds give bacteria access to your nutrient rich fluids. Bacteria live everywhere but they are especially concentrated in dirt which is why it is so important to keep wounds clean. Every time you let a wound get dirty you are sailing in pirate infested waters. The Caribbean had blood thirsty pirates like Black Beard, Calico Jack, and Captain Kidd whose notorious bacterial equivalents would be *Staphylococcus Aureus*, *Streptococcus*, and many, many others. Bacterial buccaneers have killed more people than all of the wars ever fought in history of the world. In many past wars one of the biggest killers was wound infection. Ironically the solution to small pirates is the same as big pirates; we just use smaller cannon balls.

## Story 2: Ready the Antibiotics!

The year is 1989. Hank, a 19 year old man, looked at Dr. Walker with wide eyes, “Are you sure you want me to show you my arm? It’s the most disgusting thing I have ever seen. It’s

Hank’s Infected Arm



all red and swollen and the flesh is literally blistering and bubbling off of it. I was at the zoo a few days ago and I got bit by this bug while I was looking at the Komodo Dragons. I don’t know what kind of bug it was but it had a lot of legs and the bite was super itchy. I could not stop scratching it and then it started to get all red and then over the last couple of days it turned into this. Do you think this is some kind of bug venom?”

Dr. Walker cringed as he looked at Hank’s arm, “It looks like a nasty skin infection. The technical term

is cellulitis. Its not any insect venom. Your repeated scratching of the insect bite caused breaks in your skin and allowed bacteria to get inside. Once bacteria got under your skin, probably in this case either staphylococcus or streptococcus, they were able to survive pretty well on the nutrient rich fluids that give energy to your cells. This bacterial raiding party caused the tissue damage you can see on your arm. Fortunately if you take this amoxicillin, an antibiotic I am going to prescribe, it should get better. You’ll see the area of redness and swelling shrink over the next week. The amoxicillin will kill the bacteria quickly but it will take some time for the damaged skin to heal”

Hank shook his head, “Hey Doc, do I have to take all of the pills? I think pills are unhealthy and I believe in going all natural. Can’t I just give my arm some extra sun light instead?”

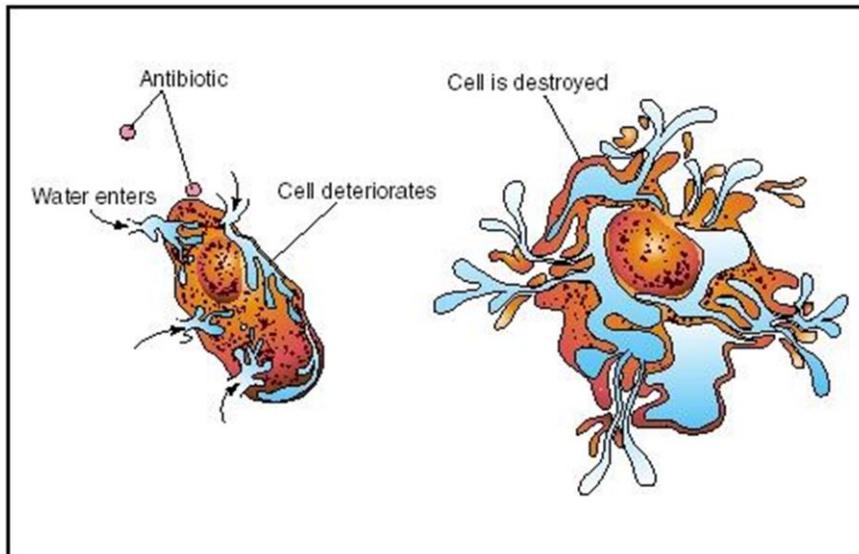
Dr. Walker quickly replied, “Take the pills and take all of them. Infections are no joke. Do you see the damage that those bacteria did to your arm? If they get in your blood stream they can cause that kind of destruction to your internal organs as well. They can destroy parts of your heart, your brain, your kidneys, your liver, or anything else. You don’t have to know much to know that’s really, really bad. Let me use an example from your trip to the zoo to illustrate how serious infections are. The Komodo Dragon kills its prey by causing massive bacterial infections with its bite. When a Komodo Dragon bites an animal it introduces all of these nasty bacteria into the unfortunate creature’s blood stream. All a Komodo Dragon needs to do is wait until the bacteria destroy its prey from the inside out. Make sure you take every last pill, bacteria that

survive an antibiotic assault can become resistant to them in the future and you don't want to end up like some poor animal with a Komodo Dragon bite."

### Scientific Explanation:

Infections are no joke but fortunately scientific research has come up with ways of controlling them. Antibiotics are drugs designed to kill/stop bacteria so that people can recover

#### Penicillin Killing Bacteria



from infections. The first antibiotics were discovered in the 1930's, which means that as a class of drugs they have been around less than a hundred years. You might also notice an increase in life expectancy in the last century because bacterial infection was a major killer. The discovery of penicillin was arguably the most important medical breakthrough of the 20<sup>th</sup> century and that was only a World War

II era discovery. **Penicillin is the cannonball of the antibiotic world**, it interferes with the way bacteria make their cell walls and the net result is that it puts holes in them and the hypotonic environment does the rest of the work. A bacterial cell is a lot like a pirate ship and its cell wall is its hull. In general the insides of bacteria and other cells have higher solute concentrations than the surrounding fluid so they exist in a hypotonic environment. When Penicillin causes holes to develop in bacterial cell walls water rushes in and the bacteria explode. Amoxicillin is a close relative of penicillin and works the same way. It is extremely important to take every antibiotic pill prescribed even if the infection improves and you feel better. If bacteria are left alive then they can develop resistance and the antibiotics become less and less effective. This is a major concern in our current time as Methicillin(another penicillin relative) Resistant *Staphylococcus Aureus*(MRSA) is a real threat. The story was dated 1989 because amoxicillin was still a reliable drug for skin infections then but resistance has made it less reliable in fewer than the 30 years it has been existed as a drug.

**Take Home Message: Osmosis and osmotic pressure are how penicillin based antibiotics kill bacteria. Bacteria want to raid your body for nutrients so open wounds are a risk for infections and keep all wounds clean. Unless specified, take all antibiotics prescribed to decrease odds of emerging bacterial resistance.**