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THE MIND OF MECHANICAL MAN*

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Brain–Mind Relationship

No better example could be found of man's characteristic desire for knowledge beyond, and far beyond, the limits of the authentic scientific discoveries of his own day than his wish to understand in complete detail the relationship between brain and mind—the one so finite, the other so amorphous and elusive. It is a subject which at present awakes a renewed interest, because we are invaded by the physicists and mathematicians—an invasion by no means unwelcome, bringing as it does new suggestions for analogy and comparison. We feel perhaps that we are being pushed, gently not roughly pushed, to accept the great likeness between the actions of electronic machines and those of the nervous system. At the same time we may misunderstand this invitation, and go beyond it to too ready an affirmation that there is identity. We should be wise to examine the nature of this concept and to see how far the electro-physicists share with us a common road. Medicine is placed by these suggestions in a familiar predicament. I refer to the dangers of our being unintentionally misled by pure science. Medical history furnishes many examples, such as the planetary and chemical theories of disease that were the outcome of the Scientific Renaissance. We are the same people as our ancestors and prone to their mistakes. We should reflect that if we go too far and too fast no one will deride us more unashamedly than the scientists who have tempted us.

Discussion of mind–brain relations is, I know well, premature, but I suspect that it always will be premature, taking heart from a quotation that I shall make from Hughlings Jackson—not one of his best-known passages—because it may have been thought to be a sad lapse on his part. I believe it myself to be both true and useful, and so I repeat it.

"It is a favourite popular delusion that the scientific inquirer is under a sort of moral obligation to abstain from going beyond the generalization of the observed facts, which is absurdly called 'Baconian induction.' But anyone who is practically acquainted with scientific work is aware that those who refuse to go beyond fact rarely get as far as fact; and anyone who has studied the history of science knows that almost every great step therein has been made by the 'anticipation of Nature'—that is, by the invention of hypotheses which, though not verifiable, often had very little foundation to start with."

He concludes by saying that even erroneous theories can do useful service temporarily. He was no doubt thinking of his own early clinical researches on local epilepsy, the theory of which necessitated crisp localization of motor function, although when first he proposed it the physiological world could not as yet support him. Had he waited for certainty he would never have got near it as early as he did.

So Jackson hinted, and Darwin in comparable words agreed with him. In more recent times K. J. W. Craik rightly drew attention to the real method of scientists, which is to see whether some idea can be substantiated by experiment. They begin without bothering their heads about rigid definitions of what they are doing. Robert Boyle was not interested in making a law but in finding out what happened when gases were compressed. The results happened to be generalizable in a formula. It is the philosophers who insist on logistic definitions which are the more perfect the more they leave out of the vast realms of human striving and usefulness. The so-called Laws of Science had generally no very tidy beginnings. They are no more than science recollected in tranquillity, and not the conscious aim of the eponymous makers of the crucial and revelatory experiments. It may be that the poet who tries to crystallize a moving experience into an immortal line is using his wits in a very similar manner. We must beware of making science too rigid, self-conscious, and pontifical. A. N. Whitehead confessed to me once that he found that he had escaped from the certainty and dogma of the ecclesiastics only in the end to find that the scientists, from whom he had expected an elastic and liberal outlook, were the same people in a different setting. I am encouraged, therefore, to proceed in the hope that, although we shall not arrive at certainty, we may discover some illumination on the way.

Ancient Automata

Before we glance at the new vistas of mechanization opening before us, let us spare a few moments to look at the past, where we shall find that the possibility of building automata has been one of man's dreams since the days of the Trojan horse—a simile more metaphorical than strictly accurate. In the seventeenth century, that era of scientific awakening, there was great interest in possible replicas of animals and men. Florent Schuyl, in 1664, gives several instances, such as the wooden pigeon of Archytas of Tarentum which flew through the air, suspended by counterweights. There was a wooden eagle, that of Regiomontanus, that showed an Emperor the way to Nuremburg, and a flying fly by the same maker. There was an earthen head that spoke; but, above all, a marvellous iron statue that knelt before the Emperor of

*The Lister Oration delivered at the Royal College of Surgeons of England on June 9, 1949.

Morocco and presented him with a request for a pardon for the man who had made him. There were even greater marvels, such as that incomparable statue the Venus of Daedalus, that had quicksilver in its veins and seemed to be alive, and " an infinity of other similar automata, moving and even speaking machines which Coelius Rodiginus mentions in his book on antiquities, and Kircher and many others describe." Gafford, in 1629, had written of statues of men and women which moved and spoke and played musical instruments, birds that flew and sang, lions that leaped, and a thousand other marvels of the inventions of man which astonished the people.

That most of the foregoing examples were no more than fables, or huge exaggerations of a grain of truth, we may be very sure. But there was some foundation for them in the many marvels which the traveller might see with his own eyes at that day, or soon after, such as the water gardens of Tivoli and Pratelino, at Saint Germain-en-Laye, at Fontainebleau, at Augsburg and Salzburg. Water- or wind-power and clockwork were the only sources of energy available, but they caused movement in some pretty toys, and although the figures moved clumsily, yet move they did. As the traveller approached a grotto, for instance, and as he stood admiring, he pressed unwittingly a lever hidden beneath a stone, causing Neptune to come forward with his trident raised to defend a water-nymph, whilst the bathing Diana withdrew among the reeds.

If such wonders had already been constructed for the pleasure of noblemen and the entertainment of their guests, how much more perfectly might not the serious scientist contrive a cunning replica of a living thing. As only too often happens, to conceive it possible was as good as its conversion into fact. It could be, therefore it was. I am sure that that is our own temptation.

Descartes's Postulation

The first convincing postulation of mechanical perfection was of course that of Descartes, who believed that animals, though live things because their hearts were hot (Galen's idea), were entirely reflex in their complicated actions, doing all that they did because their construction compelled them. They had no souls, no minds, and therefore no free will. He expressed himself in a manner which could scarcely be bettered as a fair exposition, up to that moment, of the problem of automata. His views are very apposite to the present day, which has become more Cartesian than it realizes. It should, he thought, be perfectly possible to construct an automaton that would behave not only like an animal but, in so far as he was an animal, like a man, because the organs of man and animal were in the main the same. There was an eventual difference: he saw plainly that it reposed in the highest qualities of man's mind and soul.

Descartes made the point, and a basic one it is, that a parrot repeated only what it had been taught and only a fragment of that; it never used words to express its own thoughts. If, he goes on to say, on the one hand one had a machine that had the shape and appearance of a monkey or other animal without a reasoning soul (i.e., without a human mind) there would be no means of knowing which was the counterfeit. On the other hand, if there was a machine that appeared to be a man, and imitated his actions so far as it would be possible to do so, we should always have two very certain means of recognizing the deceit. First, the machine could not use words as we do to declare our thoughts to others. Secondly, although like some animals they might show more industry than we do, and do some things better than we, yet they would act without knowledge of what they were about simply by the arrangement of their organs, their mechanisms, each particularly designed for each particular action (cp. Karel Capek's *Robots*). Descartes concluded: " From which it comes that it is morally impossible that there be enough diversity in a machine for it to be able to act in all the occurrences of life in the same way that our reason would cause us to act. By these means we can recognize the difference between man and beasts." He could even conceive a machine that might speak and, if touched in one spot, might ask what one wanted—if touched in another that it would cry out that it hurt, and similar things. But he could not conceive of an automaton of sufficient diversity to respond to the sense of all that could be said in its presence. It would fail because it had no mind.

Apart from this difference—a vital one indeed—the body seemed undeniably to be a sum of mechanisms. It was so crystal-clear to Borelli and the new scientists that both animal and human bodies were nothing more than a collection of pumps, reservoirs, bellows, fires, cooling and heating systems, tubes, conduits, kitchens, girders, levers, pulleys and ropes, that there was little left to marvel at. Let the vulgar gape, let the devout feel gratitude to God—it was all very plain to the scientist of that age. It was not as plain as they thought. Time has shown that hidden in the materials of which this body is composed are all kinds of biochemical ingenuities. It is a chemical engine such as would have astonished the mechanics. Give a man, to take the simplest of all examples, a beautifully efficient set of aluminium bones in place of his original skeleton and he will die of some unpleasant blood disease because bones are living organs as well as props.

There certainly are things to marvel at, and no small wonders they are. One is the truly extraordinary efficiency of the living organism as judged by weight, energy output, and fuel consumption by comparison with any machine whatever; another is its ability to carry on with its own feed-back controls for decades, without adjustment or repair. In the long run, of course, scientific method made great use of the mechanical likenesses that so impressed the savants of the scientific Renaissance. A great service had been done by destroying mystery and by discrediting Platonic and Aristotelian essences and humours. Most of our advances have been made by use of technical methods common both to machines and to living things. But all our advances have depended on observation of the thing itself, accepting likeness to mechanism only as analogy and not as identity.

I fancy that no one will disagree in summary of the foregoing that, however like the various processes are to other things in physical nature, however amenable they are to examination as physico-chemical processes, they remain unmistakably themselves. We shall reach the same conclusion about the brain—that, however its functions may be mimicked by machines, it remains itself and is unique in Nature. Descartes solved the difficulty by making mind supernatural, placing an immaterial mind independent of organism in the pineal. This was the age-old refuge of those faced with the inexplicable in Nature, as we still see in primitive peoples and in the superstitious. We may well doubt to-day whether a supernatural agency is the basis of mental process. But it was doubted in Lister's time. In 1870 T. H. Huxley reluctantly concluded: " I can find no intelligible ground for refusing to say that the properties of protoplasm result from the nature and disposition of its molecules . . . and if so, it must be true, in the same sense and to the same extent, that the thoughts to which I am now giving utterance, and your thoughts regarding them, are the expression of molecular changes in the matter of life which is the source of our other vital phenomena."

The passage of time which has led us to accept so much has done little to make this conclusion either less true or much more acceptable than it was to Huxley himself. To admit it seems to confess to a certain ordinariness about mind, an ordinariness to which the richness and plasticity of its powers seem to give the lie and in revenge to demand a stupendous physical explanation. And there is something more. Since no thinking man can be unaware of his fellows and of the political scene he will find that the concept of thinking like machines lends itself to certain political dogmas inimical to man's happiness. Furthermore, it erodes religious beliefs that have been mainstays of social conduct and have brought happiness and serenity of mind to many. These possibilities would have leaped to the forefront of Joseph Lister's mind as they do to mine. But I hope to show that we can take courage.

Modern Automata

Ingenuity of invention at the present time confronts our more sophisticated eyes with models as seductive as were the cruder automata of old. By means of electric motors, thermo-couples, photo-electric cells, radio tubes, sound receptors, and electrical resistances variable to moisture it should be possible to construct a simple animal such as a tortoise (as Grey Walter ingeniously proposed) that would show by its movements that it disliked bright lights, cold, and damp, and be apparently frightened by loud noises, moving towards or away from such stimuli as its receptors were capable of responding to. In a favourable situation the behaviour of such a toy could appear to be very lifelike—so much so that a good demonstrator might cause the credulous to exclaim "This is indeed a tortoise." I imagine, however, that another tortoise would quickly find it a puzzling companion and a disappointing mate.

It is the infinite variety of the behaviour of the world of animals that confuses us. The stage is too vast, the cast too numerous, the qualities of their performances too varied. We should not show any hesitation in attributing conscious mental processes to animals to-day. Greatly though information has increased, the field study of animals in their natural state is with difficulty pursued over long periods, so that we have but short chapters from their lives, and some are too shy, too evasive, or too episodic in their sojourns to allow of continuous recording. We should find great difficulty in grading animal minds. Such knowledge as we have is enough to teach us that even among creatures of the same genera there are great differences in the cleverness of individuals. There are not only clever dogs and dull ones, but clever hens and stupid hens, attractive hens (to the cock) and plain ones, and, for all we know, clever and lovely flies, clever elephants, clever snakes and fish, with dull-witted brothers and ugly sisters. Obstinacy, no doubt, varies in the mule.

At what level in the animal scale something that can be called mind appears for the first time we do not know. J. Z. Young's experiments show that even an octopus can learn, be so puzzled by problems set it as to be made what we might be allowed to call neurotic. That this could happen to monkeys we already knew from ingenious experiment, and now the reproduction of bewilderment that paralyses action in such low forms of life is singularly interesting. The child, confused by its teachers and unable to grasp the logic of its lessons, is but a more complex example of the puzzled octopus. It seems to me likely that the number of synapses in a nervous system is the key to the possible variations in its behaviour. Provided that the neurones are not too numerous and consequently the synaptic patterns of alternative routes for impulses not too varied, it is not difficult to imagine that some, though not all except the simplest, animal behaviour is the result of a pattern of reflexes, much more complicated, it is true, than the plain push-button-and-answer of some spinal reflexes.

But neither animals nor men can be explained by studying nervous mechanics in isolation, so complicated are they by endocrines, so coloured is thought by emotion. Sex hormones introduce peculiarities of behaviour often as inexplicable as they are impressive (as in migratory fish). We should not have any real idea how to make a model electronic salmon however simple relatively its nervous system is, whilst birds would be as far beyond us again. I can see that, although a good deal of instruction might be got from varying the proportion of, say, photo-electric cells, thermocouples, and sound-receivers perhaps above and below the range of human hearing to see how variations affected the antics of a model, it remains uncertain how far we should be truly enlightened on the obscurities of animal behaviour. Olfaction, which plays so large a part in some creatures, would be particularly difficult to mimic. So would the effects of satisfaction of appetites of all kinds and of fatigue—such important influences.

When all is said—and much more could be said on both sides—we emerge with the conviction that, although much can be properly explained by conditioned reflexes and determinism (in which idea mechanism lurks in the background), there is a fringe left over in which free will may act (i.e., choice not rigidly bound to individual precedent), a fringe that becomes larger and larger the more complex the nervous system. Both views are correct in their own spheres; neither is wholly correct for everything. I accept here the emendation of Niels Bohr, who sees this as the counterpart of the impossibility of fully describing the electron either as a point or as a wave. It is either, according to how it is examined or in what circumstances. This paradox the mathematicians call the Law of Complementarity, and are not afraid to regard the same thing as true in two different guises. We may do well to follow their example.

The Nervous Impulse

The electronic computing machine works as a logical system, making a choice between "yes" and "no" at a great number of points in a vast chain, with the speed of electricity. Because it uses wireless valves, wired circuits, mercury tubes, condensers, and all the paraphernalia of electricity it works thousands of times faster than can the human brain. Before we proceed further in considering machines we must see how far we can go in saying that our own nervous system is electrical. We shall see that it is not so, in the layman's meaning of the term, but the electrical processes that accompany its actions afford problems of absorbing interest. The fastest known nerve impulses in mammalian nerve or spinal cord travel at about 140 metres per second, the slowest anything down to 0.3 metre per second. What their speed may be in the brain we do not know, but very likely perhaps it does not differ much from these figures. The passage of impulses through single synapses is known by the work of Lorente de Nó and others to cause a delay of 0.75 millisecond. Such delays, and there are sure to be many in the cortex, impose a certain additional slowness on nervous actions.

The flashing speed of thought which so much impresses us is, it seems, a rather slow affair, but in view of the short distances that impulses have to travel in the brain the rate is fast enough to appear instantaneous to us. It is true that, although the electrical current cannot itself be slowed down from its normal 1,000 ft. per microsecond, it is possible to slow down the arrival of an impulse by devices such as delay systems, and especially by the trigger systems, in which each component excites the next, at a rate that can be made inferior to conduction in nerve. There is, it seems, no limit to the slowing which could be imposed, down even to 1 foot an hour. This would entail complex apparatus. For many years nothing recognizably the counterpart of such systems could be found in the structure of the nerve fibre, but there are those who believe now that the retardation is at the nodes of Ranvier, with high-speed leaps between each node (the "saltatory theory" of conduction). Significantly, nodes of Ranvier have been found in the tracts of the spinal cord.

It remains an anomaly that the speed of the nervous impulse is usually slower in the bare fibres of non-medullated than in medullated nerve, as if the nerve sheath increased the speed. To the surgeon the results of nerve injuries and the long delay in recovery seemed to negative completely the electrical nature of the impulse. It certainly would be impossible if we thought of electrical currents flowing along plain copper wires. But the delay in recovery is accounted for equally well in either view on the ground that the passage of the impulse requires a perfect conductory system, which, unlike copper wire, takes time to repair. Physiological conduction demands more than anatomical continuity, the axons must be a certain size and the sheath a certain thickness, as Young shows, and it is conceivable that the sheath needs to acquire certain physical properties proper for polarization. Whichever way one looks at it the speed of the nervous impulse presents us with a problem in electricity as a biological fact that is so special as to be unique.

Lastly, although electronic methods permit of much more local, more individual questioning of elements in the nervous system, we must not overlook the chemical agencies which transmission demands and from which nerve cells derive their energy. It seems very plain that if the nervous system is examined by electrical methods answers must be obtained in terms of electricity. But if it is examined in terms of chemistry, as Sir Henry Dale and G. L. Brown have done, the same thing now appears as a wonderfully implemented electro-chemical machine. There may be other methods of investigation still to be discovered.

It would probably be wrong to say that electrical methods are more delicate than chemical, yet it is certainly much easier to render an account of nervous actions and to represent the results of understandable diagrams by the former than by the latter means. A one-sided view is only too easily acquired, but let the artificers remember chemistry, for metabolic disorders can block transmission —the "invisible lesions" of clinical neurology of which Sir Charles Symonds has written. The recollection that chemical agencies and enzyme actions are no doubt eventually explicable in physical terms does not entirely remove the force of this reminder.

Calculating Machines

These lines of thought, however elementary, seemed to me a necessary prologue before we come to consider systems which have a purely electronic structure. We shall be right in concluding that it does not greatly matter what the nervous impulse really is, except that, vastly multiplied, it is part of a communication system, a self-controlled information system (self-controlled because of its integrating feed-backs), and could therefore be compared with man-made systems in these classes. Such systems happen to be a peculiarly rich development of our own times. But we shall be quite wrong if we approach the subject on any other terms except those of analogy.

To be just, nothing more than analogy is claimed by most of their constructors (some, like Professor Williams, do not go so far even as that), but there is a grave danger that those not so well informed will go to great lengths of fantasy. If we see that some nervous tissues behave like some electronic circuits we must all the time remember that the resemblance is with fragments of the nervous system and not with the whole integrated nervous system of man. It is only right when we do so that we recollect something else, that we cannot be sure that the highest intellectual processes are still carried out in the same way. Something quite different, as yet undiscovered, may happen in those final processes of brain activity that results in what we call, for convenience, mind.

The histological pattern of the human cortex leaves us with a host of questions unanswered. We may be in the familiar position that I sketched in earlier passages of stretching our knowledge to cover something to which it does not apply. Abstract thinking may not be a matter of neurone mechanics as we know them at lower levels. But let us proceed for the moment by supposing that the system remains the same throughout—and a large assumption it is—and that it is for the moment comparable with something of a different material composition but with a similar plan. The mechanisms of calculating machines are outside the province of neurologist or surgeon, and I have to rely upon and gratefully acknowledge the assistance of Professor F. C. Williams, professor of electro-technics in my own university, and the information gleaned from Dr. Wiener, of Boston, in his entertaining book on the new science that he has christened "Cybernetics" (1948).

Computing machines use very many fewer "neurones" than has the brain. One may compare the 10,000,000,000 cells of Adrian's estimate with the 20,000 valves of the first big American machine ENIAC at Princeton, and the 1,000 of Professor Williams's newer and more efficient experimental and most ingenious instrument in Manchester. McCulloch, of Chicago, was reported as saying that a model that contained valves and wiring anything approaching in number the neurones in the human nervous system would require a building the size of the Empire State Building to house it and the complete electrical output of Niagara Falls to run it. Calculating machines certainly consume great quantities of electricity and generate considerable heat. It is probable that McCulloch's estimate is lavish because the brain almost certainly sends out and receives the same message through several fibres and cells so that we have more nervous tissue than we need and more, certainly, than we use if the meagre effects of excisions from some areas mean what we think they mean.

Wherein do any analogies lie? They lie in certain likenesses between wireless valves and nerve cells in this way, that the valves can be so wired as to store messages, to show the Sherringtonian principles of "convergence" and "divergence," can be inhibited from action, and may be arranged so as only to transmit a message (a symbol in terms of electricity) if they are receiving impulses from one or several other valves and not to transmit if other excitations fail to come in. The likeness between such an arrangement and that of the impulses arriving in a nerve cell through its dendrites and the behaviour of neurone pools is so close as to convince us that in these actions some nervous tissues with simple patterns behave extremely like some electronic circuits.* It gives additional support to the belief that human tissues behave according to some physical laws discoverable elsewhere in Nature, without surrendering their own individuality. This is a belief old enough to be both useful and respectable.

The fact that calculating machines can be made to store electrical charges representing numbers for long periods of time suggests that there is "memory" in the machine, which must in fact "remember" how far it has got with a calculation in order to be able to proceed, just as we do ourselves. It must also "remember" all the data and the procedure leading to solution. It retains its "memory" until it is cleared of its charges. Using electronic instead of nervous impulses it can carry out calculations with such great rapidity that it will solve a simple calculation in milliseconds, and in an hour one that would employ a mathematician several months. We are invited to consider that the memory that the machine has in the form of stored charges is perhaps the same as memory in man or in animal, as a "charge" in a cell or a group of those millions of cells whose individual uses we do not know.

All that one is entitled to say is that it could be something of that kind, but that the electrical machine offers no proof that it is so. We might guess so much without a machine, nor does it tell us what the nature of the "charge" in a nerve cell is, except to assume that it is electrical (for which there is no present justification). Damage to large parts of the human brain, entailing vast cell losses, can occur without serious loss of memory, and that is not true of calculating machines so far, though so large a one might be imagined that parts of it might be rendered inoperative without total loss of function. It can be urged, and it is cogent argument against the machine, that it can answer only problems given to it, and, furthermore, that the method it employs is one prearranged by its operator. The "facilities" are provided and can be arranged in any order by "programming" without rebuilding.

It may be objected that the second argument is equally true of man; our difficulty is in his case that we have not seen the blue-print from which he was constructed, and that we have been baffled by our attempts to reconstruct it. The first objection can be met by the counter proposition that man himself answers only such propositions as are put to him by his environment, and takes us back indeed to Aristotle's "Nihil est in mente quod non," etc., that our minds are built by education and experience data, processed by the machine, our brain. But the calculating machine which man makes himself throws no light on this problem; it only appears to do so.

There is another analogy of which Wiener has made interesting use. It is this: that computing machines with complicated circuits may develop spontaneous functional faults in which the operation circles endlessly in a closed loop instead of proceeding in the way intended. This is a not uncommon "disease" of electronic computing machines. It can be cured by cutting off the current, by shaking the machine, or by putting into it a "shock" charge. Wiener makes much of the likeness between this functional machine-illness and the methods employed in curing obsessional diseases in man (sleep or narcosis, leucotomy or E.C.T.). The likeness stands or falls on the acceptance of Moniz's suggestion, and it is no more, that an obsession is a chain reaction in neurone mechanisms by which a dominant idea blocks the normal functioning of mind and behaviour. It is a good analogy, but it neither proves nor disproves the theory that obsessions are in fact exactly of that kind. They are certainly vastly more complicated than the abnormal "circulation disease" in a calculating machine. I repeat that it is again only analogy, but it is one which the impulsive may much too easily accept as ambivalent proof of identity, simple and diagrammatic.

Wiener made the suggestion that the searching process in automatic telephone exchanges, by which unoccupied circuits are looked for by the electrical equivalents of incoming number combinations, is very likely the counterpart of what happens in the nervous system. This may be true, but the alternative pathways in the cord and brain are so great that "engaged" signals will be rare. "Previous engagement" might, however, account for the failure of some messages to reach consciousness, or explain in different language our inability to do several things at the same time. Comparisons with the scanning processes of television may yet prove instructive. Ideas such as these remind us that we do not need to accept exact similarity for us to look with renewed interest at old problems. They remind us how far we have advanced since we could be satisfied by comparing the nervous system with a hand-operated telephone exchange.

Thinking

The activity of the nerve cells in the grey matter even of an isolated segment of the spinal cord can be demonstrated by electronic detectors. The activity is greater when the cord is in continuity with the brain and falls to a minimum when the roots are divided. Of the vast stream of sense data that pour into our nervous systems we are aware of few and we name still fewer. For it is the fact that even percepta are wordless. Only by necessity do we put a vocabulary to what we touch, see, taste, and smell, and to such sounds as we hear that are not themselves words. We look at a landscape, at the rich carving and majestic architecture of a cathedral, listen to the development of harmonies in a symphony, or admire special skill in games and find ourselves woefully lacking in ability to describe our percepts. Words, as we very rightly say, fail us either to describe the plain facts of these experiences or to impart to others our feelings. Gesture at times speaks more tellingly than tongues.

From these plain truths has arisen the profession of the critic, who has himself to learn and to teach the public to accept a conventional paraphrasis, sometimes taking refuge in describing painting in terms of music and vice versa. The variety of the visual and general perceptual scene alone is too great for those frail instruments—words—and it is because of this that literature flourishes. But without using words, though richer in the variety of our experience and with words only just below the surface, our minds are not very dissimilar from those of animals, and it is not difficult to conjecture that a Trappist existence might, for a brief period, be not unpleasant. The development of this theme would take me too far, but it is necessary for us to bear it in mind in considering mechanism and thinking. Granted that much that goes on in our heads is wordless (for if it is not, then we must concede words, an internal vocabulary, to animals), we certainly require words for conceptual thinking as well as for expression. It is here that there is the sudden and mysterious leap from the highest animal to man, and it is in the speech areas of the dominant hemisphere rather than in the pineal that Descartes should have put the soul, the highest intellectual faculties.

It is almost boring to repeat that it is because he has a vocabulary that man's intellectual progress has been made possible—by the day-by-day record of how far he has gone in his pilgrimage towards finite knowledge, that journey

*I am obliged to my colleague, Professor Schlapp, for deductions which he drew chiefly from the Cambridge machine and for other wise comments.

without an end. We remember more, that language is not static, but that neologisms continually mark our progress not only in general ideas but in science. We use to-day scores of scientific terms that men who lived as recently as Priestley, Lavoisier, and Darwin would not understand. It is not enough, therefore, to build a machine that could use words (if that were possible), it would have to be able to create concepts and to *find for itself* suitable words in which to express additions to knowledge that it brought about. Otherwise it would be no more than a cleverer parrot, an improvement on the typewriting monkeys which would accidentally in the course of centuries write *Hamlet*. A machine might solve problems in logic, since logic and mathematics are much the same thing. In fact some measures to that end are on foot in my university's department of philosophy. If the machine typewrites its answers, the cry may rise that it has learned to write, when in fact it would be doing no more than telegraphic systems do already.

Nor must we overlook the limitations of the machines. They need very intelligent staffs to feed them with the right problems, and they will attempt the insoluble and continue at it until the current is switched off. Their great advantage is their speed compared with a human mind, and I have given reasons for that. But, it may be asked, is that so very much more marvellous than the crane that can lift so much more than can a man or than an automobile that can move so much quicker?

The great difference in favour of the calculating machine as compared with the crane, and I willingly allow it, is that the means employed are basically so similar to some single nervous lay-outs. As I have said, the schism arises over the use of words and lies above all in the machines' lack of opinions, of creative thinking in verbal concepts. I shall be surprised, indeed, if that gap is bridged, for even supposing that electrical charges could be made to represent words, what then? I cannot see that anything but jargon would result. Not until a machine can write a sonnet or compose a concerto because of thoughts and emotions felt, and not by the chance fall of symbols, could we agree that machine equals brain—that is, not only write it but know that it had written it. No mechanism could feel (and not merely artificially signal, an easy contrivance) pleasure at its successes, grief when its valves fuse, be warmed by flattery, be made miserable by its mistakes, be charmed by sex, be angry or depressed when it cannot get what it wants.

Conclusion

I conclude, therefore, that although electronic apparatus can probably parallel some of the simpler activities of nerve and spinal cord, for we can already see the parallelism between mechanical feed-backs and Sherringtonian integration, and may yet assist us in understanding better the transmission of the special senses, it still does not take us over the blank wall that confronts us when we come to explore thinking, the ultimate in mind. Nor do I believe that it will do so. I am quite sure that the extreme variety, flexibility, and complexity of nervous mechanisms are greatly underestimated by the physicists, who naturally omit everything unfavourable to a point of view. What I fear is that a great many airy theories will arise in the attempt to persuade us against our better judgment. We have had a hard task to dissuade man from reading qualities of human mind into animals. I see a new and greater danger threatening—that of anthropomorphizing the machine. When we hear it said that wireless valves think, we may despair of language. As well say that the cells in the spinal cord below a transverse lesion "think," a heresy that Marshall Hall destroyed 100 years ago. I venture to predict that the day will never dawn when the gracious premises of the Royal Society have to be turned into garages to house the new Fellows.

I end by ranging myself with the humanist Shakespeare rather than the mechanists, recalling Hamlet's lines: "What a piece of work is a man! How noble in reason! how infinite in faculty; in form, in moving, how express and admirable! in action, how like an angel! in apprehension, how like a god! the beauty of the world! the paragon of animals!" In that conclusion, if not always in my approach to it, I feel confident that I should have won the approval of that bold experimenter and noble character in whose remembrance this oration was founded.

THE USE IN CHILDREN OF PROCAINE PENICILLIN WITH ALUMINIUM MONOSTEARATE

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Frequent intramuscular injections of penicillin preparations to children often cause much pain and unhappiness. There have been many attempts to prolong the therapeutic action of a single injection by using penicillin added to bases relatively insoluble in water. Such preparations are based on the premise that a single injection will introduce into the body a depot of penicillin which will be released slowly, thus achieving a therapeutic concentration in the blood over a prolonged period.

Procaine penicillin G, described by Salivar, Hedger, and Brown (1948) and Sullivan, Symmes, Miller, and Rhodehamel (1948), is a relatively insoluble equimolecular combination of procaine together with the sodium or potassium salts of penicillin G. It is usually prepared as a suspension in a base of refined sesame or arachis oil. The clinical value of procaine penicillin has been described by Herrell, Nichols, and Heilman (1947) and Boger, Oritt, Israel, and Flippin (1948). In adults it is claimed that adequate blood levels can be demonstrated up to 24 hours after one injection of 300,000 units. Similar levels were found after single daily injections in children by Carson, Gerstung, and Mazur (1949). That blood levels in children 24 hours after a single injection may be variable has been shown by Emery, Stewart, and Stone (1949). It is realized, however, that procaine penicillin has considerable advantages over previous preparations.

Buckwater and Dickenson (1947) described a new vehicle for the intramuscular administration of penicillin, in which penicillin salts are suspended in peanut oil combined with aluminium stearate. It would seem that the aluminium ester