

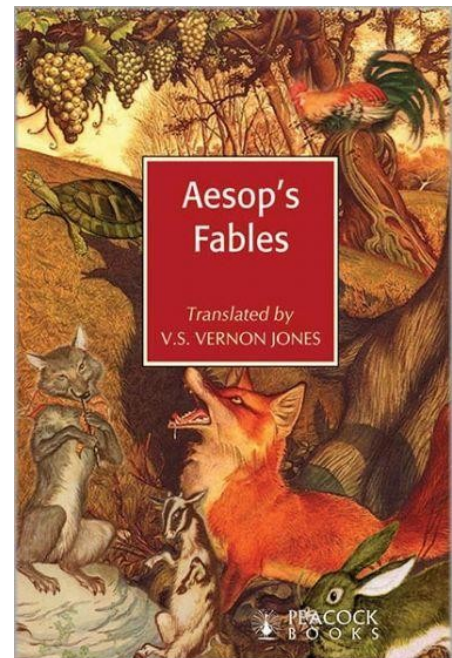
Quantum Field Theory as Aesop Might Have Taught It

Confused about Quantum Field Theory? You're not alone. Quantum Field Theory is probably the most complex and intimidating subject in advanced physics. Even physicists who understand it have a hard time explaining it to a layperson so that *they* can understand it.

This short lesson seeks to solve that problem by taking a page out of the Aesop playbook. Aesop, an ancient Greek Storyteller, is still famous today for his timeless collection of simple fables.

Here are a few Aesop fables you've probably heard...

1. The Fox and the Grapes.
2. The Farmer and the Golden Goose.
3. The Boy Who Cried Wolf.
4. The Ant and the Grasshopper.



These fables teach lessons that would otherwise take years of experience and careful reflection to learn. If you tried to teach the underlying principle of one without using the fable itself, it might take you thousands of words, and many people still wouldn't grasp the idea being taught.

Yet, the fables are so short (normally less than 250 words) and simple that even a child can quickly understand and remember them. So, we thought we'd try Aesop's approach in teaching the concept of Quantum Field Theory.

Since a common cause of confusion in learning Quantum Field Theory is the attempt to grasp the mathematics before trying to grasp the basic concept, we won't use any math in this story.

Our goal is to teach you the core concept of Quantum Field Theory as clearly and as simply as possible. Once you grasp this, you'll find the math much easier to understand and apply.

The Story of the Frog and His Son

A frog and his Son were fishing at a pond. The Son asked his Dad a simple, but intriguing question...

Son: *"Daddy, what's the world made of?"*

Dad: *"The world is made of matter, Son"*

Son: *"What's matter made of?"*

Dad: *"Matter is made of atoms."*

Son: *"What are atoms made of?"*

Dad: *"Atoms are made of subatomic particles. They're called protons, neutrons and electrons."*

Son: *"Oh. And what are those made of Daddy?"*

Dad: *"Well Son, those are made of quarks. And I guess you're going to ask me what quarks are made of, right?"*

Son: *"Uh huh!"*



Dad knew that his Son wasn't going to leave him alone until he had a clear answer about what the world was made of. So he looked out across the lake and said...

Dad: *"Well Son, quarks, and all the other little things that subatomic particles are made of, they all come from something called the Quantum Field. Some of the old, wise frogs around here call it 'The Great Pond.'"*

Son: *"Is The Great Pond made of water too Daddy?"*

Dad: *"No Son. It's made of this..."*

Dad picked up a pebble and dropped it gently into the pond. He and his Son watched the ripples spread out across the entire pond.



Dad: *"You see all those waves and ripples? Imagine if this pond was MADE of those waves and ripples instead of being made of water. That's what The Great Pond is made of."*

Son: *"But aren't the waves and ripples made of water too?"*

Dad: *"That's the thing Son. The waves aren't 'made' of anything. They're not like our feet or tongues or the flies we had for dinner. If you tried to pick one of these waves up in your hand, you wouldn't have anything to grab onto. Even if you could pick one up, it wouldn't weigh anything. It wouldn't take up any space in your hand either."*

Son: *"But if the waves don't weigh anything and they don't take up any space, how do we know they're real?"*

The Dad sighed. *‘This is going to be harder than I thought...’* he said to himself. But Dad felt confident that if he explained this well, it would save him from answering a lot of questions in the future.

Dad: *“Imagine if we drained all the water out of this pond and filled it up with thousands of our fellow frogs. These frogs can only do three things: jump, eat flies, and puke up flies. But when they jump, they can only go straight up. They can’t jump to the right, or the left, or forward or backward. All they can do is jump straight up in the air, and land in the same place they started.”*

Son: *“So, The Great Pond is made of FROGS?!”*

Dad (Pointing to a burst of tiny bubbles emerging from the murky pond): *“No. Remember, The Great Pond isn’t ‘made’ of anything. But we know it exists because we can see what it DOES to the subatomic particles we talked about. See those bubbles coming up in the pond?”*

Son: *“Yeah, that’s an otter blowing bubbles, right?”*

Dad: (Laughing) *“Yes, but how do you know there’s REALLY an otter down there? You can’t see him, can you?”*

Son: *“No, but I know he’s there because I see what he’s doing to the water!”*



Dad: *“Right! It’s the same with The Great Pond Son. It doesn’t weigh anything or take up any space. But we know it’s there because we see what it does to particles in the subatomic world!”*

Son: *“Woah! So it’s like the invisible frog in your other stories! You can’t see him, but if you throw mud on him you know he’s there, because the shape of the mud is on his face!”*

Dad: *“Yes! That’s a good way to think about it Son!”*

Son: *“Thanks Dad! But are there frogs in The Great Pond?”*

Dad: *“Well Son, because you understand what the frogs in my story do, you’ll understand what The Great Pond actually does to our Universe. And then, you’ll understand a LOT of things about the world. Now, may I finish?”*

Son: *“Yes Dad. Please finish the story!”*

Dad: *“Imagine if we drained all the water out of this pond and filled it up with thousands of our fellow frogs. These frogs can only do three things: jump, eat flies, and puke up flies --”*

Son: (Interrupting) *“Yes Daddy, you said that already!”*

Dad: *“Right! Just making sure you’re paying attention! Now, imagine if all these frogs are holding hands. But that’s not all. There’s a rule that none of the frogs can just sit still. They have to jump. Now Son, what do you think would happen?”*

Son: *“Well, let’s see.”*

The little frog sat and thought about it for what seemed like a very long time.

Son: *“If they’re holding hands, it means that when one frog jumps, the frog on his right and the frog on his left have to jump really soon after he does!”*

Dad: *“Exactly! And since THOSE frogs have to jump, the frogs beside THEM have to jump too, and now one frog’s jump turns into a wave of jumps rippling all the way across the pond!”*

Son: *“That’s cool! So is that why we call it The Great Pond? Because it ripples just like this pond does when I do this?”*

The Son started kicking his feet in the water, sending a flurry of waves that quickly traveled all the way across the pond.

Dad: *“Well, yes. But now you scared off all the fish!”*

Son: (Shrugging his shoulders)
“Meh, it’s a small pond. They have to come back to this side eventually! But now I’m confused Daddy.”



Dad: *“Confused about what, Son?”*

Son: *“The waves in THIS pond are only there because the water is moving. What’s MOVING in The Great Pond, if it’s not made of anything?”*

Dad: *“Good question! Remember Son, it’s not about what The Great Pond is made of. It’s about what The Great Pond does. And it can do it whether it’s ‘made’ of anything or not. That’s what makes it so mysterious! The Great Pond isn’t made of water that ripples when you touch it. The Great Pond IS the phenomenon of waviness!”*

The Son furrowed his brow. His Dad knew that look. He was about to lose his Son’s interest.

Dad: *“Uh, never mind that part, Son! When you’re old enough, I’ll tell you about Arthur Schopenhauer’s philosophical work on ‘The World as Will and Idea.’”*

Son: *“Arthur who?”*

Dad: *“Never mind! For now, all you need to know is that The Great Pond is ‘made’ of waviness and that something can be wavy even if it doesn’t weigh anything or take up any space. The question is...how do we KNOW that The Great Pond is wavy?”*

Son: *“Right! Tell me that Dad!”*

Son: *“Actually Dad, you said you were gonna’ tell me where ‘some-atomic’ particles came from! Remember?”*

Dad: *(Laughing) “SUBatomic particles Son! And yes, I’ll tell you where they come from! Remember I said that the frogs in The Great Pond can either eat flies or puke them up.”*



Son: *“So does The Great Pond puke up the subatomic particles, like that otter blowing the bubbles? Is that how we know it’s there?”*

Dad: *“That’s the best way I can explain it Son. But it takes a lot of energy for a frog to puke up a fly. They can’t do it by themselves. It takes a lot of them jumping in the same rhythm before they can do it.”*

Son: *“But, if a lot of them, like let’s say, twenty, are all jumping up and down at the same time, what happens then?”*

Dad: *“Then, one of them puked up a fly. Only, this fly is no longer part of The Great Pond. It actually weighs something AND it takes up space.”*

Son: *“Oh! So, the fly is like the subatomic particle?”*

Dad: *“Yes! That’s exactly it! If The Great Pond ‘waves’ enough, it causes a subatomic particle to LITERALLY pop into existence!”*

Son: *“Wow! That’s SO cool! Imagine if I could wave my hand REALLY fast and make a yummy fly appear!”*

The Son started shaking his hand frantically, looking intently at the space above it. His Dad laughed hysterically.

Dad: *“That would be something Son. But your hand already has too much energy committed to BEING a hand. Compared to a subatomic particle, your hand takes up a LOT of space and it weighs a lot. So it doesn’t have any energy left to become something else.”*

Son: *“Oh. Well, it’s still cool that EVERYTHING we’re looking at is made of, well...NOTHING! Am I right Dad!?”*

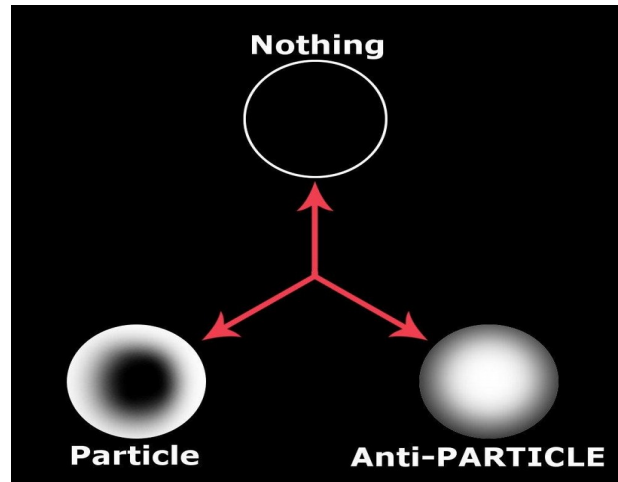
Dad: *“Well, that’s a philosophical question. You’ll be ready for that when you get older.”*

Son: *“Oh, right. That Arthur Something-Howard guy, right?”*

Dad: *“Right. But back to our story, because we need to finish this up before it gets dark. Sometimes, particles ‘appear’ out of The Great Pond, but then disappear quickly. Sometimes the frogs will eat a fly, and essentially it will no longer exist as we know it. But it can exist again if they puke it back up.”*

Son: *“Does that mean The Great Pond might get hungry someday and eat the whole world?”*

Dad: (Laughing) *“No Son. The more flies the frogs in The Great Pond eat, the more energy they get and the more they jump. This means, if you feed them a lot of flies and get a lot of them to jump at the same time, you can force them to puke up more flies. So, even if The Great Pond STARTED to swallow up a lot of particles, it would have to CREATE a lot of them too, and there would still be a world.”*



Son: *“Wow, that’s really cool. Thanks for the story Dad. I just have one more question.”*

Dad: *“What’s that Son?”*

Son: *“If it takes twenty frogs all jumping at the same time to make ONE fly, what happens if ten frogs are all jumping at the same time? Why don’t they puke up like...a half a fly?”*

Dad: *“Because The Great Pond is – well - it’s ‘picky.’ It only creates subatomic particles when it has a very specific amount of energy. Otherwise, it creates nothing. It’s like when you go to the store to buy a piece of candy for a dollar. You need to pay the full dollar to get your candy. If you only give the clerk ninety-nine cents and try to walk out with the candy anyway, he’s gonna’ stop you!”*

Son: *“Oh, that makes sense.”*

Dad: *“There’s a technical term for that. It’s called ‘rest mass energy,’ and it’s kind of like the price of the candy. When you finally save up the dollar, you can buy the candy. Likewise, if The Great Pond reaches Rest Mass Energy, it has enough energy to create a subatomic particle.”*

Son: *“But Dad...”*

Dad: *“Eh! You said that was the last question Son!”*

Son: *“Oh please, just one more Dad!”*

Dad: *“Okay, go ahead, but this is it!”*

Son: *“You said there are different kinds of subatomic particles. Does that mean The Great Pond can create different kinds of flies? Like, different sizes and stuff?”*

Dad: *“Yes. But it takes more energy to create the bigger flies. Kind of like it takes more money to buy bigger pieces of candy. If you want to create something heavy like the Higgs boson, you have to feed the frogs in The Great Pond a whole lot of flies.”*

Son: *“What’s a Higgs boson Daddy?”*

Dad: *“The Higgs boson is the particle that convinced us that The Great Pond actually exists! You see, another name for The Great Pond is ‘The Higgs Field.’ It’s named after a famous scientist named Peter Ware Higgs. He predicted that The Higgs Field existed, even though no one could actually see it!”*

Son: *“But he KNEW it was there because of what he saw happening to subatomic particles! Right Dad?”*

Dad: *“Exactly Son! Remember, we know The Great Pond exists, not because we can see it or touch it, but because we can see and measure what it does! And one thing the Higgs Field does is produce Higgs bosons!”*

Son: *“So, is the Higgs boson like a big giant fly?”*

Dad: *“I don’t know if I like the idea of a world made of giant flies, but it sure makes me hungry! Why don’t we go find some dinner?”*

Son: *“Good, I’m hungry enough to eat the whole world right now!”*

Dad: (Laughs) *“Good one! Sounds like you’ve got the big picture now.”*

The Dad and his Son laughed, picked up their fishing poles, and headed home for the night.



THE END