CHAPTER 6

Parameters

6/1. So far, we have discussed the changes shown by the variables of an absolute system, and have ignored the fact that all its changes occur on a background, or on a foundation, of constancies. Thus, a particular simple pendulum provides two variables which are known (S. 2/15) to be such that, if we are given a particular state of the system, we can predict correctly its ensuing behaviour; what has not been stated explicitly is that this is true only if the length of the string remains constant. The background, and these constancies, must now be considered.

Every absolute system is formed by selecting some variables out of the totality of possible variables. 'Forming a system' means dividing all possible variables into two classes: those within the system and those without. These two types of variable are in no way different in their intrinsic physical nature, but they stand in very different relations to the system.

6/2. Given a system, a variable not included in it will be described as a **parameter.** The word *variable* will, from now on, be reserved for one within the system.

In general, given a system, the parameters will differ in their closeness of relation to it. Some will have a direct relation to it: their change of value would affect the system to a major degree; such is the parameter 'length of pendulum' in its relation to the two-variable system of the previous section. Some are less closely related to it, their changes producing only a slight effect on it; such is the parameter 'viscosity of the air' in relation to the same system. And finally, for completeness, may be mentioned the infinite number of parameters that are without detectable effect on the system; such are the brightness of the light shining on the pendulum, the events in an adjacent room, and the events in the distant nebulae. Those without detectable effect may be ignored ; but the relationship of an effective parameter to a system must be clearly understood.

Given a system, the effective parameters are usually innumerable, so that a list is bounded only by the imagination of the writer. Thus, parameters whose change might affect the behaviour of the same system of two variables are :

(1) the length of the pendulum (hitherto assumed constant),
(2) the lateral velocity of the air (hitherto assumed to be constant at zero),
(3) the viscosity of the surrounding medium (hitherto assumed constant),
(4) the position (co-ordinates) of the point of support,
(5) the force of gravity,
(6) the magnetic field in which it swings,
(7) the elastic constant of the string of the pendulum,
(8) its electrostatic charge, and the charges on bodies nearby ;

but the list has no end.

Parameter and field

6/3. The effect on an absolute system of a change of parameter-value will now be shown. Table 6/3/1 shows the results of four

Length (cm.)	Line	Variable	Time 0	0·05	0·10	0·15	0·20	0·25	0·30
40	1	x	0	7	14	20	25	28	29
		y	147	142	129	108	80	48	12
	2	x	14	20	25	28	29	29	27
		y	129	108	80	48	12	− 24	− 58
60	3	x	0	7	14	21	26	31	34
		y	147	144	135	121	101	78	51
	4	x	21	26	31	34	36	36	35
		y	121	101	78	51	23	− 6	− 36

TABLE 6/3/1.

primary operations applied to the two-variable system mentioned above. x is the angular deviation from the vertical, in degrees; y is the angular velocity, in degrees per second; the time is in seconds.

The first two Lines show that the lines of behaviour following the state $x = 14$, $y = 129$ are equal, so the system, as far as it has been tested, is absolute. The line of behaviour is shown solid in Figure 6/3/1. In these swings the length of the pendulum was 40 cm. This parameter was then changed to 60 cm. and two further lines of behaviour were observed. On these two, the lines of behaviour following the state $x = 21$, $y = 121$ are equal, so the system is again absolute. The line of behaviour is shown dotted in the same figure. But the change of parameter-value has caused the line of behaviour from $x = 0$, $y = 147$ to change.

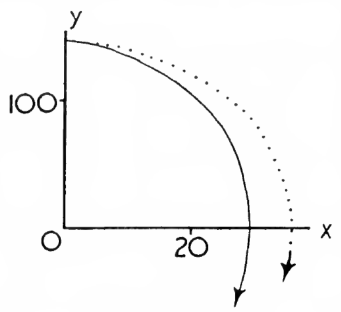

FIGURE 6/3/1.

The relationship which the parameter bears to the two variables is therefore as follows:

(1) So long as the parameter is constant, the system of x and y is absolute and has a definite field.

(2) After the parameter changes from one constant value to another, the system of x and y becomes again absolute, and has a definite field, but this field is not the same as the previous one.

The relation is general. A change in the value of an effective parameter changes the line of behaviour from each state. From this follows at once: *a change in the value of an effective parameter changes the field.*

The converse proposition is also true. Suppose we form a system's field and find it to be absolute. If our control of its surroundings has not been complete, and we test it later and find it to be again absolute but to have a changed field, then we may *deduce*, by S. 22/5, that some parameter must, in the interval, have changed from one constant value to another constant value.

6/4. The importance of distinguishing between change of a variable and change of a parameter, that is, between change of state and change of field, can hardly be over-estimated. In order to make the distinction clear I will give some examples.

In a working clock, the single variable defined by the reading of the minute-hand on the face is absolute as a one-variable system; for after some observations of its behaviour, we can predict the line of behaviour which will follow any given state. If now the regulator (the parameter) is moved to a new position, so that the clock runs at a different rate, and the system is re-examined, it will be found to be still absolute but to have a different field.

If a healthy person drinks 100 g. of glucose dissolved in water, the amount of glucose in his blood usually rises and falls as *A* in Figure 6/4/1. The single variable 'blood-glucose' is not absolute, for a given state (e.g. 120 mg./100 ml.) does not define the subsequent behaviour, for the blood-glucose may rise or fall. By adding a second variable, however, such as 'rate of change of blood-glucose', which may be positive or negative, we obtain a two-variable system which is sufficiently absolute for illustration. The field of this two-variable system will resemble that of *A* in Figure 6/4/2. But if the subject is diabetic, the curve of the blood-glucose, even if it starts at the same initial value, rises much higher, as *B* in Figure 6/4/1. When the field of this behaviour is drawn (*B*, Fig. 6/4/2), it is seen to be not the same as that of the normal subject. The change of value of the parameter 'degree of diabetes present' has thus changed the field.

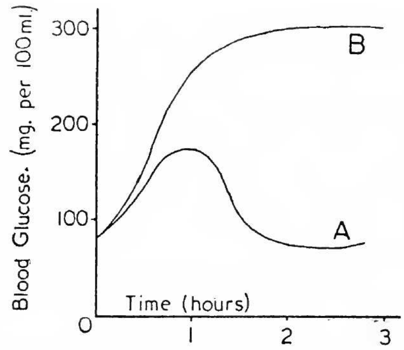

FIGURE 6/4/1: Changes in blood-glucose after the ingestion of 100g. of glucose: (*A*) in the normal person, (*B*) in the diabetic.

Girden and Culler developed a conditioned reflex in a dog which was under the influence of curare (a paralysing drug). When later the animal was not under its influence, the conditioned reflex could not be elicited. But when the dog was again put under its influence, the conditioned reflex returned. We need not enquire closely into the absoluteness of the system, but we note that two characteristic lines of behaviour (two responses to the stimulus) existed, and that one line of behaviour was shown when the

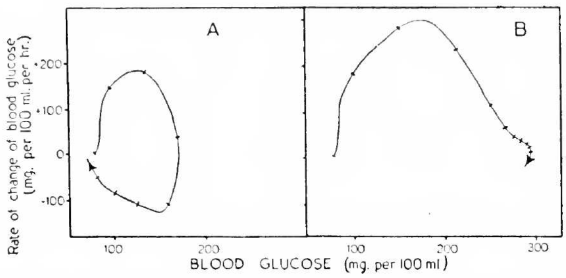

FIGURE 6/4/2 : Fields of the two lines of behaviour, *A* and *B*, from Figure 6/4/1. Cross-strokes mark each quarter-hour.

parameter ' concentration of curare in the tissues ' had a high value, and the other when the parameter had a low value.

6/5. The physicist, studying systems whose variables are all clearly marked and controllable, seldom confuses change of state with change of field. The psychologist, however, studies systems whose variables, even in the simplest systems, are so numerous that he cannot, in practice, make an exact list of them : his grasp of the situation must be intuitive rather than explicit. In his practical work he seldom fails to distinguish between the variables he is observing and the parameters he is controlling ; it is chiefly in his theoretical work, especially when he discusses cerebral mechanisms, that he is apt to allow the distinction to become blurred. To preserve the distinction between variable and parameter we must discuss, not the real ' machine ', with its infinite richness of variables, but a *defined* system. The advantage to be gained will become clearer as we proceed.

Stimuli

6/6. Many stimuli may be represented adequately as a change of parameter-value, so it is convenient here to relate the physiological and psychological concept of a ' stimulus ' to our methods.

In all cases the diagram of immediate effects is

(experimenter) → stimulator → animal → recorders.

In some cases the animal, at some resting state, is subjected to a sudden change in the value of the stimulator, and the second value is sustained throughout the observation. Thus, the pupillary reaction to light is demonstrated by first accustoming the eye to a low intensity of illumination, and then suddenly raising the illumination to a high level which is maintained while the reaction proceeds. In such cases the stimulator is parameter to the system 'animal and recorders'; and the physiologist's comparison of the previous control-behaviour with the behaviour after stimulation is equivalent, in our method, to a comparison of the two lines of behaviour that, starting from the same initial state, run in the two fields provided by the two values of the stimulator.

Sometimes a parameter is changed sharply and is immediately returned to its initial value, as when the experimenter applies a single electric shock, a tap on a tendon, or a flash of light. The effect of the parameter-change is a brief change of field which, while it lasts, carries the representative point away from its original position. When the parameter is returned to its original value, the original field and resting state are restored, and the representative point returns to the resting state. Such a stimulus reveals a line of behaviour leading to the resting state.

It will be necessary later to be more precise about what we mean by 'the' stimulus. Consider, for instance, a dog developing a conditioned reflex to the ringing of an electric bell. What is the stimulus exactly? Is it the closing of the contact switch? The intermittent striking of the hammer on the bell? The vibrations in the air? The vibrations of the ear-drum, of the ossicles, of the basilar membrane? The impulses in the acoustic nerve, in the temporal cortex? If we are to be precise we must recognise that the experimenter controls directly only the contact switch, and that this acts as parameter to the complexly-acting system of electric bell, middle ear, and the rest.

When the 'stimulus' becomes more complex we must generalise. One generalisation increases the number of parameters made to alter, as when a conditioned dog is subjected to combinations of a ticking metronome, a smell of camphor, a touch on the back, and a flashing light. Here we should notice that if the parameters are not all independent but change in groups, like the variables in S. 3/3, we can represent each undivided group by a single parameter and thus avoid using unnecessarily large numbers of parameters.

A more extensive generalisation is provided if we replace 'change of parameter' by 'change of initial state'. It will be shown (S. 7/7 and 21/4) that if a variable, or parameter, stays constant over some period it may, within the period, be regarded indifferently as inside or outside the system—as variable or parameter. If, therefore, a contact switch, once set, stays as the experimenter leaves it, we may, if we please, regard it as part of the system. Then what was a comparison between two lines of behaviour from two fields (of a set of variables a, b, c, say) under the change of a parameter p from p' to p'', becomes a comparison between two lines of behaviour of the four-variable system from the initial states a, b, c, p' and a, b, c, p''. 'Applying a stimulus' is now equivalent to 'releasing from a different initial state'; and this will be used as its most general representation.

Parameter and stability

6/7. We now reach the main point of the chapter. Because a change of parameter-value changes the field, and because a system's stability depends on its field, a change of parameter-value will in general change a system's stability in some way.

A simple example is given by a mixture of hydrogen, nitrogen, and ammonia, which combine or dissociate until the concentrations reach the resting state. If the mixture was originally derived from pure ammonia, the single variable 'percentage dissociated' forms a one-variable absolute system. Among its parameters are temperature and pressure. As is well known, changes in these parameters affect the position of the resting state.

Such a system is simple and responds to the changes of the parameters with only a simple shift of resting state. No such limitation applies generally. Change of parameter-value may result in any change which can be produced by the substitution of one field for another: stable systems may become unstable, resting states may be moved, single resting states may become multiple, resting states may become cycles; and so on. Figure 21/5/1 provides an illustration.

Here we need only the relationship, which is reciprocal: in an absolute system, a change of stability can only be due to change of value of a parameter, and *change of value of a parameter causes a change in stability*.

Reference

GIRDEN, E., and CULLER, E. Conditioned responses in curarized striate muscle in dogs. *Journal of Comparative Psychology*, 23, 261 ; 1937.