The main property of an ANN is its capability to learn. Learning or training is a process by means of which a neural network adapts itself to a stimulus by making proper parameter adjustments, resulting in the production of desired response. Broadly, there are two kinds of learning in ANNs:

1. *Parameter learning:* It updates the connecting weights in a neural net.
2. *Structure learning:* It focuses on the change in network structure (which includes the number of processing elements as well as their connection types).

The above two types of learning can be performed simultaneously or separately. Apart from these two categories of learning, the learning in an ANN can be generally classified into three categories as: supervised learning; unsupervised learning; reinforcement learning. Let us discuss these learning types in detail.

2.3.2.1 Supervised Learning

The learning here is performed with the help of a teacher. Let us take the example of the learning process of a small child. The child doesn't know how to read/write. He/she is being taught by the parents at home and by the teacher in school. The children are trained and molded to recognize the alphabets, numerals, etc. Their each and every action is supervised by a teacher. Actually, a child works on the basis of the output that he/she has to produce. All these real-time events involve supervised learning methodology. Similarly, in ANNs following the supervised learning, each input vector requires a corresponding target vector, which represents the desired output. The input vector along with the target vector is called *training pair*. The network here is informed precisely about what should be emitted as output. The block diagram of Figure 2.12 depicts the working of a supervised learning network.

During training, the input vector is presented to the network, which results in an output vector. This output vector is the actual output vector. Then the actual output vector is compared with the desired (target) output vector. If there exists a difference between the two output vectors then an error signal is generated by

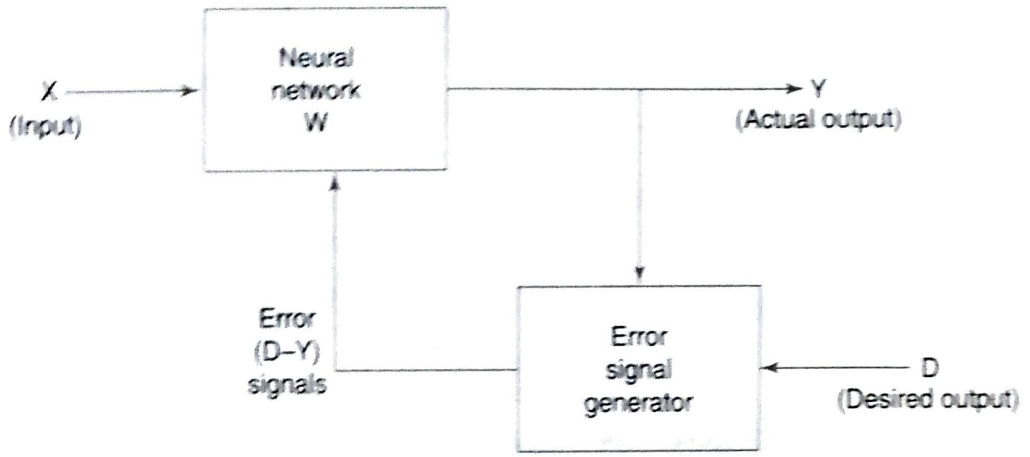

Figure 2-12 Supervised learning.

the network. This error signal is used for adjustment of weights until the actual output matches the desired (target) output. In this type of training, a supervisor or teacher is required for error minimization. Hence, the network trained by this method is said to be using supervised training methodology. In supervised learning, it is assumed that the correct "target" output values are known for each input pattern.

2.3.2.2 *Unsupervised Learning*

The learning here is performed without the help of a teacher. Consider the learning process of a tadpole, it learns by itself, that is, a child fish learns to swim by itself, it is not taught by its mother. Thus, its learning process is independent and is not supervised by a teacher. In ANNs following unsupervised learning, the input vectors of similar type are grouped without the use of training data to specify how a member of each group looks or to which group a number belongs. In the training process, the network receives the input patterns and organizes these patterns to form clusters. When a new input pattern is applied, the neural network gives an output response indicating the class to which the input pattern belongs. If for an input, a pattern class cannot be found then a new class is generated. The block diagram of unsupervised learning is shown in Figure 2-13.

From Figure 2-13 it is clear that there is no feedback from the environment to inform what the outputs should be or whether the outputs are correct. In this case, the network must itself discover patterns, regularities, features or categories from the input data and relations for the input data over the output. While discovering all these features, the network undergoes change in its parameters. This process is called *self-organizing* in which exact clusters will be formed by discovering similarities and dissimilarities among the objects.

2.3.2.3 *Reinforcement Learning*

This learning process is similar to supervised learning. In the case of supervised learning, the correct target output values are known for each input pattern. But, in some cases, less information might be available.

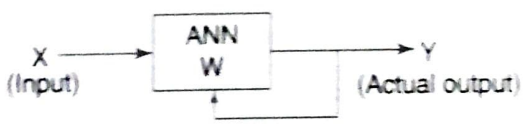

Figure 2-13 Unsupervised learning.

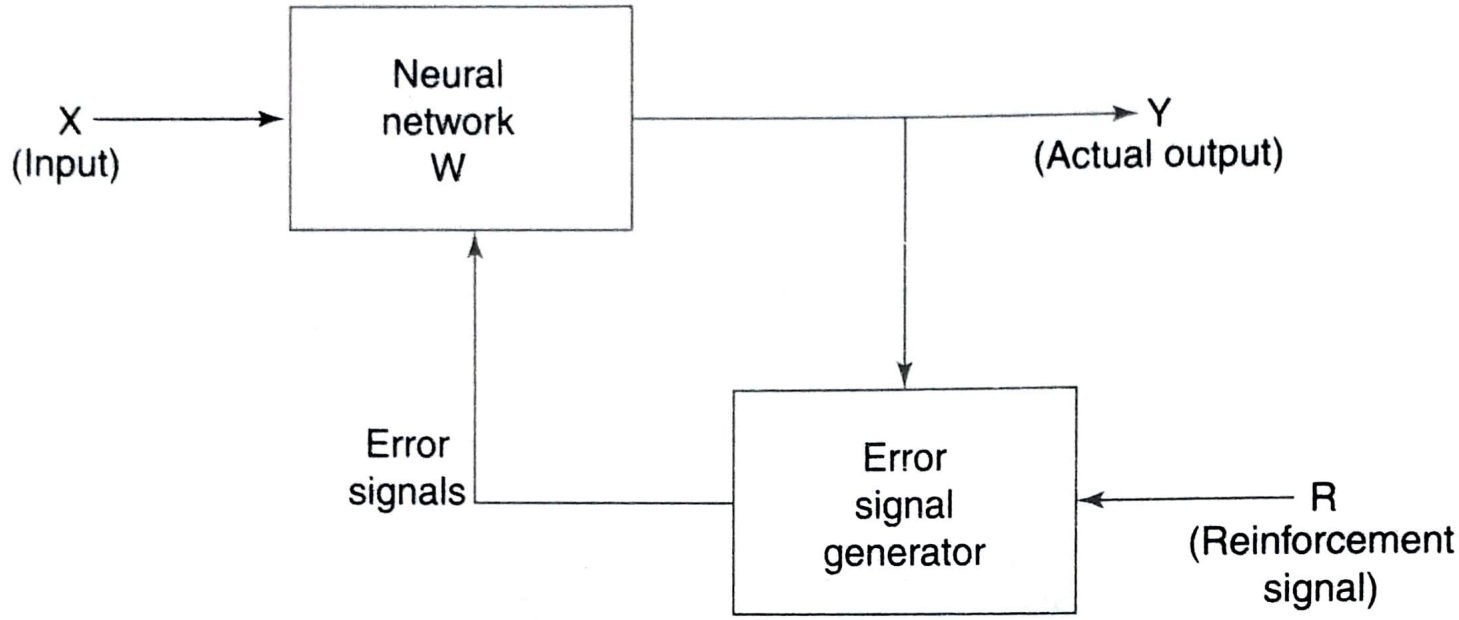

Figure 2-14 Reinforcement learning.

For example, the network might be told that its actual output is only "50% correct" or so. Thus, here only critic information is available, not the exact information. The learning based on this critic information is called *reinforcement learning* and the feedback sent is called *reinforcement signal.*

The block diagram of reinforcement learning is shown in Figure 2-14. The reinforcement learning is a form of supervised learning because the network receives some feedback from its environment. However, the feedback obtained here is only evaluative and not instructive. The external reinforcement signals are processed in the critic signal generator, and the obtained critic signals are sent to the ANN for adjustment of weights properly so as to get better critic feedback in future. The reinforcement learning is also called learning with a critic as opposed to learning with a teacher, which indicates supervised learning.

So, now you've a fair understanding of the three generalized learning rules used in the training process of ANNs.