CHAPTER 1

CHEMICAL MACHINES AND ACTION SYSTEMS

1. Introduction. Living organisms and machines

Jacques Loeb's investigations into the behavior of numerous lower organisms are justly famous. In particular, he carefully documented the way in which the orientation of bilaterally symmetrical lower animals depended on light, i.e. phototropism, a phenomenon that the botanist Julius Sachs had studied in plants. And Loeb's systematic monograph, *Comparative Physiology of the Brain and Comparative Psychology* published at the dawn of the twentieth century (Loeb, 1900), made his work popular with researchers in various fields.

The moth that infallibly flies towards a light source always brings to mind the explanation offered by Loeb: the muscles on the side of the animal struck by the light become more active than those on the opposite side. Hence the moth tends to orient its plane of symmetry in the direction of the light source and move towards it (a case of "positive heliotropism," see Figure 1.1). Thus the fact that the moth flies into the flame "turns out to be the same mechanical process as that by which the axis of the stem of a plant puts itself in the direction of the rays of light" (Loeb, 1905: 3). So Loeb concluded that organisms like this are nothing other than "chemical machines," and specifically "heliotropic natural machines."

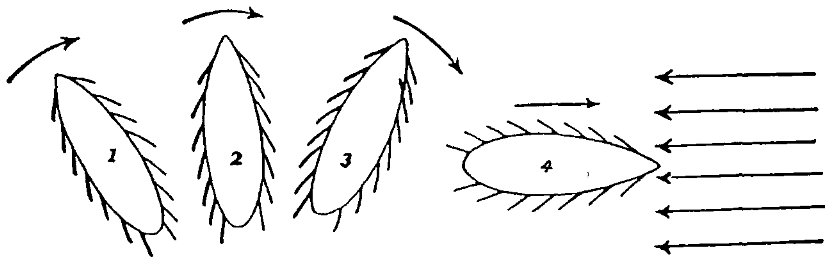


Fig. 1.1. Positive heliotropism (from Jennings, 1906).

Loeb soon generalized the results of his experimental studies in an attempt to establish a "mechanistic conception of life" that left no room for any explanation of the action of organisms, from the simplest all the way up to man, that was not expressed in "mechanical process" terms. This explanation could be as complicated as you wished, but would be qualitatively indistinguishable from explanation in physics and chemistry. Not only most animal instincts but also the "voluntary" actions of humans ought to be reducible to tropisms, and these in turn ought to be reducible to the physical and chemical properties of living protoplasm. Loeb realized that this was a long way to achieve a "complete" mechanistic view of life, i.e. one that could explain consciousness and free will in terms of physics and chemistry. Nonetheless, he reaffirmed his conviction that the study of simple organisms as heliotropic machines could lay the groundwork for understanding complex organisms (Loeb, 1912: 35).

In those same years the difficulties implicit in such a radical claim lent plausibility to very different approaches to the same problems. These approaches were developed not only by vitalist biologists such as Hans Driesch but also by who, without adopting extreme forms of reductionism, did not give up trying to find a mechanical explanation of the behavior of living organisms. Herbert Jennings was one of these. His ideas too gained popularity through a book, published a few years after Loeb's, *The Behavior of the Lower Organisms*, in which Jennings summed up his earlier investigations (Jennings, 1906). The simple organisms studied by Jennings, such as the *Paramecium* and the *Stentor*, are no less familiar to biologists and psychologists than Loeb's moth. But in Jenning's view, they display substantially different behavior.

It was Jennings who later radicalized the contrast with Loeb. Instead of the "synthetic" method inspired by radical reductionism that he ascribed to Loeb, Jennings proposed his "analytical" method, based on the study of the ways in which organism and environment, considered as a single system, interact. For Jennings this meant that the behavior of organisms cannot be reduced to tropisms or chains or hierarchies of tropisms. Even lower organisms could not always be studied directly as chemical machines reacting passively to the external environment. Instead, there were general laws regulating the behavior of organisms that could be discovered by observing how organisms are influenced by the environment and how they in turn influence the environment by following different adaptive strategies, depending on the complexity of the action system at their disposal.

The rift between Loeb and Jennings arose in the area of the study of lower organisms. Although interest in this kind of study soon flagged, the issues faced were among those that marked the evolution of influential trends in the sciences of the mind and behavior in the twentieth century, especially with the emergence and then the dissolution of behaviorist psychology.

A goodly number of these issues stand out among those we will be considering in the following chapters. These issues will come up from a less familiar angle in the present chapter, where they will be considered in relation to the different machine models that Loeb and Jennings proposed in their investigations of lower animals. Alongside the reductionist stance in the study of organism behavior, there is another stance, for which the behavior of "inorganic" machines and that of living organisms as well can be studied by referring to their functional organization.

Consistent with this stance is the thesis that in the control and prediction of the behavior of living organisms, starting with the lower animals, it is impossible to do without a teleological and mentalistic vocabulary, one that uses the terms 'meaning,' 'purpose,' 'choice,' 'intelligence,' and so on. The question arises whether this language can legitimately be used outside the world of living organisms, namely, in the world of inorganic nature and machines, a question which will arise again and again in the following chapters and which has been a much-debated issue among philosophers of mind. Actually, the possibility that the same regulatory principles that find their most complex realization in the behavior of living organisms are also at work in the world of the inorganic lays the groundwork for a reconciliation of the teleological and the causal explanation.

2. Loeb and the orientation mechanisms of Hammond: "natural" and "artificial" machines

In the years round 1915 it was not unusual to read in American newspapers and popular science magazines alike the description of a machine that looked like little more than a toy but attracted much attention for its unprecedented features as an "orientation mechanism." It was designed in 1912 by John Hammond Jr. and Benjamin Miessner and constructed by the latter, who introduced it two years later in the *Purdue Engineering Review* under the name by which it became popularly known, the "electric dog." It is worth looking at how Miessner described the behavior of such a machine in his book *Radiodynamics: The Wireless Control of Torpedoes and Other Mechanisms.*

> This orientation mechanism in its present form consists of a rectangular box about three feet long, one and a half feet wide, and one foot high. This box contains all the instruments and mechanism, and is mounted on three wheels, two of which are geared to a driving motor, and the third, on the rear end, is so mounted that its bearings can be turned by electromagnets in a horizontal plane. Two five-inch condensing lenses on the forward end appear very much like large eyes. If a portable electric light be turned on in front of the machine it will immediately begin to move toward the light, and, moreover, will follow that light all around the room in many complex manoeuvers at a speed of about three feet per second. The smallest circle in which it will turn is of about ten feet diameter; this is due to the limiting motion of the steering wheel, moving so long as the light reaches the condensing lenses in sufficient intensity. Upon shading or switching off the light the dog can be stopped immediately, but it will resume its course behind the moving light so long as the light reaches the condensing lenses in sufficient intensity (Miessner, 1916: 194-196).

Figure 1.2 shows what this phototropic robot looked like, and Plate 1.1 describes the way the orientation mechanism worked. The explanation of its working, Miessner stressed, was "very similar to that given by Jacques Loeb, the biologist, of reasons re-

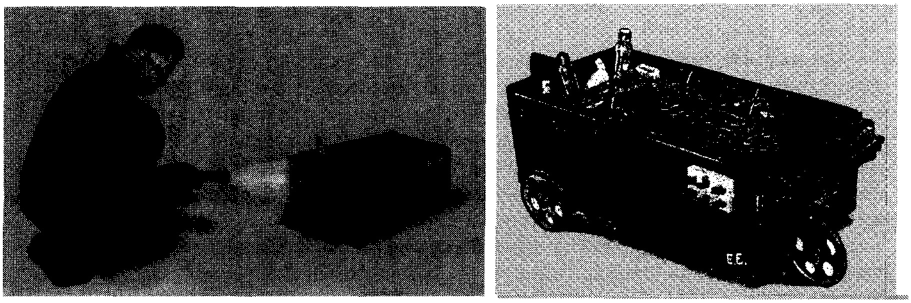
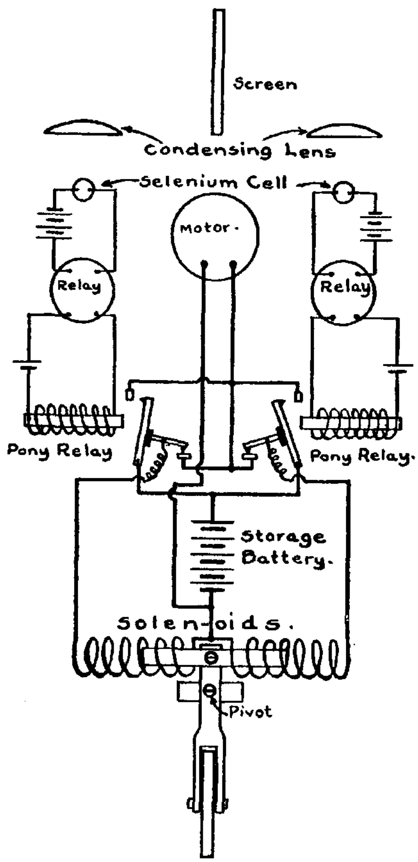


Fig. 1.2. Hammond and Miessner's phototropic robot. Left, the robot follows a flashlight beam; right, the inside of the robot (from Miessner, 1916; also published in *Electrical Experimenter*, 1915).

Plate 1.1



The orientation mechanism of Hammond's "electric dog" possesses two selenium cells, which, when influenced by light, effect the control of two sensitive relays. These relays in turn control two electromagnetic switches which effect the following operations: when one cell or both are illuminated, the current is switched onto the driving motor; when one cell alone is illuminated, an electromagnet is energized and effects the turning of the rear steering wheel. In this case, the resultant turning of the machine will be such as to bring the shaded cell into the light. As soon and as long as both cells are equally illuminated in sufficient intensity, the machine moves in a straight line towards the light source. By throwing a switch, which reverses the driving motor's connections, the machine can be made to back away from the light. When the intensity of the illumination is so decreased by the increasing distance from the light source that the resistances of the cells approach their dark resistance, the sensitive relays break their respective circuits, and the machine stops. (From Miessner, 1916) sponsible for the flight of moths into a flame." In particular the lenses corresponded to "the two sensitive organs of the moth" (p. 196). Miessner explained the main reason for interest in this automatic device: Hammond's dirigible torpedo "is fitted with apparatus similar to that of the electric dog, so that if the enemy turns their search light on it, it will immediately be guided toward that enemy automatically" (p. 198).

This use as war material should not come as a surprise. At the time Europe was engulfed in the war that would come to be known as the First World War. Hammond and Miessner pioneered the study of radio-controlled mechanisms and then target-seeking automatic systems. Several of their patents made a fortune during both world wars. At the time Hammond was already famous for the dirigible torpedo described by Miessner, which, in effect, was a remote control radio-directed boat. The *Electrical Experimenter* gave an enthusiastic description of the device in 1915 and pointed out its possible military uses as an "intelligent" weapon (it seems to have "almost superhuman intelligence"), finding it one of the more "hair-raising inventions" so far employed "in the present titanic struggle for the supremacy of Europe."[1]

Efforts had already been made to construct wireless controlled systems, partly for military use. Miessner himself had reconstructed and reported that story for *Scientific American*, and the latest advances in technology seemed about to make their construction a reality (Miessner, 1912). Since 1910 Hammond had been running a research laboratory in Gloucester, Massachusetts, where, attracting increasing attention from the military, he was perfecting his radio-controlled torpedoes. Miessner was one of his main collaborators in the years 1911 and 1912 and wrote a long description of these devices for *Radiodynamics*, in which he also referred to earlier work, in particular the so-called "teleautomata" or "self-acting automata" built in New York between 1892 and 1897 by Nikola Tesla, another pioneer of radio-controlled systems.

But the collaborative efforts of Hammond and Miessner were short-lived. Miessner was convinced that his work in Gloucester had not received the recognition it deserved, and the two men quarrelled over the priority of various patents and inventions. Miessner gave his version of this story in a book published decades later, *On the Early History of Radio Guidance* (Miessner, 1964).[2] He said that "Hammond tried desperately to stop its [*Radiodynamics*] publication, by intimidating the publisher and myself, and by appealing to the War Department on grounds of security" (p. 42). One of the bones of contention was priority in the invention of the electric dog. Miessner claimed that his contribution was decisive for the actual design and construction and mentioned some of his earlier insights as well as a sketch Hammond drew in 1912 (Figure 1.3). Miessner also remarked that "Hammond had been much taken with the writings of Jacques Loeb" (p. 36).

Miessner considered the automatic orientation mechanism he designed for the elec-

[1] The magazine reported the interest of both American and Japanese governments in acquiring the patent (*Electrical Experimenter*, September 1915: 211). The June 1915 issue of the magazine described the public exhibition of "Seleno," as the electric dog was called (p. 43).

[2] Miessner died in 1967 at the age of eighty-six and outlived Hammond (1888-1965). He was an electrical engineer, and as an inventor no less eclectic than Hammond (although their lives were quite different). At the time Miessner published his 1964 book, radio-controlled systems were no longer his main field of interest, and he was mainly concerned with building electronic musical instruments.

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