

Do Electrons think?

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Electrons are charged particles, the minutest type we find in analyzing the ~~simplest~~ ultimate constitution of matter. To think that such a particle can think is so ~~absurd~~ ~~patently~~ absurd, that I might give the answer No and ~~thus~~ ~~conclude~~ ^{have} my talk ~~finished~~ ^{finished} over. However the idea has been launched not very long ago. Not, of course, in this ~~crude form~~, in which it is patently absurd form, but under a disguise. I ~~have written~~ ^{of late} ~~it has~~ ^{met with quite} ~~occurred~~ ^{honourable} ~~met~~ ^{reception.} ~~intellectual~~ ^{has been} ~~set~~ ^{set} on it. I wish to plead here for the fertility of this hope. To explain matters I must go far back.

There is a very old dilemma in natural philosophy: are our bodies and ^{the bodies} ~~those~~ of the animals machines that act of necessity, ~~under influence of~~ ^{including} the ~~surrounding~~, including according to their material constitution and under the material influence of the ~~surrounding~~, ⁱⁿ environment, including the impressions ~~received~~ ^{on the} ~~by~~ ~~the~~ sense organs? eyes, ears, etc. ~~receive from the surrounding?~~ This question - are we automata? - has ~~been~~ ^{been} asked as often, answered emphatically in the ~~negative~~ ^{positive} as in the negative. It would lead us too far

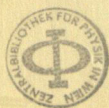


to follow ~~xxx~~ all the arguments that came to the fore in the long history of this controversy. Strange compromises were suggested. ~~According to~~ Descartes, for instance, deemed ^{us to be} ~~that~~ on the whole ~~xxx~~ ^{he said,} automaton, only the physical plane, ^{was not.} According to Descartes it was this organ which controlled and directed ~~all~~ ^{all our} ~~our~~ ^{spontaneous} ~~movements,~~ ^{movements,} ~~the~~ ^{the} ~~we~~ ^{we} ~~feel~~ ^{feel} ~~them~~ ^{them} ~~to~~ ^{to} ~~be~~ ^{be} ~~directed~~ ^{directed} ~~by~~ ^{by} ~~the~~ ^{the} ~~decisions~~ ^{decisions} ~~of~~ ^{of} ~~our~~ ^{our} ~~mind.~~ ^{mind.}

What is ^{attitude} ~~According to~~ the present ~~attitude~~ ^{to the question} of physiology? ~~for which~~ ^{for it} He may take the word of its great master Sir Charles Sherrington. ^{According to Sherrington} there is no boundary between the animate and the inanimate.

The same laws of physics and physical chemistry hold within the living body as outside. ~~At~~ ~~the~~ ~~most~~ ~~careful~~ ~~investigation~~ ~~of~~ ~~all~~ ~~physiological~~ ~~processes,~~ ~~including~~ ~~those~~ ~~in~~ ~~the~~ ~~nervous~~ ~~and~~ ~~in~~ ~~the~~ ~~brain,~~ ~~reveals~~ ~~no~~ ~~leverage~~ ~~whereby~~ ~~mind~~ ~~could~~ ~~take~~ ~~direct~~ ~~influence~~ ~~on~~ ~~matter.~~ "Mind, ^{per se (that is by its very nature)} ~~of its own,~~ ^{per se (that is by its very nature)} cannot play the piano - mind ~~of its own~~ cannot move a finger of a hand."

This leaves us with the outlook that our body is as automatic or non-automatic as any ~~other~~ ~~matter,~~ ~~any~~ ~~mechanical,~~ ~~chemical,~~ ~~electrical,~~ ~~mechanical,~~ ^{piece} ^{of} ~~matter,~~ ^{contrivance} ~~only~~ ~~infinitely~~ ~~more~~ ~~complicated~~ ~~than~~ ~~even~~ ~~the~~ ~~most~~ ~~ingenious~~ ~~man-made~~ ~~mechanism.~~ ^{mechanism.} The question



is ~~as to~~ ^{thus} ~~referred~~ ^{referred} from the tribunal of physiology to that of physics and chemistry. But in the tribunal ~~keeping to~~ - to keep to the simile for a moment - there sits by the side of the judges a non-jurisprudent assessor, namely our own little self which finds it distasteful to ~~be~~ ^{pass for} an automaton.

Now what does physics say to it? ^{The situation} ~~Here we meet~~ ^{is} peculiar, ~~situation~~. From the earliest beginnings of physical science we meet with the firm conviction, that ~~all~~ ^{everything that happens is} ~~occurs~~ ^{governed} by inviolable laws, so that the course of ~~happening~~ events forms an ~~unalterable~~ ^{unalterable} and ~~inevitable~~ ^{inevitable} and unalterable infinite sequence of causes and effects.

The first atomic physicist was Leucippus, a contemporary of Socrates in the fifth century B.C. ^{any} From ~~the~~ ^{the} ~~sayings~~ ^{sayings} of Leucippus only two sayings are ~~reported~~ ^{preserved}, one that he refused to believe that sun, moon and the stars are living beings, the other, that nothing comes to pass without a cause, but everything happens ~~by~~ ^{by} reason and of necessity. That ~~he~~ ^{he} ~~said~~ ^{maintained} in the 5th century B.C. Toward the end of the 19th century A.D. physicists were ^{fully} prepared to endorse ~~his~~ ^{his} opinion.

But now comes the peculiar thing. Inve within $2\frac{1}{2}$ thousand years there was a notable departure from the belief in ^{the} strict necessity of physical events.

time ~~the~~ this happened
 The first ~~was suggested by Epic~~ only about a 150
 years after Leucippus, ~~by Epicurus~~ as he
 gather ^{this} from the didactic poem of Lucretius ~~who lived~~
 who was ^{the posthumous} Epicurus a month-piece ~~in the first~~
 in the 4th ^{Their suggestion} century B. C. The second ~~departure~~ ^{occurred} ~~it had~~
 no consequences, it was all but forgotten. The
~~second time~~ The second time the strictly causal
 linkage ~~between~~ ^{between} talks in the chain of physical
~~the~~ ^{on} happenings was thrown into doubt
 30 years ago by Franz Exner in Vienna. About
 10 years later the disbelief in strict ^{causation} ~~causality~~
 became part and parcel of the New Creed now
 adopted by most physicists and called Quantum
 Mechanics.

Both times, ~~in the century of Lucretius~~ ^{by Lucretius} ~~by Lucretius~~
~~about 600 B. C.~~ ^{in our days} ~~and again quite necessarily~~
~~by some~~ ^{atomic} physicists, the break
 down of strict causality in the ~~domain~~ ^{domain} of physics
 was hailed for removing the obstacle in ^{our} under-
 standing the spontaneity ^{of the} ~~movements~~ of the
 animals and of man - ~~free~~ ^{free} ~~for~~ ⁱⁿ understanding
 free will, as one usually calls it. Let us see
 whether this claim is justified.

The hypothesis, as reported by Lucretius, was
 very simple indeed. He ^{justly} ~~simply~~ states that the
 atoms ~~do~~ ^{swerve} ~~swerve~~ in a very small but certainly

undetermined end inforeseeable way from the
 courses you would expect them to take from
 the supposed strict physical laws. No theory of the
~~swerves~~ ^{is} offered. This amounts to saying that
~~there are no strict laws~~ the strict laws are
 only fictions, The actual ^{path} ~~behaviour~~ of a
 particle is to a small extent arbitrary in the
 neighbourhood of the fictitious prescribed path.
 It is ^{not quite} ~~absolutely~~ illogical to surmise that the
~~apparent~~ ^{several little} ~~to~~ arbitrarinesses ^{of the single atoms} collaborate to bring
 about the apparent ~~to~~ arbitrariness in the
 behaviour of the animals ^{and} of ~~the~~ man. What
 Lucretius forgets is that he has ~~thereby~~ ~~thus~~
 explained, nothing, he has solved no problem.
 He has only referred ^{the problem} ~~it~~ back to the ultimate
 particles, where it has become much more difficult
 to grapple with. The simplest spontaneous ^{body's} ~~move-~~
 ment, say the lifting of my arm, would require
 the planned collaboration of billions of single
 atoms in their undetermined swerves, if they
 should bring about the interpreted action. The
~~mutual coordination of swerves would imply laws of~~
~~interaction much more complicated than anything~~ ^{the} ~~subject~~
~~or the physicist has ever~~ ~~tried to conceive.~~

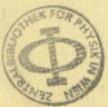
The ^{denial} ~~abrogation~~ of strict ^{causation} ~~causality~~ in modern
 physics is of entirely different nature, in two
 respects. First there is no question of ^{only} small
 departures from a fictitious exact law of motion.



The behaviour of minimal particles, as electrons for instance, or of small atomic systems composed of only a few of them, is now supposed to be indeterminate and unpredictable within wide limits, a wide margin of uncertainty. It is thought that in times we have to allow ~~that~~ ^{a particle} the choice between several entirely different courses to take. ~~But~~ Let this for the moment be ~~only~~ ^{for} figurative speech, meaning only that nothing in the observed situation determines the course ~~the~~ particle actually takes. But on the other hand the ~~same~~ situation is supposed to determine with rigorous precision the statistics of the various possible "choices" ^{for} ~~in~~ ^{of} given the same situation over and over again the particle will, for instance, in exactly two thirds of the cases follow one course, in one third of the cases the other one; and similarly when there are more than two courses to follow.

Again, the same as 2000 years ago, it has been suggested that this breach of strict causation leaves room for ~~moderation~~ ~~the~~ ~~strictly~~ the display of ^{the spontaneous} ~~arbitrary~~ movements in the animals and in man. Is this claim justified? I think not. There are grave objections from physics, from physiology and from philosophy.

From physics: if the individual or its mind or whatnot could make free use of ~~the~~ ^{the} "choice"



left to the single electrons, ~~it~~ ^{this} would infringe the statistical laws, when a synoptic ~~view~~ view of many similar cases is taken. This is as bad or as good as a breach of ~~the~~ strictly causal laws. If we suspend physics in the living body we can explain ~~whatever we wish to explain~~ ^{anything}. I have put this point briefly and drastically. It could be clinched in all detail.

To ~~understand~~ ^{explain} the physiological objection, let me still observe, that physics strictly disallows a mutual dependence of the "choices" taken by various electrons (~~or small atomic systems~~ ^{various}) that unless they are close neighbours, ~~are at any distance from each other~~. One would therefore have to assume - and this has been proposed - a master-cell and within it a master-molecule, ~~where~~ ^{here} the choice on the atomic scale ^{would} take place ~~and~~ ^{and} determine a spontaneous movement of the whole body. This is ~~in~~ flatly contradicted by what we know about the ~~very~~ functioning of the brain. The number of ~~cooperating~~ brain cells cooperating in such a case is enormous and the idea that they should ^{always} be set at work by one master-cell - even if it were not ^{to be} always the same one - is ~~very~~ ludicrous.

But assume you could override even this objection - there might be a delicate system of relais - ^{may} action which we have hitherto failed to discover.

Then ~~we are~~ I am left to believe that a single electron or a very few of them, by making use of the free "choice" the primitive laws of physics leave

However ~~that~~ them, should enact a movement of my body, ~~but~~ this movement is some times which I feel ~~to~~ ~~be~~ ~~may~~ ~~have~~ ~~been~~ ~~preceded~~ ~~by~~ the result of a long deliberation, a careful weighing of motives and maybe painful weighing of motives, which ~~this~~ ultimately ~~disposes~~, say, ~~to~~ ~~open~~ my mouth ~~and~~ to pronounce ~~a~~ ~~name~~ the name of a person I hesitated to give away.

It is not only obvious but factually indubitable that ~~them~~ preliminary ~~deliberations~~ ~~some~~ ~~decisions~~ involve ~~not~~ extended parts of the brain, billions and billions of cells. ~~But~~ ~~to~~ assume that their activity eventually ~~determines~~ the decision ~~of~~ ~~the~~ ~~master~~ ~~group~~ in the supposed master-group of electrons would entirely spoil the game; ~~of~~ ~~later~~ for ~~the~~ ~~point~~ ~~was~~ ~~that~~ ~~their~~ ~~behaviour~~ was to be exempt from ~~deliberation~~ ~~and~~ ~~physical~~ ~~causation~~. ~~To~~ ~~maintain~~ ~~this~~, ~~is~~ ~~impossible~~ ~~unless~~ ~~you~~ ~~are~~ ~~ready~~ ~~to~~ If you want to keep this up, you needs must be prepared to let all the ~~weighing~~ ~~and~~ ~~weighing~~ of motives be done by the ~~one~~ ~~master~~ ~~group~~ of electrons ~~alone~~ ~~and~~ ~~themselves~~. ~~And~~ ~~this~~ ~~is~~ ~~absurd~~. without any accompanying physical process. This is absurd.

Do electrons think ?

Electrons are charged particles, the minutest we find in analysing the ultimate constitution of matter. To think that such a particle can think is so absurd, that I might give the answer No and have my talk over. However the idea has been launched not very long ago. Not, of course, in this patently absurd form, but [↑]under a disguise[↑]. Of late it has off and on met with quite honourable reception. Some intellectual hope has been set on it. I wish to plead here for the futility of this hope. To explain matters I must go far back.

There is a very old dilemma in natural philosophy: are our bodies and the bodies of the animals machines that act of necessity, according to their material constitution and under the material influence of the environment, including the impressions on the sense organs ? This question - are we automats ? - has about as often been answered emphatically in the positive as in the negative. It would lead us too far to follow all the arguments that came to the fore in the long history of the controversy. Strange compromises were suggested. Descartes, for instance, deemed us to be on the whole automats, only the pineal gland, he said, was not. According to Descartes it was this organ which controlled and directed all our spontaneous bodily movements.

What is the present attitude of physiology to the question ?

We may take for it the word of its past master Sir Charles Sherrington. According to Sherrington there is no boundary between the animate and the inanimate. The same laws of physics and physical chemistry hold within the living body as outside. The most careful investigation of the physiological processes, in the nerves and in the brain, reveals no leverage whereby mind could take direct influence on matter. "Mind, per se (that is by its very nature), cannot play the piano - mind per se cannot move a finger of a hand."

This leaves us with the outlook that our body is as automatic or non-automatic as any inanimate piece of matter, any mechanical, chemical, electrical contrivance, only infinitely more complicated than even the most ingenious man-made machinery. The question is thus referred from the tribunal of physiology to that of physics and chemistry. But in the tribunal - to keep to the simile for a moment - there sits by the side of the judges a non-jurisprudent assessor, namely our own little self which finds it distasteful to pass for an automaton.

Now what does physics say to it? The situation is peculiar. From the earliest beginnings of physical science we meet with the firm conviction, that every thing that happens is governed by inviolable laws, so that the course of events forms an inevitable and unalterable infinite sequence of causes and effects. The first atomic physicist was Leucippus, a contemporary of Socrates in the fifth century B.C. Of Leucippus only two sayings are preserved, one that he refused to believe that

sun, moon and the stars are living beings, the other, ^{which concerns us here, namely} that nothing comes to pass without a cause, but everything happens by reason and of necessity. This he maintained in the 5th century B.C. ^{and} Toward the end of the 19th century A.D. physicists were fully prepared to endorse his opinion.

But now comes the peculiar thing. Twice within $2\frac{1}{2}$ thousand years there was a notable departure from the belief in the strict necessity of physical events. The first time this happened only about 150 years after Leucippus. We gather this from the didactic poem of Lucretius, who was the posthumous mouth-piece of Epicurus, who lived in the 4th century B.C. Their suggestion had no consequences, it was all but forgotten. The second time the strictly causal linkage in the chain of physical happenings was thrown into doubt 30 years ago by Franz Exner in Vienna. About 10 years later the disbelief in strict causation became part and parcel of ^{what you might call} the New Creed now adopted by most physicists and called Quantum Mechanics.

^{alleged} Both times, the break-down of strict causality in the domain of physics was hailed for removing the obstacle in our understanding the spontaneity of the movements of the animals and of man - in understanding free will, as one usually calls it. Let us see whether this claim is justified.

The hypothesis, as reported by Lucretius, was very simple, indeed. He just states that the atoms do swerve in a very small but entirely undetermined and unforeseeable way from the

courses you would expect them to take from supposed strict physical laws. No theory of the swerves is offered. This amounts to saying that the strict laws are only figments. The actual path of a particle is to a small extent arbitrary in the neighbourhood of the fictitiously prescribed path. It is not illogical to surmise that the several little arbitrarinesses of the single atoms collaborate to bring about the apparent arbitrariness in the behaviour of the animals and of man. What Lucretius forgets is that he has explained nothing, he has solved no problem. He has only referred the problem back to the ultimate particles, where it has become much more difficult to grapple with. The simplest spontaneous bodily movement, say the lifting of my arm, would require the planned collaboration of billions of single atoms in their undetermined swerves, if they should bring about the integrated action.

In modern physics the denial of strict causation is of entirely different nature, in two respects. First there is no question of only small departures from a fictitious exact law of motion. The behaviour of primal particles, as electrons for instance, or of small atomic systems composed of only a few of them, is now supposed to be undetermined and unforeseeable within a wide margin of uncertainty. It is thought that in times we have to allow a particle the choice between several entirely different courses to take. Let this for the moment be figurative speech, meaning only that nothing in the observed situation determines the course the particle

L actually takes. L But on the other hand the situation is supposed to determine with rigorous precision the statistics of the various possible "choices". Given the same situation over and over again the particle will, for instance, in exactly two thirds of the cases follow one course, in one third of the cases the other one; and similarly when there are more than two courses to follow.

Again, the same as 2000 years ago, it has been suggested that this breach of strict causation leaves room for the display of the spontaneous movements in the animals and in man. Is this claim justified? I think not. There are grave objections from physics, from physiology and from philosophy.

From physics: if the individual or its mind or whatnot could make free use of the "choice" left to the single electrons, this would infringe the statistical laws, when a synoptic view of many similar cases is taken. This is as bad or as good as a breach of strictly causal laws. If we suspend physics in the living body we can explain anything. I have put this point briefly and drastically. It could be clinched in all detail.

To explain the physiological objection, let me still observe, that physics strictly disallows a mutual dependence of the "choices" taken by various electrons unless they are close neighbours. One would therefore have to assume - and this has been proposed - a master-cell and within it a master-molecule. Here the choice on the atomic scale would take

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place and determine a spontaneous movement of the whole body. This is flatly contradicted by what we know about the functioning of the brain. The number of brain cells cooperating in such a case is enormous and the idea that they should always be set at work by one master-cell - even if it were not to be always the same one - is ludicrous.

But assume you could override even this objection - there might be a delicate system of relay-action which we may have hitherto failed to discover. Then I am left to believe that a single electron or a very few of them, by making use of the free "choice" the primitive laws of physics leave them, should enact a movement of my body. However this movement is sometimes preceded by a long deliberation, a careful and maybe painful weighing of motives. This ultimately disposes, say, my mouth to open and to pronounce the name of a person I hesitated to give away. L 28

It is not only obvious but actually indubitable that the preliminary deliberations involve extended parts of the brain, billions and billions of cells. To assume that this activity eventually determines the decision in the supposed master-group of electrons would entirely spoil the game; for the point was that their behaviour was to be exempt from physical causation. If you want to keep this up, you needs must be prepared to let all the thinking and weighing of motives be done by the one master-group of electrons alone and without any accompanying physical process. This is absurd.