MARKUS KLUTE: Welcome back to 8.701. In the previous lecture, we have seen how the gauge bosons, the W, and the Z boson acquire mass, while the photon remains massless, through the Higgs mechanism. We introduced a new field, a new complex doublet field, the Higgs field, which then broke, through its vacuum expectation value, the symmetry. And then through the coupling to the gauge bosons, they acquired mass. Right.

But we also have to find a solution for the fermions. You cannot simply add a fermion mass onto the Lagrangian. That would change, or that could violate, break, the gauge invariant.

So how do we do this? We do this in a very similar way-- even easier. But before we look into how this is done, let's have a look at the masses itself. It's spectacular. The top quark is our heaviest known fermion. It has a mass of about 172 GeV. The tau has a mass of 1.7 GeV. The muon is an order of magnitude lighter, with 0.1 GeV. And for the electron, we have to go to 0.51 MeV. OK?

And we haven't even tried to understand, or we were not able to measure, actually, the masses of neutrinos. We will talk about neutrinos in one of the following lectures.

So here you have six orders of magnitude. And you have to go further down here in order to find the neutrinos on this mass scale. So we have to have a mass-giving mechanism which allows this broad spectrum of masses to occur.

And the very simple ad hoc mechanism which was introduced to the standard model is one where the particle simply interacts with the Higgs field. So we have our Higgs field here. Let's say we have a left-handed particle coming in. And the interaction with the Higgs field turns it into a right-handed particle.

This is a little bit simplified, but what we do there here is simply introducing terms into the Lagrangian which do nothing else. We turn our left-handed particles, via the interaction with the Higgs field, into right-handed, and the other way around. And we have to do this for up-type particles and for down-type particles.

So here is another view of this. The strength here is the mass of the particle over the vacuum expectation value. This number here, this number, this lambda d, it's the so-called Yukawa coupling. And those Yukawa couplings now change from fermion to fermion. Each fermion comes with their own Yukawa coupling. It's basically a free parameter in our theory in the standard model. So instead of talking about the masses being free parameters, we talk about the coupling to the Higgs field as free parameter. But they are one and the same.

All right. So this was rather straightforward. It's a simple coupling; you introduce this term ad hoc, and then hope for the best that it's actually realized in nature. And you'll see that this is indeed the case for some of the fermions later.