

## Chapter 18

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# The neural hierarchy

The idea of means and ends, of instrumentality, is an old idea. But how can it work? If we want to build a model that will exhibit the phenomenon of means and ends in the behavior of a living creature, how can we go about it? How can I control, all at the same time, a visualization of arriving at the library, a recognition of the statue of Beethoven that I pass on my way to the library, the proper amounts of movements of the muscles of the neck as I move my visual focus from Beethoven to the library building, the movements of foot, leg, and spine, and so on? How can I alter my internal standards for the walking movements, for example, as I turn at corners, go up steps, and slow to let someone walk in front of me, all the while maintaining a perception of progress toward the library? And how can I do all that while thinking of Claire's dear smile that I will see when I get home and put in her hands the book she asked me to get for her?

You might say, well, let's not get too ambitious. Let's just see if we can build a model that will mimic the lifting of a foot. Gradually, you might say, small bit by small bit, psychologists and others can assemble a model of the whole creature and its trip to the library and to Claire. That strategy, however, if it is strictly limited to a foot and a lifting motion, is doomed to failure. We already know that a foot does not, in normal life, lift without purpose. The purpose, in turn, is carried out by lifts of the foot that must vary in amount, direction, speed, and timing with other movements. The variations that occur do not occur randomly. A particular variation of foot lifting occurs that will serve the purpose in a particular situation and serve it while acting against some particular disturbances to the controls for amount, direction, and speed. In other words, a model of one small

motion of the human body cannot be correctly built without having a fair notion of the ways *many motions can be coordinated* in serving a purpose—not the ways they can be coordinated by an experimenter in an unchanging laboratory environment, but by the real, walking person in a normal, changeable environment.

It is true, nevertheless, that we can start small. There is a limit to how small a part we can model without losing the character of control, but we can build models that consist of only a few feedback loops while nevertheless mimicking some simple behavior. I described one such simple model in Chapter 8 under the heading "Hierarchy." (What do I mean by "simple" behavior? Well, I guess I mean behavior that can be mimicked by a simple model.) The point is that even such a simple model as that one in Chapter 8 cannot be made without a design for the way those feedback loops might be connected to larger networks in the whole animal. For example, the reference vectors labeled R(2,1) and R(2,2) in Figure 8–6 of Chapter 8 can appear in that model only because PCT postulates a hierarchy of levels of control. It is true that we do not at present know how to build models of most of the more complex kinds of behavior exhibited by humans. (For an example of a model of one kind of complex behavior, see Powers 1994.) But we must theorize about a larger structure than we are able at present to model, because the larger theorizing will propose connected hypotheses through which we hope eventually to achieve a more comprehensive perception of human functioning. The neural hierarchy that is part of PCT proposes ways for multiple feedback loops to be connected so that complex perceptions can be controlled despite the disturbances all of us continuously encounter.

### THE LEVELS

Figure 18–1 shows the neural unit—the basic feedback loop. It is a simplification of Figure 4–1 (which was already a simplification). Its placement on the paper is changed, too; compared to the figure in Chapter 4, the figure here is rotated and then turned with a pancake turner so as to be seen as in a mirror. But just follow the arrows, and you won't get lost. In Figure 18–1, I stands for Input, p for perceptual signal, r for reference signal or internal standard, C for Comparator, e for error signal, and O for Output.

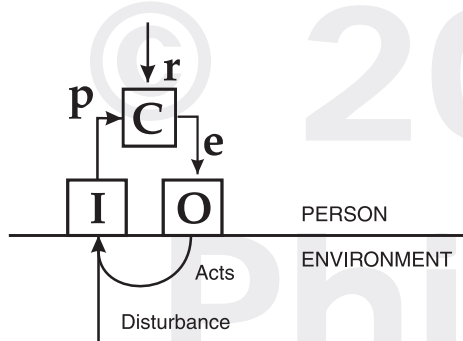


Figure 18–1. *The loop*

The neural hierarchy is built by connecting many unit loops in a particular way. In the hierarchy, only the “lowest” loops send outputs into the environment. The “higher” loops send their outputs to the comparators of loops at the lower level. Figure 18–2 is an illustration containing only five loops in two levels. Figure 18–2 is a simplification of Figure 8–6; it omits some detail that was necessary to the discussion in Chapter 8. In one way, however, it is more complete than the figure in Chapter 8. There, the loop at the lower right corner of the diagram was incomplete; only the input was shown. Here, that loop is drawn complete. With that exception, all the connections (p, r, and e) among functions (I, C, O, and acts) are the same here as they were in Chapter 8.

The connections among functions are no more haphazard among loops than they are within loops. That is, many connections that are conceivable do not occur. The input from the environment “upward” into the lowest-level loop (through the input function “I”) always goes both to the comparator of the loop and to the input functions of some higher-level loops. But that signal going upward out of “I” does *not* go to the input functions of other loops at its own level, it does not skip over the higher-level input function to

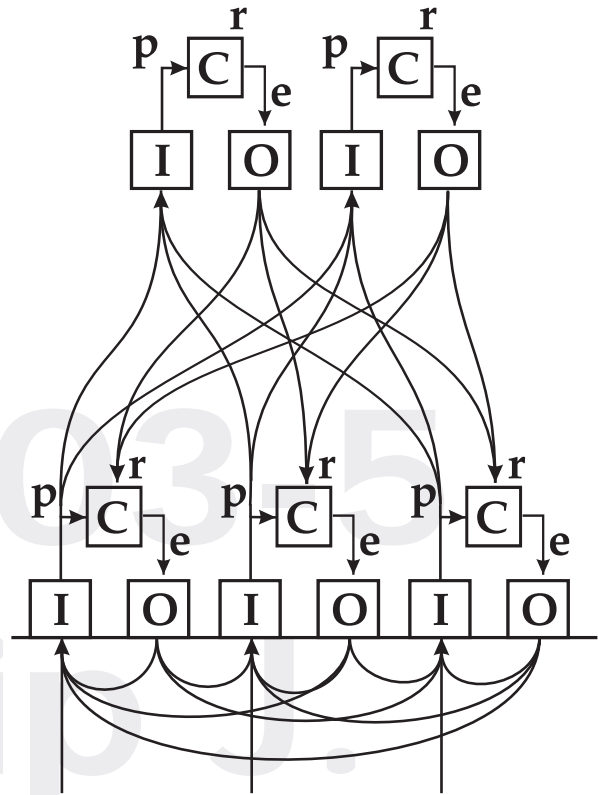


Figure 18–2. *Two levels of control*

get to the comparator there, nor does it go directly to outputs anyplace. The outputs from the upper levels (going downward from “O”) go to comparators at the next lower level; they do *not* skip levels and do not go directly to muscle fibers or glands for action in the environment.

An input signal into a lower-level loop also reaches upward to the input functions of several loops at the higher level. (In the animal body, “several” can be thousands.) Each comparator at the upper level will then emit an error signal which is the difference between that incoming signal and the reference signal the comparator is getting from a still higher loop. Those error signals combine with others by means of weightings such as those shown in Figure 8–6 by the values at  $M(i, j, k)$ , and each result of a weighted combination becomes the reference signal for a comparator at the lower level. By this pattern of connection, reference signals at a lower level can be altered by outputs from a higher level. The loop through the upper-level control systems is completed when the outputs from lower-level control systems affect actions in the environment, which in turn