

Curriculum Vitae

1906. *The Integrative Action of the Nervous System*. Charles Scribner's Sons, New York.
1910. Page May Memorial Lecture, London University.
Member of Board of Trade Sight-Tests Committee.
1913. Croonian Lecture, Royal College of Physicians.
Member of Home Office Committee on Lighting of Factories and Workshops.
Waynflete Professor of Physiology, Oxford, to 1935.
- 1914-17. Fullerian Professor of Physiology, Royal Institution.
- 1916-17. War Office Committee on Tetanus.
Alcohol Committee, Central Board of Control.
1918. Chairman. Industrial Fatigue Research Board.
1919. *Mammalian Physiology. A course of practical exercises*. Clarendon Press.
- 1920-25. President of the Royal Society.
1922. President, British Association, Hull.
1925. *The Assaying of Brabantius and other verse*. Oxford University Press.
- 1925-34. Member of Medical Research Council.
- 1926-34. Editor, *Journal of Physiology*.
1927. Dunham Lecturer, Harvard.
Lister Oration, Canadian Medical Association, Toronto.
1929. Ferrier Lecture, Royal Society.
1932. *Reflex Activity of the Spinal Cord*, with Creed, Denny-Brown, Eccles and Liddell. Clarendon Press.
Nobel Laureate, Medicine, with E. D. Adrian.
1934. Rede Lecture, Cambridge.
- 1937-38. Gifford Lecturer, Edinburgh.
1940. *Man on his Nature*. Cambridge University Press.
1946. *The Endeavour of Jean Fernel*. Cambridge University Press.

FOREWORD TO 1947 EDITION

Let me here tender thanks to the Physiological Society, its Officers and all its Members and quite particularly to Professor Samson Wright, for the present generous compliment paid to my rather elderly book. I comply with pleasure to their request for a foreword to it. Owing to various circumstances, the text of the book has remained exactly as when first published. This seems a suitable opportunity to deal with some ambiguities which have in course of time arisen.

(a)

To describe the action of nerve as integrative is, although true, hardly sufficient for a definition. If the nature of an animal be accepted as being that of a whole presupposed by all its parts, then each and every part of the animal is integrative. This is illustrated strikingly by cancer, the growth of which being outside the integrative plan of the body is destructive both to the normal body and to itself. Our search for a more satisfying definition of nerve has then to ask what is the specific contribution which nerve makes to animal integration. Finger-pointings toward an answer are that nerve in any strict sense of the term is not an element of the plant-world. Nor is it found in unicellular animals, although it is practically universal in the multicellular. In these latter, similarly universal, is an organ of mechanical work, muscle, executant of movements and attitudes, the animal's motor behaviour. This behaviour falls into two divisions. One digestive, excretory, in short visceral; the other inclusive of all which is not merely visceral. This latter behaviour is that of external relation, so called. In it, motor behaviour reaches its highest speeds and precision, nerve attains its greatest and supreme developments.

The volume here reprinted concerns itself predominantly with the type of motor behaviour which is called 'reflex'; it might give the impression that in reflex behaviour it saw the most important and far-reaching of all types of 'nerve' behaviour. That is in fact

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not so. But reflex action presents certain advantages for physiological description. It can be studied free from complication with the psyche: also free from complication by that type of 'nerve' activity which is called autochthonous (or 'spontaneous') and generates intrinsically arising rhythmic movements, e.g. breathing, etc. But taken in comparison with the great field of behaviour in general, pure reflex action of itself cannot be seen to cover such extensive ground as do the instincts actuated by 'urges' and 'drives'. But the mechanism of these has hardly yet been analysed sufficiently for laboratory treatment. The pure apsychical reflex has a smaller role. Studied in that self-contained animal group, the Vertebrates, behaviour seems to become less and less reflex as the animal individual becomes more and more complexly individuated. The 'spinal' man is more crippled than is the 'spinal' frog.

(b)

A 'reflex' can be diagrammatized as an animal reacting to a cosmical 'field' containing it. Animal and 'field' are of one category, both being comprised within the physicist's term 'energy'. They are machines which interact—a point taken by Descartes. His wheelwork animals geared into the turning universe. Cat, dog, horse, etc. in his view had no thoughts, no ideas; they were trigger-puppets which events in the circumambient universe touched-off into doing what they do. It was a view less strange than might seem from this condensed epitome. But it lets us feel Descartes can never have kept an animal pet. Experiment to-day does, however, put within reach of the observer a puppet-animal which conforms largely with Descartes' assumptions. In the more organized animals of the vertebrate type the shape of the central nerve-organ allows a simple operation to reduce the animal to the Descartes condition. An overlying outgrowth of the central nerve-organ in the head can be removed under anaesthesia, and on the narcosis passing off the animal is found to be a Cartesian puppet: it can execute certain acts but is devoid of mind. That it is devoid of mind may seem a dogmatic statement. Exhaustive tests, however, bear the assertion out. Thoughts, feeling, memory, percepts, conations, etc.; of these

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no evidence is forthcoming or to be elicited. Yet the animal remains a motor mechanism which can be touched into action in certain ways so as to exhibit pieces of its behaviour.

An outline of the spatial arrangement of nerve illustrates how this comes about. From points within and on the surface of the animal, nerve-threads run to its muscles, but in their course thither are engaged by the central organ and are there relayed; the central organ becoming a sort of switchboard where muscles can be switched on or off. The starting-point of the nerve-thread is not equally responsive to all the various types of the field forces. Each starting-point is armed with a structure, the receptor, which reacts to one specific class of field agency, e.g. one to light, not heat, another to heat, not light. The reaction of the nerve-thread itself is, in all nerve-threads, to generate a repetitive series of brief and minute electric currents which run away from the starting-point and, by relays through the central organ, reach this or that set of muscles determined by the topography of the starting-point concerned. As the play of the 'field' shifts over the animal, different sets of receptors come into and go out of action. The receptors thus analyse the successive situations occurring between animal and field in terms of the selective receptors, and ultimately in terms of the muscles of the limbs, etc. Change in the external situation brings corresponding change in the muscles brought into and released from contraction. A train of motor acts results therefore from a train of successive external situations.

The movements are not meaningless; they carry each of them an obvious meaning. The scope commonly agrees with some act which the normal animal under like circumstances would do. Thus, the cat set upright (Graham Brown) on a 'floor' moving backward under its feet walks, runs or gallops according to the speed given to the floorway. Again, in the dog a feeble electric current ('electric flea') applied by a minute entomological pin set lightly in the hair-bulb layer of the skin of the shoulder brings the hind paw of that side to the place, and with unsheathed claws the foot performs a rhythmic grooming of the hairy coat there. If the point lie forward at the ear, the foot is directed thither, if far back in the loin the foot goes

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thither, and similarly at any intermediate spot. The list of such purposive movements is impressive. If a foot tread on a thorn that foot is held up from the ground while the other legs limp away. Milk placed in the mouth is swallowed; acid solution is rejected. Let fall, inverted, the reflex cat alights on its feet. The dog shakes its coat dry after immersion in water. A fly settling on the ear is instantly flung off by the ear. Water entering the ear is thrown out by violent shaking of the head. An exhaustive list would be much larger than that given here. The experiments of Graham Brown and of R. Magnus give excellent examples. But when all is said, if we compare such a list with the range of situations to which the normal cat or dog reacts appropriately, the list is extremely poverty stricken as a conspectus of behaviour. It contains no social reactions. It evidences hunger by restlessness and brisker knee-jerks; but it fails to recognize food as food: it shows no memory, it cannot be trained or learn: it cannot be taught its name. The mindless body reacts with the fatality of a multiple penny-in-the-slot machine to certain stimuli, all of them, as in the case of the penny-in-the-slot machine, physical, and not psychical.

A point is that these mindless acts yet treat the animal's motor machinery as a united whole. Thus the mindless machine can walk, and run, and gallop; it can also spring. These acts include 'balance' and adjustments of poise as well as phasic movements duly coordinated. There is integration although purely motor integration. What is noteworthy is that such acts should be carried out in absence of mind, that is to say of mind in any ordinary acceptance of the term. Of course we do not forget that here what we observe is an artefact; but it is an analytic artefact. And that an artefact of such effectiveness should obtain in animals so highly mentalized as cat and dog, suggests that in creatures less mentalized than they a residuum of behaviour still larger relatively to the total behaviour will be 'reflex'. The behaviour of the spider is reported to be entirely reflex; but reflex action, judging by what we can sample of it, would go little way toward meeting the life of external relation of a horse or cat or dog, still less of ourselves. As life develops it would seem that in the field of external relation 'conscious' behaviour tends to replace reflex, and

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conscious acts to bulk larger and larger. Along with this change, and indeed as part of it, would seem an increased role for 'habit'. Habit arises always in conscious action; reflex behaviour never arises in conscious action. Habit is always acquired behaviour, reflex behaviour is always inherent and innately given. Habit is not to be confounded with reflex action.

The examples of reflex action taken for study here have been for the most part isolated artificially by extracting them so to say from animal lives of relatively highly* developed external relation, e.g. cat and dog. Examples of reflex behaviour could have been taken under much less artificial conditions by resort to animals of less complex external relations (of lower animal type), e.g. the frog. But then the reactions, though more naturally obtainable, would have been more open to equivocal interpretation as to purpose and less rich in executive complexity.

(c)

We turn to behaviour of a different kind, some say even of a different category of act. The field of the psyche is entered. An old adage has it that to the trodden worm its own trodden self is the world's greater half. That anthropomorphic worm may typify ourselves to us; the 'self' of each of us goes far to epitomize the integration we are now to look at. We can retain the scheme of spatial nervous arrangement we used before, this time, however, not mutilating the central organ, but keeping the animal—the human animal if you will—intact. The receptors at the starting-points of the nerve-thread we find now to be, by conspiracy with a psyche in the central organ, sense-organs. The full panel of the 'five-senses' is in session, and by further collaboration with the psyche, a world of subject and object for the individual is in being. The individual has attained a psychical

* The terms 'higher' and 'lower' as applied to animals in this book regard range of life of external relation. Mr K. W. Monsarrat expresses this: "by a higher animal is meant here one that displays a greater range and variety in its dealing with its surrounding than some other with which it is being compared." *Myself, My Thinking and My Thoughts* (1942), p. 117. Some biologists use the terms more broadly.

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existence. Phases and moods of mental life accrue. Each waking day is a stage dominated for good or ill, in comedy, farce or tragedy, by a *dramatis persona*, the 'self'. And so it will be until the curtain drops. This self is a unity. The continuity of its presence in time, sometimes hardly broken by sleep, its inalienable 'interiority' in (sensual) space, its consistency of view-point, the privacy of its experience, combine to give it status as a unique existence. Although multiple aspects characterize it it has self-cohesion. It regards itself as one, others treat it as one. It is addressed as one, by a name to which it answers. The Law and the State schedule it as one. It and they identify it with a body which is considered by it and them to belong to it integrally. In short, unchallenged and unargued conviction assumes it to be one. The logic of grammar endorses this by a pronoun in the singular. All its diversity is merged in oneness.

How habitually and unwittingly the self regards itself as one is instanced by binocular vision. Our binocular visual field is shown by analysis, to presuppose outlook from the body by a single eye centred at a point in the midvertical of the forehead at the level of the root of the nose. It, unconsciously, takes for granted that its seeing is done by a cyclopean eye having a centre of rotation at the point of intersection just mentioned. In this visual field it obtains visual depth by unknowingly combining besides the actually identical fixation points, the host of homonymously—and heteronymously—crossed images of not too great lateral disparation. The combining of these last rests on a cancelling out—an algebraical submental summation—of the two disparations of right and left eye images respectively. Oneness is obtained by compromise between differences, if not *too* great, offered to the perceiving 'self'. There are other perceptual instances. The brightness of a binocular field differs hardly sensibly from that of either of two equally illuminated uniocular fields composing it. But the quantity of stimulus received by the eyes is roughly double in the binocular observation that which it is in the uniocular. If, with relatively simple fields, the brightness of one uniocular field is less, but not too greatly less, than that of the twin field offered to the other eye, the binocular brightness

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is intermediate between that of the two uniocular fields. If the difference of brightness between the two uniocular fields is too great there is alternating oscillation, rivalry instead of binocular fusion. Again, with colours, binocular fusion results in an intermediate tint: thus the red and green postage stamps give a sheeny bronze when binocularly united. The well-known outline-figures, often called equivocal-figures, with which while we gaze at what depicts for instance an overhanging eave the interpretation suddenly changes to a set of ascending steps, have the character of giving always wholly either the one thing or wholly the other. The meaning is never at the same time partly this and partly that. Doubtless because to be so would be to have no meaning. Psychical integration is immensely influenced by meaning. An early trouble for the squinter is the 'doubling' of things. He has to school himself to accept that doubleness not as of the things but of himself, the visual self. Each of the two-of-a-thing which the squint gives enters at first convincingly enough as a separate item into the visual picture of the moment. The squint prevails at first despite the self's reasoned criticism that there are truly not two of the thing. But the self learns to suppress one of them. Conjunction in time *without* necessarily cerebral conjunction in space is thus an element in the unification of the mind. Simultaneity will of itself make a mental unity. It is somewhat as if two persons of similar make-up could pool their separate psychical experiences to one.

(d)

There remains yet another type of integration which claims consideration, although to saddle it upon nerve may perhaps encounter protest. Integration has been traced at work in two great, and in some respects counterpart, systems of the organism. The physico-chemical (or for short physical) produced a unified machine from what without it would be merely a collocation of commensal organs. The psychical, creates from psychical data a percipient, thinking and endeavouring mental individual. Though our exposition kept these two systems and their integrations apart, they are largely complementary and life brings them co-operatively together at

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innumerable points. Not that the physical is ever anything but physical, or the psychical anything but psychical. The formal dichotomy of the individual, however, which our description practised for the sake of analysis, results in artefacts such as are not in Nature. Each such is a quasi-organism which does not resemble ourselves, nor does it, *pace* Descartes, resemble dog or cat. For our purpose the two schematic members of the puppet pair which our method segregated require to be integrated together. Not until that is done can we have before us an approximately complete creature of the type we are considering. This integration can be thought of as the last and final integration.

But theoretically it has to overcome a difficulty of no ordinary kind. It has to combine two incommensurables; it has to unite two disparate entities. To take an example: I see the sun; the eyes trained in a certain direction entrap a tiny packet of solar radiation covering certain wave-lengths emitted from the sun rather less than 10 minutes earlier. This radiation is condensed to a circular patch on the retina and generates a photo-chemical reaction, which in turn excites nerve-threads which relay their excitation to certain parts of the brain, eventually to areas in the brain-cortex. From the retina onward to the brain the medium of propagation is wholly nervous; that is to say, the reaction can be subsumed as electrical. Some of this electrical reaction generated in the eye does not reach the brain-cortex but diverges by a side-path into nerve-threads which relay it to a small muscle, which by contracting prevents excess of light attaining the retina. The electric current propagated to the muscle activates the muscle. The chain of events stretching from the sun's radiation entering the eye to, on the one hand, the contraction of the pupillary muscle, and on the other to the electrical disturbances in the brain-cortex are all straightforward steps in a sequence of physical 'causation', such as, thanks to science, are intelligible. But in the second serial chain there follows on, or attends, the stage of brain-cortex reaction an event or set of events quite inexplicable to us, which both as to themselves and as to the causal tie between them and what preceded them science does not help us; a set of events seemingly incommensurable with any of the events leading

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up to it. The self 'sees' the sun; it senses a two-dimensional disk of brightness, located in the 'sky', this last a field of lesser brightness, and overhead shaped as a rather flattened dome, coping the self, and a hundred other visual things as well. Of hint that this scene is within the head there is none. Vision is saturated with this strange property called 'projection', the unargued inference that what it sees is at a 'distance' from the seeing 'self'. Enough has been said to stress that in the sequence of events a step is reached where a physical situation in the brain leads to a psychical, which however contains no hint of the brain or any other bodily part. We cannot of course suppose that in the instance taken, the 'seeing the sun' breaks into a visual vacuum; in the waking day 'seeing' of some sort is always going on: on the physical side similarly electrical waves in the brain from one source or another must be practically unremitting during the waking day. The supposition has to be, it would seem, two continuous series of events, one physico-chemical, the other psychical, and at times interaction between them.

This is the body-mind relation;* its difficulty lies in its 'how'. As to the utility of the liaison that appears patent enough, namely that the psychical may influence the physical act. In illustration—a simple everyday illustration—a morsel of food in the mouth is subject to the movements of the lips, tongue, cheeks, etc. The conscious self is aware of it, perhaps, acutely—if it is savoury or distasteful. In the former case the self can swallow it, in the latter reject it. If the former, the tongue and fauces push it from the mouth into the grasp of the gullet. That done, our conscious self is aware of the morsel no more, although the morsel is still within the grasp of muscle and nerve and they skilfully deal with it further. The conscious self has, however, lost it and control of it. Even if the morsel be poison the self can no longer directly intervene. That is, the morsel vanishes from an experience at the moment when our choice in regard to it becomes inoperative. The psyche does not persist into conditions which would render it ineffective.

Further it is claimed that the psychical can increase the reactivity

* For luminous treatment of this point see W. Russell Brain, *Philosophy* (1946), vol. XXI, p. 134.

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of the body's physical system. Thus, it is shown that under favourable circumstances the reaction of the retina to as few as six photons can be perceived; and a visual reaction can release motor behaviour of the whole body. But without the visual perception there would be no general reaction. The process by which a reaction of merely 'quantum' order is biologically raised to molar dimensions is called by some biologists 'amplification'. A means to 'amplification' is emotion. As physical stimulus a ghost may be of barely threshold power; but given emotion, and it can convulse the whole individual. Intensification of behaviour by emotion accompanies animal life very widely. I once had opportunity to watch under the microscope a flea 'biting'. The act, whether reflex or not, seemed charged with the most violent emotion. Its Lilliput scale aside, the scene compared with that of the prowling lion in 'Salambo'. It was a glimpse suggesting a vast ocean of 'affect' pervading the insect world. An inference is, that part at least of the *raison d'être* for our psychical experience is to exert influence on the body's physical acts. The service of the psychical to the individual life seems to lie in influencing the body's acts, in the interest of self-conservation, an aim innate in the individual from a primordial outset. The psychical therefore implements more fully a principle already implicit in life.

When this situation is viewed broadly to-day it reveals a circumstance at first sight strange. We perceive that the immemorial principle of self-conservation is being challenged by a 'new deal'; a novel order of things antagonizes a preceding; a new moral value is appearing over the horizon. The principle of altruism has arisen. A great antinomy is shaping. A behaviour actuated by 'charity' even to the extent of sacrificing one's own self for the sake of another's self. The soldier gives his own life for that of others. This new spirit seems to be largely correlated with the development of man on our planet. Lord Acton had in purpose a History of Liberty. A history of Altruism might be not less worth while. This may be thought to be digressing from physiology, but in fact I do not think it is. St Augustine's *De Civitate Dei* contains not a little physiology. In so far as physiology involves man as a physio-

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logical factor on our planet this great antinomy of which he is the protagonist is not alien to the scope of physiology.

Agreeing that the biological function of the physico-psychical liaison is to enhance the organism's power of disposing of its acts, a further question asks of what service is the physical organism to the psychical? This question is only in part a reciprocal of the other, because only some organisms possess the psychical component. In such as do, however, it is clear that the body-mind liaison provides in a largely physical world the physical means of giving expression to the psychical.

In all those types of organism in which the physical and the psychical coexist, each of the two achieves its aim only by reason of a *contact utile* between them. And this liaison can rank as the final and supreme integration completing its individual. But the problem of *how* that liaison is effected remains unsolved; it remains where Aristotle left it more than 2000 years ago. "There is, however, one peculiar inconsistency which we may note as marking this and many other psychological theories. They place the soul in the body and attach it to the body without trying in addition to determine the reason why, or the condition of the body under which such attachment is produced. This, however, would seem to be a real question."* Instead of, as is usual in physiology, leaving that impasse unmentioned, it seemed better to draw attention to it by the experimental observations in this book's final chapter.

The demand for discussion of this liaison between two incommensurable factors can be avoided, but at a cost, by adopting either of two other courses. If for instance we start out from the notion of the psychical self and proceed thence to its apprehended world including its apprehended body, the whole scheme is a mental one, and the body-mind incompatibility falls. The self and its world are then one in their nature. Or again, remembering that common sense and physics and chemistry, from their analysis of our body and its cosmical surround reduce these ultimately to a single factor, 'energy', we can suppose that our thinking is likewise an outcome of 'energy'. Then again the body-mind disparation

* *De Anima*, I. 3, §§ 22-3 (Wallace's translation, p. 35).

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disappears, because both have become forms of 'energy'—though in this case by means of an assumption which seems to many an unjustified one.

Of these two views Cajal tells how he was for a time a zealous disciple of the former, and noticed that to his practical life adherence neither to the one nor other seemed to make any difference whatever. I should myself have supposed that the Berkeleian view would impair the 'zest' of the waking day, nor can I imagine the achievements of ancient Rome emerging from such a doctrine.

That our being should consist of *two* fundamental elements offers I suppose no greater inherent improbability than that it should rest on one only.

C. S. SHERRINGTON

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THE
INTEGRATIVE ACTION
OF THE
NERVOUS SYSTEM

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