not yet know how this is possible. Many factors could explain improved human performance—for example, the brain may use very large ensembles of classifiers or Bayesian inference techniques. One popular hypothesis is that the brain is able to leverage unsupervised or semi-supervised learning. There are many ways to leverage unlabeled data. In this chapter, we focus on the hypothesis that the unlabeled data can be used to learn a good representation.

15.1 Greedy Layer-Wise Unsupervised Pretraining

Unsupervised learning played a key historical role in the revival of deep neural networks, enabling researchers for the first time to train a deep supervised network without requiring architectural specializations like convolution or recurrence. We call this procedure **unsupervised pretraining**, or more precisely, **greedy layer-wise unsupervised pretraining**. This procedure is a canonical example of how a representation learned for one task (unsupervised learning, trying to capture the shape of the input distribution) can sometimes be useful for another task (supervised learning with the same input domain).

Greedy layer-wise unsupervised pretraining relies on a single-layer representation learning algorithm such as an RBM, a single-layer autoencoder, a sparse coding model, or another model that learns latent representations. Each layer is pretrained using unsupervised learning, taking the output of the previous layer and producing as output a new representation of the data, whose distribution (or its relation to other variables such as categories to predict) is hopefully simpler. See algorithm 15.1 for a formal description.

Greedy layer-wise training procedures based on unsupervised criteria have long been used to sidestep the difficulty of jointly training the layers of a deep neural net for a supervised task. This approach dates back at least as far as the Neocognitron (Fukushima, 1975). The deep learning renaissance of 2006 began with the discovery that this greedy learning procedure could be used to find a good initialization for a joint learning procedure over all the layers, and that this approach could be used to successfully train even fully connected architectures (Hinton *et al.*, 2006; Hinton and Salakhutdinov, 2006; Hinton, 2006; Bengio *et al.*, 2007; Ranzato *et al.*, 2007a). Prior to this discovery, only convolutional deep networks or networks whose depth resulted from recurrence were regarded as feasible to train. Today, we now know that greedy layer-wise pretraining is not required to train fully connected deep architectures, but the unsupervised pretraining approach was the first method to succeed.

Greedy layer-wise pretraining is called **greedy** because it is a **greedy algo-**