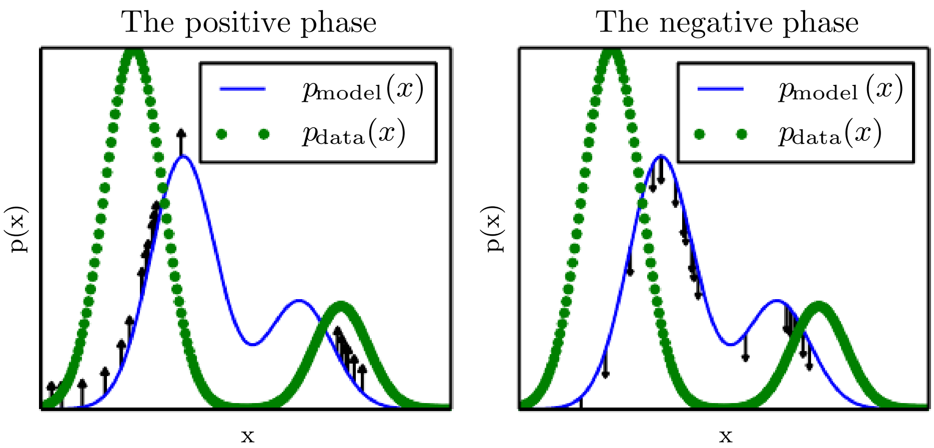

Figure 18.1: The view of algorithm 18.1 as having a "positive phase" and "negative phase." *(Left)*In the positive phase, we sample points from the data distribution, and push up on their unnormalized probability. This means points that are likely in the data get pushed up on more. *(Right)*In the negative phase, we sample points from the model distribution, and push down on their unnormalized probability. This counteracts the positive phase's tendency to just add a large constant to the unnormalized probability everywhere. When the data distribution and the model distribution are equal, the positive phase has the same chance to push up at a point as the negative phase has to push down. When this occurs, there is no longer any gradient (in expectation) and training must terminate.

for dreaming in humans and other animals (Crick and Mitchison, 1983), the idea being that the brain maintains a probabilistic model of the world and follows the gradient of $\log \tilde{p}$ while experiencing real events while awake and follows the negative gradient of $\log \tilde{p}$ to minimize $\log Z$ while sleeping and experiencing events sampled from the current model. This view explains much of the language used to describe algorithms with a positive and negative phase, but it has not been proven to be correct with neuroscientific experiments. In machine learning models, it is usually necessary to use the positive and negative phase simultaneously, rather than in separate time periods of wakefulness and REM sleep. As we will see in section 19.5, other machine learning algorithms draw samples from the model distribution for other purposes and such algorithms could also provide an account for the function of dream sleep.

Given this understanding of the role of the positive and negative phase of learning, we can attempt to design a less expensive alternative to algorithm 18.1. The main cost of the naive MCMC algorithm is the cost of burning in the Markov chains from a random initialization at each step. A natural solution is to initialize the Markov chains from a distribution that is very close to the model distribution,