

Essay assignment

“Make Sandwiches To Explore Physics: a systematic way of encoding physical systems”

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*(1) Describing my current research*

Let's talk about physics. First, make a sandwich. -Wait, why? That's because it is a powerful theoretical tool for investigating the physics of our world.

Ok, then what is it? We choose the proper ingredients according to what aspect of physics we want to know. Bread is a boundary condition, and we use two different types of bread called “symmetry” and “dynamics”. Sandwiching them together gives us the theoretical model of our physical world. All the information of the original system is encoded separately into two parts (“symmetrical” and “dynamic” structure), hosted by each boundary bread. The interplay of these two structures is represented in the bulk ingredient, making the whole story of physics rich and interesting.

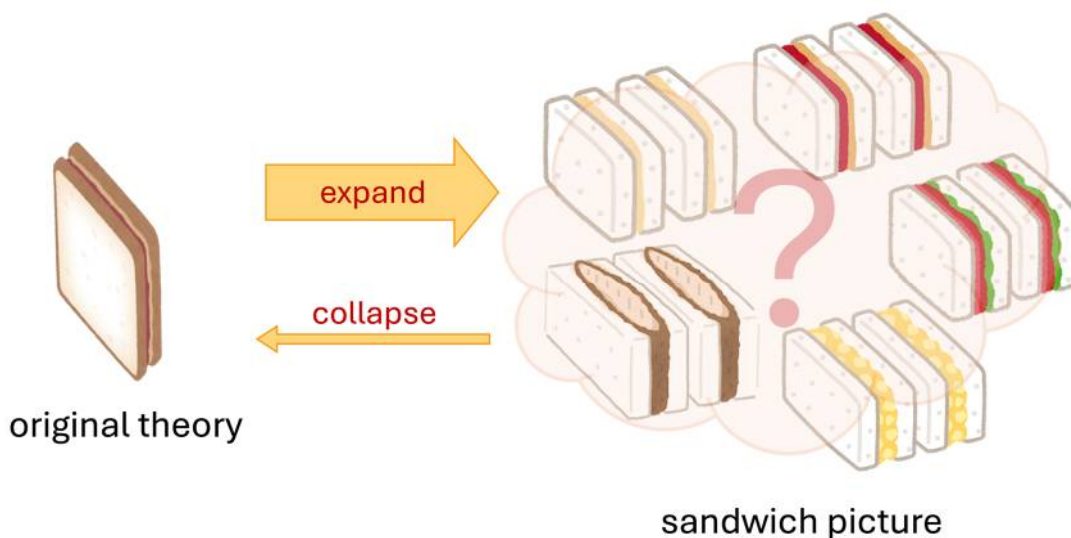
But, why sandwich? The point is that the obtained sandwich model is one-dimensional higher than the original system. It is not a miniature in the true sense: rather, this is the expansion of our world of physics into a one-dimensional higher construction (it might be good to call this “sandwich expansion” instead). The original picture of our physical world can be seen as a projection onto a lower-dimensional slice of bread, or by “collapsing” the sandwich till the point where it looks just like a single slice of bread.

Plus, the sandwich structure itself makes things simpler. As mentioned before, by forming a sandwich, we can separately study different physical structures that originally lived together in the same place. Imagine that, you have finely chopped bacon, lettuce, and tomatoes, all

scattered onto a single slice of bread. It may still look tasty, but not well-arranged. Instead, we may treat these ingredients separately with two slices of bread, forming a nice-looking sandwich. We can tell immediately where the bacon, lettuce, and tomatoes are, when looking at the 3D sandwich construction. This situation is like holography, where the information of a 3D image is projected onto a 2D hologram. We cannot grasp what is on when we only look at the hologram itself, but we can understand the figure once we see the 3D image.

You may think that physicists are just playing with weird pie in the sky (although it is actually sandwich!). However, this sandwich picture is indeed useful in studying the mechanics of the original system, thanks to the profound mathematical structure behind it (note for future you: this is “topological quantum field theory”).

My goal is to give a clear understanding of various physical phenomena appearing under various conditions, by utilizing the delicious theoretical strategy.



## (2) Why I find it interesting

Symmetry has played a very important role throughout the history of physics. When we have information about symmetry, we can extract many things from this. For example, we can

restrict the possible motion of the system by demanding that it respect some symmetry. We can also find conserved quantities by just studying its symmetry. Our world is very complicated, with an inconceivable number of particles interacting with each other. It's literally impossible to keep track of all the motions of all particles. Nevertheless, symmetry provides us with the essential features of the system without looking at all the details.

Though symmetry itself is indeed important, its "breaking" is also very interesting. Some non-trivial properties emerge only after a certain kind of symmetry somehow fails to hold. In fact, if there were no symmetry breaking, there would be completely nothing in our universe. How boring it would be!

Another concept that makes our physical world diverse is boundary. The word boundary means the interface between two different physical systems. Everything in the universe has its boundaries. Boundary constrains and characterizes the dynamics of systems inside. Animals have skin separating them from the outer world. We distinguish the sky from the sea at the horizon, the interface of the two regions.

Sometimes, non-trivial phenomena emerge on the boundary, even though nothing special happens inside. One important example is the so-called "topological insulators", where we can see a non-declining electron current only on the boundary while keeping the inside insulated. The existence of boundary makes our physics much richer.

Let's go back to sandwiches. Sandwich construction is a way to provide a theoretical model for given systems, characterized by symmetry and boundary structure. By making use of this sandwiching, we might be able to systematically answer the question "Under what symmetry, and what boundary condition, what physical phenomena can we see?". We may further exploit this method for engineering the emergent physics on the interfaces of two different systems. Sandwich construction has the potential to give us a clear understanding of the

interplay between symmetry, boundary, and the world of physics.

### *(3) Advice to my 12-year-old self*

Now comes the advice session to you, a 12-year-old myself.

First, do what you really want to do. Don't be too modest and shy. Explain what you are really thinking, without considering too much about the possible bad reactions of others. You, as a 12-year-old boy, are on the one hand kind and harmless to others, but on the other hand, too modest and hesitant. You are likely to be bullied just because you rarely counterattack. You may lose good opportunities just because you underestimate yourself and hesitate to take action. Good learners are always active and passionate. You should be an active learner and take advantage of every opportunity you can have. You can do way more than you think. Be ambitious.

Second, read more books. Expose yourself more to letters and sentences. You are not good at just sitting still and focusing on reading. Unfortunately, such a tendency does not vanish spontaneously. Future you still struggles to read long textbooks without losing attention. Since all scientific progress is based on the previous work in history, scientists must learn from the past and understand previous results well to do something new. Thus, I really recommend that you develop a reading habit when you are young. If you get used to reading for a long time, it will loosen your psychological hurdle towards long textbooks. What is more, if you have more experience with books, it will mean that you have more literacy of your world and society, which will be beneficial in various situations.

I believe, following the advice will definitely make your academic life easier and better if you are going to go the scientific road. However, your future is not determined, and you can aspire to anything at your age. No matter what future you will choose, I strongly hope the

advice will be beneficial for future you.