Now let's move to the bicycle pump, which is 11.4.1, I believe-- there we go, 11.4.1.

We have a bicycle pump, and I push down on the bicycle pump. Here is the piston, and there must be a valve in here, so that air can be let in. Here at the bottom there must also be a valve so that air can flow into the tire when I push down. It's clear they have to do positive work, the pressure increases, and when the pressure here is higher than there, the air will flow out.

It should be immediately obvious that I do positive work: it's clear that I have to overcome the pressure of gas. I'm suppressing it, so my force of Walter Lewin is all the way down, and I move down, so there' no arguing that I do positive work. It means that the gas does negative work-- I think there's no arguing with that, either. Let us now assume-- I make that assumption-- that there is no heat loss while I'm pumping, and that there is no heat added, just as a start.

That means Q equals 0, and we have a name for that-- that is what we call an adiabatic process. There is no heat added, and no heat is lost. Let's look now at the equation Q equals delta u plus W-- keep in mind that this is the work done by the gas. We agree that in this situation where I do the work, that this work done by the gas is less than 0-- it's negative. We also agree that this is 0 per definition because it's an adiabatic process, and so the conclusion is immediately that delta u will have to be positive.

If delta u is positive, it means that the final temperature is larger than the initial temperature, and so the gas will heat up. A few of you will say, oh, that's great, so you've made your point-- it will heat up. I don't think it's complete yet, because now what happens when the thing is down, air is flowing out, and the pressure that originally was high will be released to some degree. Now I want to move the piston back to its original position, and when I bring the piston back to its original position, do I again have to do positive work?

If the answer is yes, then it is clear if the process remains adiabatic, that again the temperature will increase. Not only will the temperature increase when I move it down, but if I have to do positive work to bring it back up to the original position, I again have to do positive work, and again, the temperature will increase.

It's not so obvious that I will have to do positive work if I move it up. Suppose the amount of work that I had to do was the same as I had to do before, except that it's negative now-- then there may not be any temperature increase in the gas, but that's not the case. I have the piston lay down, the pressure has moved out, and so the pressure has already been released. Of course, this pressure here is still higher than the pressure there, and when I let it simply go, the piston will go up all by itself. That means the gas now does positive work, and that means Walter Lewin will do negative work.

But where will the piston stop? Will the piston be pushed out as if this were a spring all the way to the original position, and the answer is no. Why is that no? One reason is obvious: at the very bottom, I let pressure out.

When this pressure, which is under the piston higher than the pressure outside, it wants to push the piston back. I will never make it to very top where I started, because I have released pressure at the bottom: that is at least one very good reason. How now can I bring this piston back all the way to the top? I will have to force it to the top-- I'll have to do work again in order to let the air from the outside suck back in again. Thus, Walter Lewin will have to do positive work again during that phase of the expansion, and that means the temperature will become even higher.

So you see, I do positive work, both in the cycle when I push down, and in the cycle when I push up. If I do this very, very fast, it's clear that I do a lot of work, and so that the temperature will go higher that if I were to do the whole process very slowly. You have to realize, however, if the temperature goes up, that the process will not remain adiabatic, because you are going to get a heat loss, for sure. You're going to get a heat exchange with the outside air, and there may come a time that there's sort of a heat situation in equilibrium and the exchange is such that the temperature of the gas column remains approximately constant.

When then that's the case-- if you now look at Q equals delta u plus W, and if the temperature on average when I pump up and down remains constant, then delta u will be 0. The gas is doing negative work: we agreed to that, because Walter Lewin is doing positive work through a whole cycle. Clearly, Q now also going to be negative, and what does that mean when Q is going to be negative? That there is a heat loss-- that is exactly heat leak.

The thing gets hot, I keep pumping, the temperature goes up, more and more heat will leak out of the system, I get an equilibrium temperature, it's no longer adiabatic, and as I keep pumping, there comes a moment where I reach sort of equilibrium, and where the leak of heat-- Q is negative-- the heat loss is such that I reach this equilibrium position. The whole system is quite clear that, on the whole, I do positive work, the temperature goes up, and pump gets hot.