THE VALUE OF STATISTICAL LAWS IN PHYSICS AND SOCIAL SCIENCES[1]

Ettore Majorana

Ettore Majorana (Catania, 1906- ?) was accepted into Enrico Fermi's group due to his renowned talent for Physics. He spent the winter of 1933 studying with Heisenberg in Germany, when Hitler was at the height of his powers. However, the young Sicilian was also a religious man, who contemplated with horror the possibilities of nuclear fission. On his return to Italy, when Mussolini began to be interested in his work, he took a decision: in no way would he collaborate in the making of an atomic bomb. He organized his own disappearance, and he was last seen on the night of 25th March, 1938 on the deck of the Naples-Palermo post-boat. Some days later, his distraught mother found, in a box in his worktable, this article, which we publish here translated into English.
In addition to this translation, we provide the reader an interpretation of the life and work of Majorana and a brief sociological commentary.

Ettore Majorana.- Last article.- Physical statistics.- Social statistics.- Indeterminism.- Sociological Commentary

MAJORANA: MATERIALS FOR A BIOGRAPHY

(By Carlos Allones Pérez)

Youth

Ettore Majorana was born in Catania, Sicily, in 1906, in the bosom of a family of lawyers, engineers and politicians. When he was 11 his family moved to Rome and Ettore continued his secondary education at a Jesuit school and later got a place at the Engineering School of Rome University. Some of the students at this school tended to complain about the excessively technological character and applied nature of the classes which the teachers gave as they were more interested in theoretical speculation. These

[1] The Spanish version of this article can be found in C. ALLONES (2004): "El valor de las leyes estadísticas en la Física y en las Ciencias Sociales", *Empiria*, núm. 7, (pp 183-209). Madrid

students gathered around Enrico Fermi, who was a professor at the Physics Institute in Rome. Emilio Segrè, a childhood friend of Ettore and also a Sicilian, was one of these dissatisfied students and it was he who took Ettore for the first time to the Institute of *Via Panisperna* and introduced him to Fermi. As a result Ettore gave up Engineering and started to study Theoretical Physics. He read his Thesis *"Sulla mecánica dei nuclei radioattivi"*, which was supervised by Fermi, on the 6th July, 1929.

From the very first moment the "Kids from Via Panisperna" (as the Fermi disciples were called in Rome) were most impressed by Majorana's intellectual qualities. What most struck them was his critical spirit, which he applied both to his own work and other people's and which earned him the nickname of "The Great Inquisitor". His ingenuity for choosing the easiest and most elegant way of facing problems, based on an "almost prophetic" (AMALDI 1966: 81) sense of intuition, which, nevertheless, scrupulously respected the experimental results. His authority in the mathematical expression of these intuitions, in which he took risks in putting forward symmetries which greatly simplified their resolution, etc… All these elements made Majorana, according to his colleagues (who included figures such as Fermi, Segrè, Heisenberg, Amaldi…) a theoretical figure of the first standing, who stood out from the rest, and whose opinions, in any case, were worth taking into account…

What also resulted attractive was his original personality, as it seemed as if he studied Physics more as a hobby than as a profession, as if he was one of those characters which his admired Pirandello created, about whom we never know for sure if they are part of the plot or not.[2]

In his excellent biography of Majorana, Edoardo Amaldi, the great institutional figure of Physics in Italy in the post-war period, and his personal friend, tells us various anecdotes from Majorana's youth which allow us to get to know him more closely. From all of them we have chosen this one:

> "Towards the end of January, 1932, we began to receive the issues of the "Comptes rendues" containing the famous notes by F. Joliot and I. Curie on the penetrating radiation discovered by Bothe and Becker.
> In the first of these notes it was shown that the penetrating radiation emitted by Be under bombardment with polonium *alfa* particles could transfer kinetic energies of about 5 millions electron volts to the proton present in small layers of various hydrogenated materials (such as water or cellophane). In order to interpret these

[2] Refer in particular to *The deceased Matias Pascual* (1904).

observations the Joliot-Curies (1923)[3] at first put forward the hypothesis that the phenomenon was similar to the Compton effect, namely that the incident photon undergoes an elastic collision with a proton; they had calculated, by applying the laws of energy and momentum conservation, that the incident photons should have had an energy of about 50 million electron volts in order to be able to transfer such high energy to a proton. However, they had very soon realized that when Klein and Nishina's formula was applied to the protons, the cross-section was too small by many orders of magnitude, and had suggested that the effect observed was due to a new type of interaction between *gamma* rays and protons, different from that responsible for the Compton effect.
When Ettore read these notes he said, shaking his head: "They haven't understood a thing. They are probably recoil protons produced by a heavy neutral particle". A few days later we got, in Rome, the issue of *Nature* containing the letter to the editor from Chadwick dated 17 February, 1932, entitled "Possible existence of a neutron", in which he demonstrated the existence of the neutron on the basis of a classical series of experiments, in which recoil nuclei of some light elements (such as nitrogen, for instance), were observed in addition to recoil protons. (Amaldi 1966: 50)
Amaldi continues: "Soon after Chadwick's discovery, various authors understood that the neutron must be one of the components of the nucleus and began to propose various models which included *alfa* particles, protons, electrons and neutrons.
The first to publish the idea that the nucleus consists solely of protons and neutrons was probably Iwanenko (1932). Neither I nor his other friends questioned remember whether Ettore Majorana came to this conclusion independently. What is certain is that before Easter of that year he tried to work out a theory on light nuclei, assuming that they consisted solely of protons and neutrons (or neutral protons as he then said) and that the former interacted with the latter through exchange forces. He also reached the conclusion that these exchange forces must act only on the space co-ordinates (and not on the spin) if one wanted the *alfa* particle, and not the deuteron, to be the system saturated with respect to binding energy.
He talked about this outline of a theory to his friends at the Institute, and Fermi, who had at once realized its interest, advised him to publish his results as soon as possible, even though they were partial. However, Ettore would not hear of this, because he considered his work to be incomplete. Thereupon, Fermi, who had been invited to participate in the Physics conference which was to take place in July of that year in Paris in the wider framework of the Fifth International Conference on Electricity, and who had chosen as his subject the properties of the atomic nucleus, asked Majorana for permission to mention his ideas on nuclear forces. Majorana forbade Fermi to mention them but added that if he really must he should say they were the ideas of a well-known professor of electrical engineering who, among others, was to be present at the Paris conference and whom Majorana considered to be a living example of how not to carry out scientific research.
Thus, on 7 July, Fermi presented his report in Paris on "The Present State of the Physics of the Atomic Nucleus" (1932) without mentioning the type of force which was subsequently called "Majorana force" and which had actually been thought of, although in a crude form, some moths earlier.
The issue of the "Zeitschirft für Physick" dated 19 July, 1932, contained Heisenberg's first paper on "Heisenberg's exchange forces", namely forces involving the exchange of both the space and spin coordinates.
This paper made a great impression in the scientific world; it was the first attempt to put forward a theory of the nucleus which, although incomplete and imperfect,

[3] The dates in brackets indicate the year of publication for the scientific articles which we refer to here, and they can be found correctly referenced in the text by AMALDI (1966) which on these pages we are using.

succeeded in overcoming some theoretical difficulties which had so far seemed insurmountable. Everyone at the Physics Institute of the University of Rome was extremely interested and full of admiration for Heisenberg's results, but at the same time disappointed that Majorana had neither published nor even allowed Fermi to mention his ideas at an international conference. Heisenberg's paper tackled the problem from a wider and fuller point of view but Ettore Majorana had completely understood, or so at least it appeared to us, the consequences of the action of the exchange forces in so far as the binding energy of light nuclei was concerned.
Fermi again tried to persuade Majorana to publish something, but all his efforts and those of his friends and colleagues were in vain. Ettore replied that Heisenberg had now said all there was to be said and that, in fact, ha had probably even said too much. Finally, however, Fermi succeeded in persuading him to go abroad, first to Leipzig and then to Copenhagen, and obtained a grant from the National Research Council for his journey, which began at the end of January, 1933 and lasted six or seven months." (Amaldi 1966: 51-53)

That year in Germany Majorana was a direct witness of Hitler's rise to power. On 30 January, after a long government crisis, Hindenburg constitutionally appointed Hitler Chancellor of the Reich; on 27 February the Reichstag fire was engineered by the Nazis and attributed by them to the communists. On 28 February, taking advantage of the impression produced by the Reichstag fire, Hitler made Hindenburg sign a document suppressing the articles of the Constitution guaranteeing individual and civil liberty. On 5 March new elections were held, and on 21 March the first meeting of the new Reichstag of the Third Reich was held; the Nazis did not yet have a majority, but they had enough power to succeed during the next few days in putting Hitler finally in power.

To finish with the anecdote, which is so typical of Majorana's attitude as regards his academic career, Amaldi tells us:

"Feenberg remembers attending one of Heisenberg's seminars on nuclear forces, in which Heisenberg also mentioned the contribution made by Majorana to this subject; he said that he author was present and invited him to say something about his ideas, but Ettore refused. When he left the seminar, Uhlenbeck told Feenberg how much he admired Majorana's penetrating ideas which had been mentioned by Heisenberg.
During this period Majorana became friendly with Heisenberg, for whom he always had a great admiration and a feeling of friendship. It was Heisenberg who persuaded him without difficulty by the sheer weight of his authority to publish his paper on nuclear theory, which appeared in the same year, 1933, both in the *Zeitschrift für Physik* and in *Ricerca Scientifica*." (Amaldi 1966: 56)

Majorana's first disappearance

But let us stay a little bit longer with Amaldi:

> "When he returned to Rome in the autumn of 1933, Ettore was not in good health, because of gastritis which he had developed in Germany. It is not clear what caused this, but the family doctors attributed it to nervous exhaustion.
> He began to attend the Institute in the Via Panisperna only at intervals, and after some months no longer came at all: he tended more and more to spend his days at home immerse in study for a quite extraordinary number of hours.
> At that time he was more interested in political economy, politics, the fleets of various countries and their respective power, and the constructional characteristics of the ships than in Physics. At the same time his interest in philosophy, which had always been great, increased and prompted him to reflect deeply on the works of various philosophers, particularly Schopenhauer.
> It was probably at this time that he wrote the paper on *The value of statistical laws in Physics and the Social Sciences* which was found among his papers by his brother Luciano, and was published after his disappearance by Giovanni Gentile junior.
> In addition to these old and new interests he found a new one on medicine, a subject which he perhaps tackled in order to understand the symptoms and significance of his illness.
> A considerable number of attempts by Giovanni Gentile junior, Emilio Segré and myself to bring him back to living a normal life met with no success. I remember that in 1936 he rarely left the house, not even to go to the barber's, and his hair was therefore abnormally long; during this period some of his friends who had been to see him sent him a barber, in spite of his protests. However, non of us succeeded in finding out whether he was still doing theoretical physics research; I believe he was, but I have no proof." (Amaldi 1966: 57-8)

All of which begs the question. What investigations were being carried out at that time at the Via Panisperna in which we know for sure Ettore Majorana did <u>not</u> participate? Those which were made between 1934 and 1935 by Enrico Fermi and some of his collaborators: Amaldi, D'Agostino, Pontecorvo, Rasetti, y Segrè.

After the announcement made by Joliot-Curie at the beginning of 1934 of the discovery of artificial radioactivity induced by an *alfa* particle, E. Fermi suggests to Rasetti the possibility of observing analogous effects, though this time induced by neutrons. On the 25th March a letter to the *Ricerca Scientifica* announces the first results of the systematic bombardment of the successive chemical elements in a growing order of atomic number; in the following months (April and May) the group publishes in rapid succession an ample series of new results, which were about to allow the start of a systematic classification of the nuclear reactions produced by neutrons. Meanwhile it becomes evident that there is a clear difference between light and heavy elements: in the first the active product has a smaller number Z than in the original nucleus, whereas in the heavy elements, with the exception of Uranium and Thorium, the active product is always an isotope of the bombarded nucleus.

The importance of this investigation received ample recognition in other countries, particularly from Lord Rutherford and his group in the Cavendish Laboratory. In particular, Amaldi and Segré, sent on assignment by Fermi, visit him in Cambridge in July 1934.

In that moment it was still not clear if the reaction produced by isotopes of the bombarded nucleus were of type (n, *gamma*) or of type (n, 2n). A variety of considerations and results made Fermi's group favour more the first hypothesis, even though this demonstrated that the "single-particle" model of the nucleus was inadequate.

The second phase of Fermi research starts in September 1934 and leads almost immediately to the discovery of the powerful influence over the processes (n, *gamma*) of the hydrogenated substance placed around the spring. Fermi recognizes that the effect is due to the slowing down of the neutrons which is a result both of the elastic collisions with the protons present in the environment and the increases of the effective section when the energy of the neutrons decreases.

In 1935 the research continues on a theoretical level and on an experimental level; in particular the problem of the selective absorption of slow neutrons was analyzed, and this led, in the winter 1935-36, to an understanding of multiple aspects of the processes of radioactive capture. It was at this very same moment, in February 1936, the fundamental theoretical papers by Bohr and by Breit and Wigner appear.

However, the most transcendental element for the history of Physics had occurred almost at the beginning of this research, as in the spring of 1934 nothing less than a nuclear fission had taken place *for the first time!…* And what is even more extraordinary is that Fermi's group *did not realize what had happened!*

Indeed, in May 1934 Fermi was irradiating Thorium and Uranium, but with the bombing of the Uranium some effects and some unexpected activities appeared which gave rise to certain difficulties in identifying the nuclei produced. Nevertheless Fermi and his group offered their habitual interpretation, and as Uranium was the last of the elements identified, with the order number Z = 92, they concluded that the Uranium had caused the formation of an unknown *neighbour* with an order number higher than 92, something known as *trans-uranium*, and they published their results accordingly.

It was Ida Noddack alone who criticized this interpretation[4] and suggested that the nuclei of heavy elements bombarded by neutrons could break into various larger pieces (larger than the *alfa* particles or protons), thereby forming isotopes of known elements, though *not* neighbours of those irradiated.

However, her suggestion seemed to be more of a speculation aimed at revealing the lack of rigour in Fermi's arguments about the formation of element 93 than a truly serious explanation of the observations. On the other hand, in this year Hahn and Meitner confirmed Fermi's conclusions and consequently the Rome group abandoned the "Uranium puzzle", and concentrated especially on the study of the absorption of slow neutrons and rejected, without hardly considering it, Noddack's interpretation. This was something that Amaldi would regret for the rest of his life:

> "I seem to remember some discussions among members of our group, including Fermi, in which the ideas of Ida Noddack were hastily set aside because they involved a completely new type of reaction. Enrico Fermi, and all of us at his school followed him, had always been very reluctant to invoke a new phenomena as soon as something new was observed: new phenomena have to be proven! As later developments have shown, a much more fruitful attitude would have been to try to test Noddack's suggestion and to eventually disprove it. But Fermi and all of us were, on that occasion, too conservative: an explanation of the "uranium case" in terms of what we have found for all lower values of Z was much simpler and therefore preferable. Two reasons or, maybe, two late excuses… She never tried, alone or with her husband, to carry out experiments on irradiated uranium, which

[4] I. NODDACK, Über das Element Z = 93, *Angewandte Chemie,* 47, 1934, 653-655, September 10, 1934.

> they certainly could have done. Furthermore, in those years the Noddacks had fallen into some disrepute because of their claim to have discovered element Z = 43, which they have called "masurium"." (Battimeli and Paoloni eds. 1998: vi).

Nevertheless, O. Hahn can't have been very satisfied with his own interpretation of the bombing of Uranium and he undertook over many years, in partnership with F. Strassmann, a meticulous radio-chemical analysis of the waste products. This led him to inform in December 1938 that, contradicting all the previous experiences of nuclear Physics,

> "… our isotopes of Radium have the chemical characteristics of Barium. If we speak as chemists, we should even have to say these new substances are Barium and not Radium."[5] (Amaldi 1984: 27)

Nuclear Fission had been discovered![6]

This is precisely the investigation that Majorana did <u>not</u> make. However, at the same time, during all those years, shut up in his house, what is it that <u>he did do</u>? Or what is it that *he wanted* to do?

Precisely what he did do was to write the article which we are studying, in which Majorana refers to *two* physical phenomena, whose statistical behaviour reminded him of some physical phenomena, and which help him to reflect on the determinism *in human acts*.

In the first he shows us how the macroscopic state of a gas hides many possible internal configurations in the instantaneous spatial disposition of the molecules which compose it, a disposition which, due to practical difficulties of observation, we cannot know at a specific moment. What we are able to calculate is the number of these possible

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[5] But what was more exciting were the calculations (which Fermi and his *lads* at that time were unable to make) of the immense energy liberated in such a fission. Using as a base the energy produced in normal chemical reactions, the fission of the atom produced 200 millions times more!
Furthermore, in contrast to what was then thought, when in the spring of 1940 Frisch and Peierls calculated for the first time, for Uranium 235, the *critical mass* capable of provoking a chain reaction it was discovered, to everybody's surprise amazement that only 500 grams were needed!
So that, after all, an atomic bomb was physically possible, at least in theory!

[6] (Refer to AMALDI 1984). I thank François Albert Kazadi (Doctor in Physical Science of the USC) for his help in interpreting the questions dealt with here which are strictly about Physics.

configurations, and those that are of the highest probability, from an energetic point of view (which correspond with the macroscopic state of greater entropy). And this allows us to foresee, with absolute security (except for an insignificant number of exceptions) the macroscopic evolution of the system during a time t.

Here, at macroscopic level, there is no in-determination (or an insignificant level), but rather there is, at a microscopic level, a practical incapacity of observation.

The second is the phenomena of the natural radiation of a single concrete atom. It takes place unexpectedly, in isolation, nothing is done to start it, nothing can be done to stop it, and we are unable to say if it is going to happen or not. What we are able to do, if we have a specific simple chemical element, is to calculate statistically how long it is going to take for half of this mass to be transmuted by natural radiation. We know that a specific number of atoms are going to emit an *alfa* particle or a *beta* particle spontaneously, transmuting itself into another element, but not which atom in particular is going to do so.

Here there is genuine in-determination in the behaviour of the isolated atom (it is not due to practical difficulties of observation) although not in the statistical behaviour fo the mass which it forms with all the rest.

This unpredictability in the individual behaviour and, on the other hand, the mathematical security in the prediction of the collective behaviour, could in the 30's scandalize the atomic physicist who for the first time came up against it, whereas for sociologists this experience is our 'bread and butter' which has accompanied us from the very beginning of our Science. Maybe it was for this reason that Majorana began to be interested in Sociology.

Given, for example, the statistical regularity in the number of road accidents at national level on specific dates, the sociologist will be able to predict with sufficient accuracy (with a perhaps insignificant number of errors) the total number of accidents which are going to occur the next long weekend bank holiday in (when normally 10.000.000 car journeys are made every year). Certainly something which would help us a great deal to accurately identify this number would be to know the journeys made for work or for pleasure by each of the users of the road network on these dates, something which is relatively impossible for practical motives. This example reminds us of that of gas (whose macroscopic evolution can be determined with a high level of security).

But even this prediction will tell us nothing about if Fred Bloggs in particular is going to have an accident on this bank holiday or not, nor when (at what time), nor where, nor how, nor why. This example reminds us of how impossible it is to predict the natural radiation of a concrete atom: here there is (and there always be) a genuine in-determination.

So, in his article Majorana now attacks head-on, and he does so with all his proverbial ingenuity and *directness*, which he had already shown in Physics, the problem which in our opinion is the first and foremost of all Sociology, this being the problem of the determinism of human actions and if they can *or can not* be predicted mathematically. (From here comes the reference that he makes in his article to a chapter in a work by G. Sorel).

And it seems to him that they are susceptible for being predicted by the calculation of probabilities (which will depend, logically, on the specific conditions which their changing social content establish). Though at the same time he denies to Sociology as such all possibility of predicting the behaviour of a specific isolated individual.

Second disappearance

However, let us leave for the third part of this text the critical judgement which as sociologists this concept of the statistical behaviour of our object might deserve. Specifically as regards how this conception could be affected by the evident capacity to reflect linguistically about its own activity and that of others which human individuals have. A *linguistic capacity* which is not possessed in any way by molecules or atoms.

For the time being we are here for another thing: we are only attempting an intellectual biography of Majorana, and we are trying to understand the conception that Majorana had or had acquired of social life, and in particular *conjecture* (reasonably, we hope), about the effects that such a conception could have when he had to decide on his own professional life, which out of necessity had to be developed in the historic society in which he lived. We do this, however, without attempting to judge yet if this sociological concept seem to us to be correct or erroneous.

In those years, shut up in his house, Majorana has become *one of us*, and is now not only a physicist but also a sociologist, or at least he has been maturing and perfecting a genuinely sociological point of view,… self-taught, in his own way one might say, but sociological…

When he reflects on collective behaviour in "a modern European-style society" (Majorana 1942: 63) he extrapolates logically, as he could not fail to do, from the scientific culture in which he was trained, which is that of the most advanced Physics of the period, and he comes to the conclusion that this behaviour, *in so far it is collective*, is susceptible to mathematical prediction –in a probabilistic way, just as "Quantum Mechanics has taught us to see" (Majorana 1942: 66).

He now clamours for a genuinely mathematical Sociology, for an increase in the role of statistical laws in Social Sciences which "is not only that of empirically establishing the result of a large number of unknown causes, but more than anything else is that of giving a concrete and immediate testimony, whose interpretation requires a special art, not exactly secondary to the art of government" (Majorana 1942: 66)

He tells us this at the end of his article, the only one that he has written in the last four years, and for which he has had to carry out a violent break with the epistemological limits of Physics, which is at the same time a break (no less violent) with the epistemological limits of Sociology; a *double* break which allows us to affirm that a technical knowledge *(mathematically defined)* of human society is possible, and that its government should be based on this knowledge. (*Not* that it must *be reduced* to this).[7]

In the light of this article, we can suppose (and we do not take any great risk in doing so) that Majorana, from the point of view of political opinions, and after being shut up in his house for four years, looked on with both disinterest and distance at all the political actors *who are giving orders* in his age: the Nazi voluntarism (which he had first hand knowledge of, and which was then intervening in the horrible war in Spain) must *now* seem to him pathetic; Leninist state-capitalism, a crude violation of social spontaneity; Anglo-Saxon *laissez-faire* (if such a thing exists) a head in the sand policy, unworkable, insufficient, in the end irresponsible.

However, for the atomic physicists, as for everybody, the moment of political choice was approaching. This choice would in some cases be voluntary and in others imposed. The time was approaching for everybody, but especially for the atomic physicists who

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[7] For this reason Majorana's friends, who were generally so appreciative of the worth of his articles on Physics, were mistaken when they thought that this article, which we are commenting on (Majorana's tenth and last), was *only* an article for *general circulation*. And it is natural than they made this mistake, as clearly this is certain from the point of view of Physics, although *it is not* true from the point of view of Sociology. Their judgement about Majorana was, for this very reason, necessarily incomplete, insufficient and perhaps erroneous.

Apart from that, only time will tell us if this article by Majorana is, *in the way we believe it is*, a necessary contribution to Sociology.

had stood out in the 30' and whose work, the manipulation of atoms, if there was a war (and there already was a war) would become without a shadow of doubt a *question of State* (as indeed it did become). For this reason some physicists, such as Heisenberg, chose to remain in Germany; others, such as Kapitza, were retained in Russia; and others, well, like Einstein or Fermi, emigrated to America, and collaborated (directly or indirectly) in the making of the Bomb.[8]

And Majorana? What will Majorana do? What will our young *Sicilian* decide? Really, he has already decided, as for many years he has lived recluded, he is *missing* (for Physics and for society), shut up in his house, solitary, dedicated to his studies and hobbies, withdrawn from academic life. Since he returned from Germany years ago he has done nothing, he has published nothing, aloof from the activities of the Physics Institute, leading a private life, an organized life, which not even the war (if it were to break out) would be able to alter or interrupt, at least not seriously.

But then half-way through 1937 public examinations are held for various professorships, this having been motivated by Fermi's international recognition. His friends at the Institute of Physics put pressure on him to apply, but Majorana has doubts. However, they do persuade him to publish an article he has kept in a drawer for five years. He wrote this article in 1932 and in it he qualifies some aspects of Paul Dirac's well-known thesis on anti-particles, which continues to be (even today) a work of reference. In the end, without consulting or saying anything to anyone, he makes his decision and applies for the professorship in Palermo.

However, this forced the intervention of senator Gentile, alarmed by the formidable competition which Majorana represents for his son, Giovanni Gentile junior. In order to avoid such competition, senator Gentile gets Mussolini to appoint Majorana Professor

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[8] In his letter to Roosevelt of the 2nd August, 1939, Einstein warned: "In the course of the last four months it had been made probable -through the work of Joliot in France as well as Fermi and Szilard in America- that it may become possible to set up a nuclear chain reaction in a large mass of uranium, by which vast amounts of power and large quantities of new radium-like elements would be generated. Now it appears almost certain that this could be achieved in the immediate future.
This new phenomenom would also lead to the construction of bombs, and it is conceivable –though much less certain- that extremely powerful bombs of a new type may thus be constructed. A single bomb of this type, carried by boat and exploded in a port, might very well destroy the whole port together with some of the surrounding territory. However, such bombs might very well prove to be too heavy for transportation by air." http://hypertextbook.com/eworld/einstein.shtml

Remember, as regards to this, notes number 4 and 5, and Majorana's sudden interest (already in 1934!) in knowing the fleets of various countries and the characteristics of the construction of the ships. *Had Majorana resolved, at such an early date, the "Uranium Puzzle"? Even before Ida Noddack?*

of Theoretical Physics at the University of Naples in November 1937… And for his outstanding reputation!, without even passing an exam!

And then we see how Majorana takes up his professorship on the 13th January, 1938, and carries out his duties punctually, leading a complete normal life, at least in appearance. But on the 25th March of this same year he sends, from Palermo, a letter to the director of the Naples Institute of Physics, where he works, Antonio Carrelli, in which he says "I have taken a decision which after everything is inevitable", and that he will give up his classes, and that he will keep fond memories of the professors and students of the Institute "at least until eleven o'clock tonight, and possibly even later"…

And the next day, 26th March, Majorana sends a telegram, asking him to ignore the letter, and yet another letter (was it sent at the same time as the telegram?) in which he tells Carrelli that "the sea has rejected me", but that he does not wish to return to the classes…[9]

The police, alerted by his friends and relatives, find a witness *who thinks* that he saw him on the night of 26th March on the Palermo-Naples postal boat, but is not sure… And this is everything, as hat is certain is that he was never heard of again, nobody saw him again, nobody knows if he killed himself, or if his shut himself away in a convent, if he took off to Argentina, as he left tracks to all of these… *or baits*.[10]

Some days later his distraught mother found in a drawer of his desk this article which we now present and which for the first time has been translated into English.

Bibliography

[9] Refer to LALUMIA (1993)

[10] The biographers of Majorana have noticed that the circumstances in which his disappearance took place reminds us of *the Principle of Uncertainty* which so impressed the physicists of his era (and of our own). Clearly it is applied here, not to physical actions, but to human ones, a possibility in which *only* Majorana had reflected…
A few years later of his disappearance, while discussing the theme with common friends, Fermi observed that "with his intelligence, once he has decided to disappear or make his body disappear, Majorana would certainly have been successful". (AMALDI 1966: 85-86)
In any case, the interested reader can find different interpretations of the life, works and disappearance of Majorana, for example in the books by AMALDI (1966), SCIASCIA (1978), RECAMI ed. (1987), LALUMIA (1993), FINZI (2003), and in numerous pages in the internet that dedicated to him.

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THE VALUE OF STATISTICAL LAWS IN PHYSICS AND THE SOCIAL SCIENCES

Ettore Majorana[11]

The deterministic conception of nature holds in its very being a real motive of weakness because irremediably contradicts the most evident data of our conscience. G. Sorel tried to compose this dysfunction by distinguishing between artificial nature and natural nature *(this later being a-causal), although in this way he denied the unity of Science. On the other hand, the formal analogy between the statistical laws of Physics and those of Social Sciences supports the opinion that also human actions were submitted to a rigid determinism. It is important then, that the principles of Quantum Mechanics have lead to a recognition (as well as a certain absence of objectivity in the description of phenomena) of the statistical character of the ultimate laws of elemental processes. This*

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[11] This article by Ettore Majorana -the famous theoretical physicist of the University of Naples, who disappeared without a trace on March 25,1938- was written initially for a Sociological journal. However, it was not published, perhaps due to the author's strong reluctance to open up to others, and which persuaded him far too often to leave important pieces of work in the drawer. This article has been preserved with loving care by his brother, and is presented here not only for the interest of the argument in itself, but also because it shows us a side of Majorana's rich personality, which so attracted those who known him. He was a thinker who combined a sharp sense of realism with an extremely critical, though not sceptical, spirit. Here he adopts a clear position in the much debated problem of the statistical value of the fundamental laws of Physics. What may seem to many to be a defect, or a denunciation of indeterminism in the evolution of nature, is on the other hand, for Majorana, a motive for reivindicating the intrinsic importance of the statistical method, until this time applied in essence only in Social Sciences, and that, in the new interpretation of the laws of Physics, refinds completely its original meaning.

Presentation by Giovanni Gentile jr (1942)

(Translated by Richard Harris and Carlos Allones). Majorana's italics.

conclusion has made substantial the analogy between Physics and Social Sciences, and has produced between them an identity of value and method.

The study of the relations, real or supposed, which links Physics with other Sciences has always attracted considerable interest due to the special influence which Physics has held, in modern times, over the general direction of scientific thinking. It is well-known that the laws of Mechanics, in particular, have for a long time appeared as an insuperable example of our knowledge of nature, and it has even been believed by many that the imperfect notions produced in other sciences should have been redirected towards that type of laws. This will serve as a justification for the study we are about to undertake.

1. The concept of nature according to Classical Physics

The exceptional high reputation which Physics enjoys evidently derives from the discovery of the so called exact laws, which consist of relatively simple formulas. These were originally thought up as being based on fragmentary and approximate indications of experience, but immediately reveal themselves to be of universal value, either because they are applied to new orders of phenomena or because the progressive perfecting of experimental art submits them to an every more rigorous control. It is well known to everyone that according to the fundamental conception of Classical Mechanics, the movement of a material body is entirely determined by the initial conditions (position and speed) in which the body finds itself and by the forces which act over it. As regards the nature and measurement of the forces which can be created in the material systems, the general laws of Mechanics establish, naturally, some limitation or condition which must always be satisfied. Such a character is held by, for example, the principle of equality between action and reaction, to which have been added, in a less distant period, other general rules such as those related with linked systems (principle of virtual works) or elastic reactions, and even more recently with the mechanical interpretation of heat and also the principle of the conservation of energy, as a general principle of Mechanics. Apart from such general indications, it is, however, a duty of each speciality of Physics to discover step by step what happens in each case, for an effective use of the principles of Dynamics: that it to say: the knowledge of all the forces in play.

In a case however it has been possible to find a general expression of the forces which arise between material bodies: in the case in which these have been isolated and therefore act only according to the reciprocal *distance*. In this case, by ignoring the electromagnetic forces discovered subsequently and which become evident, however, in particular conditions, the only agent forces are reduced to universal gravitation, whose notion was suggested to Newton by the mathematical analysis of Kepler's laws. Newton's Law is normally applied to the study of the movements of stars, which, as they are separated by immense empty spaces, can only be influenced effectively by an action which occurs apparently at a distance. As is well known, such a Law is enough to predict in every aspect and with marvellous accuracy all the complex development of our planetary system. A single minimal exception in relation to the secular movement which the perihelion of Mercury suffers, constitutes one of the greatest experimental proofs of the recent Theory of General Relativity.

The sensational success of Mechanics applied to Astronomy has naturally highlighted the supposition that the most complicated phenomena of common experience must in the end behave according to a similar mechanism, which will only at times be more general than the Laws of Gravitation. According to this way of thinking, which has given rise to a mechanism concept of nature, the whole material universe develops obeying an inflexible law; in such a way that its state in a certain instant is entirely determined by the state in which it was in the preceding instant. This is a sign that all the future is implicit in the present, in the sense that it can be foreseen with absolute certainty if the current state of the universe is completely known. Such a clearly deterministic concept of nature has immediately had numerous confirmations; the subsequent developments of Physics, from the discovery of the laws of electromagnetism to the Theory of Relativity, have suggested a progressive lengthening of the principles of Classical Mechanics, though on the other hand they have vigorously confirmed the essential question, this being: the total causality of Physics. It is not questionable that the determinism has the main and almost exclusive merit for having made possible the grandiose modern development of Science in fields far removed from that of Physics. Nevertheless, determinism, which leaves no space for human liberty and makes it necessary to consider as illusory in their apparent purpose all the life's phenomena, shows a cause of real weakness: the immediate and irremediable contradiction with the most evident data of our conscience. We will explain later how it is that its effective and apparently definitive superseding has taken place precisely in Physics over the last years. Our final objective continues to be that of illustrating the renewal that the traditional concept of statistical laws must undergo as a consequence of the new direction followed by contemporary Physics. For the moment we still wish to stick to the classical concept of Physics, not only because of its enormous historical interest, but also because it is still the most well-known outside the specialist circle.

Before closing this part of the introduction, we believe that it is opportune to remember that the critics of determinism have multiplied, especially in times quite close to our own. The philosophical reaction, when it has been adequate, has not left its own field, thereby leaving substantially intact, though circumscribed in its importance, the strictly scientific problem. An attempt to resolve the latter can be found on the other hand in G. Sorel (Sorel 1921), who represents the pragmatic and pluralistic school of thought. According to the supporters of this movement, an effective heterogeneous of the natural phenomena, rules out the possibility of having an unitary knowledge of them. Each scientific principle would then be applicable to a determined area of phenomena, without ever being able to aspire to possessing a universal validity. Sorel develops in a very particular way the criticism of determinism by affirming that this would only deal with the phenomena he calls of an *artificial nature*, and which are characterized by the fact that they are not accompanied by an appreciable *degradation* of energy (in the sense of the second principle of Thermodynamics). Such phenomena occur from time to time in nature, often in Astronomy, and so constitute material for simple observation; however, more frequently, they are provoked in laboratories by researchers, who pay particular attention to eliminate passive resistance. The other phenomena, those of common experience or of *natural nature*, in which cases passive resistance come into play, would not be dominated by definite laws, but would depend, to a greater or lesser extent, according to each case. Sorel explicitly refers to a metaphysics principle of G. B. Vico. We do not wish to argue here about the arbitrary importance given to a particular aspect of Science, as it appeared in an age which is not ours; however we must emphasize that the pragmatic principle of judging scientific doctrines depending on their real utility does not justify in any way the attempt to condemn the ideal of the unity of Science, which has revealed itself to be the most efficient stimulus for the progression of ideas.

2. The classical meaning of statistical laws and social statistics

In order to understand well the meaning of statistical laws according with Mechanics, it is necessary to refer to a hypothesis about the structure of material which, although well-known in ancient times, in fact entered the field of Science at the end of the 19th Century, in the works of Dalton. He was the first to recognize in this hypothesis a natural explanation of the general laws of Chemistry, which had shortly before been discovered. According to modern Atomic Theory, which has been definitively confirmed with Physics very own methods, there exist in nature as many species of elemental and individual particles, or *atoms*, as there are simple chemical bodies; out of the union of two or more atoms of equal or diverse species, including of isolated atoms, are created *molecules*, which are the ultimate particles capable of an independent existence into which a clearly-defined chemical substance can be subdivided. The molecules, and including also the atoms in the interior of the molecules, far from occupying a fixed position, are stimulated by an extremely rapid movement of translation and rotation around themselves. The molecular structure of the gassy bodies is particularly simple. In reality, in gases in ordinary conditions, the molecules can be considered to be especially independent and at reciprocal distances, which are considerable in relation to their very reduced dimensions; following the principle of inertia, their way of translation is rectilinear and uniform, undergoing almost instantaneous modifications in the direction and speed only on occasions of reciprocal "impulses". If it is supposed that we know exactly the laws that regulate the mutual influence of the molecules, we must think that, according to the general principles of Mechanics, it is *also* enough simply to know the disposition of all the molecules and their speeds of translation and rotation at the initial instant, in order to be able to predict *in principle* (although in the midst of calculations which are too complex to be carried out from a practical point of view) what will be the exact conditions of the system after a certain time. The use of a deterministic scheme taken from Mechanics suffers, however, a real limitation of principle, when we take into account the fact that the *ordinary* methods of observation do not enable us to know exactly the instantaneous conditions of the system, but that they only give us a certain amount of global information. Given for example the physical system which is the result of a certain quantity of a specific gas, we only need to know its pressure and density in order to identify all those other magnitudes, such as temperature, coefficient of viscosity, etc., which could be the object of specific measurements. In other terms, the value of pressure and density are sufficient in this case to determine entirely the state of the system *from a macroscopic point of view*, but are evidently not sufficient to establish of each instant its exact internal structure, in other words, the distribution of the positions and the speeds of all particles.

In order to set out clearly, briefly and without any mathematical device, the nature of the relation which exists between the *macroscopic state* (A) and the real state (a) of a system, and to draw some deductions from this, we must sacrifice precision without altering in an essential way the true substance of the actions. We must therefore understand that a great number of effective possibilities a, a', a'',… correspond to the apparent or macroscopic state (A), and that our observations will not allow us to distinguish one from another. The *number* N of these internal possibilities, according to strictly classical concepts, would naturally be infinite, though Quantum Theory has introduced in the description of natural phenomena an essential discontinuity, in virtue of which the number N of such possibilities in the intimate structure of a material system is in fact *finite*, even though very large. The value of N provides a measure of the degree of the *hidden* in-determination of the system; it is, however, preferable in practice to consider a magnitude proportional to its logarithm:

$$S = K. \log N$$

In which K is the universal constant of Boltzmann determined so that S coincides with a fundamental magnitude already known by thermodynamics: *entropy.* The entropy appears in reality as a physical magnitude similar to weight, energy etc, above all because like these other magnitudes it possesses the additive property: in other words, the entropy of a system which is the result of independent parts is the same as the sum of the entropies of the singular parts. In order to understand it is sufficient observe that the number of possible latent of a composed system is evidently equal to the product of the analogous numbers relative to the constituent parts, and on the other hand to bear in mind the well-known elementary rule that establishes the correspondence between the product of two or more numbers and the sum of their respective logarithms.

As regards the way of determining the set of internal configurations a, a', a'',… which correspond to the macroscopic state A, does not give rise to general difficulties. It is on the other hand open to debate as to whether all the singular possibilities a, a', a'',…

must be analyzed or not as equally probable. However, according to the ergodic or almost ergodic hypothesis, which is believed, and with reason, to be generally verified, if a system persists *indefinitely* in a state A it is possible to affirm that this last an equal fraction of its time in each one of the configurations a, a', a'',… and so we are led to consider in effect as equally probable all the possible internal determinations. This is in reality a new hypothesis, as the universe, far from remaining indefinitely in the same state, undergoes continuous transformations. We will therefore accept as a working hypothesis, even though its most far-reaching consequences can not be verified, that all the possible internal states of a system in determinate physical conditions be a priori equally probable. In this way the *statistical set* associated with each macroscopic state A is entirely defined.

The general problem of mechanical statistics can be summarized in this way: after being statistically defined, as has been said, the initial state A of a system, what are the possible predictions in relation to its state in time t? It might seem, at first sight, that this definition is too strict, because, in addition to the strictly dynamic problem it is also possible consider other of *static* character; for example, what is the temperature of a gas whose pressure and density are known? And so on in all the cases one wishes of some characteristics of a system sufficient to define its state and to deduce others that might be of interest. The distinction can, on the other hand, be formally ignored by incorporating adequate measuring instruments to the system, and this will lead us back to the previous case.

Let us suppose then that the initial state of the system under examination is the result of the statistical set

$$A = (a, a', a'',\dots)$$

of possible cases and, according to what has been said previously, equally probable. Each one of these complete determinations is modified over time according to a law that, following the general principles of Mechanics, we must still consider rigidly causal, as, after a certain time we pass from the series (a, a', a'',…) to another well-defined series

$$(b, b', b'',\dots)$$

The statistical set (b, b', b'',…) which is also made up of N equally probable elements, like the imaginary set A (Lioville's Theorem) defines all the possible predictions about the development of the system. For reasons that only a complex mathematical analysis could specify, its turn out that in general all the simple cases which belong to the series b, b', b''… *except an insignificant number of exceptions*, constitute *totally or in part* a new statistical set B, defined like A by a state which has been well defined *macroscopically*. We can therefore enunciate the *statistical law* according to which it is practically certain that the system must pass from A to B. As a result of what has been said up to now, the statistical set B is as ample as A, that is, it contains a number of elements not inferior to N; we can deduce that the entropy of B is equal to that of A *or greater*. During any transformation that is realized *in accordance with the laws of statistics*, the entropy remains constant or increases, but never diminishes, this being the statistical foundation of the famous second principle of Thermodynamics.

It is worth pointing out that from a practical point of view the movement from A to B can be considered certain, which explains why historically the laws of statistics have been considered from the start as being as fatal as the laws of Mechanics, and that only due to the progress in theoretical investigation has its true character been finally recognized. Statistical laws cover a great part of Physics. Among the most well-known applications we remind the reader of: the equation of the state of gasses, the theory of diffusion, that of thermal conductibility, that of viscosity, that of osmotic pressure, and of many other similar ones. The statistical theory of radiation deserves a place apart. It was this theory which introduced for the first time in Physics the concept of *discontinuity*, symbolized by the constant of Plank. However, there also exists another entire branch of Physics, Thermodynamics, whose principles, although directly based on experience, can be integrated in the general notions of Statistical Mechanics. As a result of what we have seen up to now, it is possible to summarize in the following way the meaning of statistical laws according to Classical Physics: 1.º, natural phenomena obey an absolute determinism; 2.º, the ordinary observation does not allow us to identify exactly the internal state of a body, but only to establish an innumerable set of indistinguishable possibilities; 3.º, once we have established a plausible hypothesis about the probability of diverse possibilities, and have accepted as valid the laws of Mechanics, the calculation of probabilities allows us to make a more or less certain prediction of future phenomena. We can now examine the relationship that exists between the laws established by Classical Mechanics and those clearly empirical regularities which are known by the same name, especially in Social Sciences.

First and foremost it is necessary to be convinced about the formal analogy, which cannot be too strict. When we state, for example, the statistical law: "in a modern European society the yearly coefficient of marriages is nearly 8 per thousand inhabitants", it is quite clear that the system on which we must develop our observations is defined only on the basis of certain global characters and that we deliberately rule out the possibility of examining all those other data –such as for example the biography of each one of the individuals which compose the society in question-, knowledge of which would, without a doubt, be useful to predict the phenomena with greater security and accuracy that it is permitted by the general statistical law. Just in the same way do we normally define the state of a gas because its pressure and volume, and we decide deliberately not to investigate the initial conditions of all the singular molecules. On the other hand one might think that there is a substantial difference between the mathematically defined character of the statistical laws of Physics and that other clearly empirical character of the statistical laws of Social Sciences; but it is possible to attribute the empiricism of social statistics (that is: the inconsistency of its results *beyond the part related with the case*) to the complexity of the phenomena that these consider, it not being possible to define exactly the conditions and content of the law. On the other hand Physics also recognizes empirical laws when it studies phenomena of a purely applicable interest; for example, laws about the magnetic properties of different types of irons and other similar laws. To sum up, we could give a special importance to the difference in the methods of exploration, which in Physics are global -thus it is sufficient the reading of a measuring instrument to know the pressure of a gas, although this derives from the sum of the independent impulses which the individual molecules transmit to the walls-, while in Social Sciences it is the individual actions which are normally registered; however, not even this is an absolute antithesis, as is proved by the existence of a variety of methods of indirect exploration. Once we admit the reasons which lead us to believe in the existence of a real analogy between statistical laws in Physics and in Social Sciences, we are induced to consider as plausible that, just as the first logically imply a rigid determinism, so do the later for their part provide a direct proof that the most absolute determinism also govern human actions; an argument which has had better luck, as we said at the beginning, when for independent reasons had already been shown the tendency to see in the casualty of Classical Physics a model of universal value. It would be out of place here to take up again old and never-ending arguments, but we have to remember as a generally admitted fact, that the lack of conciliation in our contradictory intuitions of nature has weigh heavily for many years in modern thinking and moral values. It is therefore not due to simple scientific curiosity the fact that in recent years Physics has been obliged to abandon its traditional direction, this being: the absolute determinism of Classical Mechanics, and do so in a truly definitive way.

3. The new concepts of Physics

It is impossible to set out with any degree of amplitude in a few lines the mathematical scheme and experimental content of Quantum Mechanics (Heisenberg 1930), and so we will limit ourselves to a rough outline. There exist some experimental facts, which have been known for many years (phenomena of interferences) which incline us irrefutably in favour of the Ondulatory Theory of light. However, other facts, discovered more recently (Compton effect) suggest on the contrary and no less decisively the opposite Corpuscular Theory. All the attempts to resolve the contradiction within the framework of Classical Physics have turned out to be completely fruitless, which could seem to be of little significance. Although from such inexplicable deeds and from others no less inexplicable and of the most diverse nature, and from *almost all* the phenomena known to the Physicists and which until now had been insufficiently explained, we have found, and really only a few years ago, the unique and marvellously simple explanation: that which is contained in the Principles of Quantum Mechanics. This extraordinary theory is in this way so solidly based on experience than any other had been; the criticism to which it has been and is subjected cannot compromise in any way the legitimacy of its use for the effective prediction of phenomena, but rather the opinion shared by many is that the new direction indicated by it must be kept and even stressed more in future developments of Physics.

The characteristic aspects of Quantum Mechanics which make them different to those of Classical Mechanics are:

a) Laws do not exits in nature which express a fatal succession of phenomena; also the ultimate laws related with elemental phenomena (atomic systems) have a statistical character, allowing us to establish only the *probability* that a verified measuring in a system prepared in a specific way gives a certain result, and that this is the case whatever the means are that we dispose of to determine with the greatest possible precision the initial state of the system. These statistical laws indicate a real lack of determinism, and have nothing in common with the Classical laws of statistics, in which the uncertainty of the results derives from a voluntary decision, for practical reasons, not to investigate the particular aspects of the initial conditions of physical systems. Later we will see a well-known example of this new type of natural laws.

b)A certain lack of *objectivity* in the description of the phenomena. Any experience executed in an atomic system imposes on this a finite disturbance which cannot be, for reasons of principle, eliminated or reduced. For this reason the result of any measuring seems to be related more with the state to which the system has been moved during the course of that experience, rather than which the unknown state in which it existed prior to being disturbed. This aspect of Quantum Mechanics is, without a doubt, more disquieting, that is to say: more distant from our ordinary intuitions, than the simple lack of determinism.

Among the laws of probability of elemental phenomena that which regulates radioactive processes is recognized as being the oldest. Each atom of a radioactive substance has a defined possibility

$$m\,dt$$

of being transformed in the infinitesimal time dt due to the emission of either an *alpha* particle (nucleus of helium) or in other cases of a *beta* particle (electron). The *death rate* m is constant, that is to say: independent of the *age* of the atom, which gives a particular shape to the *curve of survival* (exponential); the average life is equal to $1/m$ and it is also possible to similarly determine in an elementary way the *probable life*, also known as the *period of transformation*. Both are independent of the age of the atom, which apart from that does not show any other sign of real aging with the passing of time. There exists various methods for the observation, and also for automatically registering the individual transformations which occur in the very hart of a radioactive substance, and it has therefore been possible to verify, by means of direct statistical explorations and applications of the calculation of probability, that the individual radioactive atoms do not suffer any reciprocal or external influence as far as the instant of transformation is concerned.

Quantum Mechanics has taught us to see in the Exponential Law of radioactive transformations an elemental law which cannot be reduced to a simple causal mechanism. Naturally also the statistical laws recognized by Classical Mechanics and relative to *complex systems* keep their validity according to Quantum Mechanics. This modified on the other hand the rules for the determination of internal configurations and does so in two different ways depending on the nature of the physical systems, thus given rise respectively to the statistical theories of Bose-Einstein, and of Fermi. However, the introduction in Physics of a new type of statistical law, or simply a probabilistic one, which was hidden under the supposed determinism of ordinary statistical laws, obliges us to revise the bases of the analogy which we have previously established with the statistical laws in Social Sciences. It is unquestionable that the statistical character of these latest laws derives at least in part from the way in which the conditions of the phenomena are defined: a generic way, that is to say: statistically speaking, capable of permitting an innumerable set of different concrete possibilities. On the other hand if we remember what has been said earlier about the *mortality tables* of radioactive atoms we are induced to ask ourselves if there does not exist here a real analogy with the social acts which are described with a similar language.

At first sight there is something that seems to exclude it; the disintegration of an atom is a simple act, something unpredictable, which takes place in an improvised and isolated way after a wait of thousands and even millions of years, while nothing similar occurs in deeds registered by social statistics. This is not however an insurmountable objection. The disintegration of a radioactive atom can oblige an automatic counter to register it with a mechanical effect if provided with adequate amplification. Common laboratory devices are then enough to prepare in one form or another a spectacular and complex chain of phenomena which are governed by the accidental disintegration of a single radioactive atom. There exists nothing, from a strictly scientific point of view, to prevent us from considering as plausible that in the origin of human events can be found an equally simple, visible and unpredictable vital action. If this is so, in the way we believe it is, the statistical laws of Social Sciences will see their role increased and it will now not only be that of empirically establishing the result of a great number of unknown causes, but more than anything else is that of giving a concrete and immediate testimony, whose interpretation requires a special art, which is not exactly unimportant in the art of government.

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SOCIOLOGICAL COMMENTARY

(By Carlos Allones Pérez)

"When you cannot measure your knowledge is meagre and unsatisfactory"

Lord Kelvin

The relevance of this article by Majorana for contemporary sociologists resides, as we understand it, in a double analogy, both real and formal, which the author tries to establish between the statistical laws of Physics and the statistical laws of Social Sciences.

It is a formal analogy, because as the laws of Quantum Mechanics and of Radioactivity recognize a real lack of determination in the behaviour of the phenomena that they study, and as they therefore need to turn to probabilistic procedures for their description, they reminded physicists of social behaviour (as was natural), and the statistical way in which they are normally described.

Furthermore, in particular Majorana seemed to feel especially impressed by the real analogy that there could be between de disintegration of a radioactive atom (on the one hand), and the disruptions which could be suffering the death-rates or marriage-rates in a modern "European-type society" (on the other hand).

With this double comparison, Physics *threw down the gauntlet* at Sociology, which has no alternative but to pick it up. With its own arguments it has to declare if it considers such a comparison to be adequate or not. However, we immediately realize that Sociology cannot, at this moment in time, just as it was not able to do 65 years ago, answer back Physics fully. A perhaps insurmountable hurdle exists: the laws of Physics (although they are probabilistic) are expressed by means of mathematical equations (if not they are not accepted), and they are statistical laws of a defined mathematical character; whereas Sociology (as far as we know) lacks such equations and its statistics are merely empirical… And one must not mix them.

If Sociology for its part were capable of formulating useful mathematical equations to define its object of study, this being collective human behaviour, it could then compare its own formulae with those that are used by Physics and therefore could respond objectively.

But is this possible? Is it possible to submit human interaction to mathematical calculation (something which would be of course probabilistic)?

In this brief commentary on the Majorana article we wish to do three things: firstly, to defend that the linguistic condition of social action does not impede its statistical prediction; secondly, to refer to a procedure by which it might perhaps be possible to make this prediction; and thirdly, to recognize the task which awaits Sociology if it wishes to declare scientifically about the validity of this real analogy which Majorana sets out at the end of his article, between the behaviour of a radioactive atom and contemporary death-rates or marriage-rates, which was what perhaps led him to write it.

I. As regards the first, it is certain that the fundamental explanation for the corporal activities of individuals which are interwoven in a social or coordinated action, *does not lie strictly in themselves*, but rather in the mental, ideational, linguistic activity that these individuals are performing at the same time. The understanding of the subjective sense of the action (Weber 1964) is the decisive part in the sociological explanation. The relationships between the acts of individuals do not obey the laws of physical casualty (these laws that physicists have recognized and studied) but rather are much more similar to those which exist (for example) between the different phrases of a conversation.

However, the fact that human actions are made by means of language, does not mean that they are not presented with regularity and does not mean that they are not repeated in time (in fact this is obviously so) but rather they are possible precisely because they are repeated and they can be repeated *thanks* to language (and not in spite of it).

It is language that makes collective human action possible, as it is *thanks* to its use that the individual can *forsee* in every moment the answer that other are going to give to his or her own action, and can act in consequence. It is for this that language serves. It was for this that it was *invented* during historic course of collective action by the group which now *imposes it* on each and every one of the members that joins it.

For this reason it must not surprise us sociologists that grammarians have detected *something* in the rhythm of language which predetermines in itself the rhythm of the action. Wherever and whenever there are men acting together, this rhythm and this regularity appears, independently of what they are doing, and therefore of the historic or local variation which this activity can suffer. It is certain that with the passing of time this activity cannot cease to be modified and to be changed finally into another thing, although it will always achieve, and will always crystallize (because of language) in *another* rhythm of common action, another repetition. And this other repetition, by definition, will have associated *another* probability, which can also be calculated (with a greater or lesser degree of difficulty, with better or worse luck).[12]

Given this substantial *intervention* of language in our object of study, sociologists cannot do science *in the same way* as physicists, although this does not mean that we cannot do science *in our own way*, nor that it has to be less exact than theirs (especially now that we know that Physics was not *so* exact, either).

II. As regards the second –in order to point out a procedure which will allow us to advance with respect to the use of defined mathematical equations in Sociology, which we are trying to achieve- it would be of great help to us if we found (for our object of study) *an empirical principle of general validity*, such as the principle of action and reaction, or of conservation of energy, or others which Physics has been using since Newton. Of general validity means that it is applicable to any activity in common, in any place or time. To be empirical, or of empirical reference, means that the concepts which constitute it make reference to aspects or parts of social reality which are susceptible for measurement, which can always be found in this social reality, and which can always be quantified. All of this without prejudice to the fact that, in accordance with the compulsory procedure of sociological explanation which we has already accepted, the understanding of the evolution of such parameters *always* resides in the linguistic, ideational, qualitative part (that cannot be reduced to a number) of collective action.

In this sense, after looking again through the literature, we have found this paragraph by Durkheim, which seems to have been written for the occasion:

[12] Refer to the seminal article by García Calvo (1973). And more extensively, its continued exploitation in García Calvo (1979) and 2 volumes more.

> "Moreover, it is understandable that the reaction of punishment is not in every case uniform, since the emotions that determine it are not always the same. In fact they vary in intensity according to the strength of the feeling that had suffered injury, as well as according to the gravity of the offense sustained. A strong state of feeling reacts more than does a weak one, and two states of equal intensity react unequally according to the degree to which they have been violently attacked. Such variations must necessarily occur, and are useful, moreover, for it is important that the strength invoked should be proportionate to the extent of the danger. If too weak, it would be insufficient; if too violent, it would represent a useless dissipation of energy. Since the gravity of the criminal act varies according to the same factors, the proportionality everywhere observed between crime and punishment is therefore established with a kind of mechanical spontaneity, without any necessity to make elaborate computations in order to calculate it. What brings about a gradation in crimes is also what brings about a gradation in punishments; consequently the two measures cannot fail to correspond, and such correspondence, since it is necessary, is at the same time constantly useful." (Durkheim 1997: 57)

We therefore have here two things which it is always possible to observe and quantify: the actions of the individual which the group considers criminal, and the punitive action which immediately after the group imposes on the individual. We believe, as Durkheim does, that these two types of actions take place every where, that they accompany all collective activity, and that they are a *structural* part of this activity. We also believe that there exists a *proportionality* between crimes and punishments: and that what establishes this proportionality is precisely the recurrent, collective reflection about its calculation –a calculation which for this very reason cannot be excessively sophisticated, but rather has to be easy to understand by any member of the group.[13]

[13] To say that a proportionality exists between crimes and punishments, is the same as saying that the relationship between them is produced with regularity. A regularity which (in its historical length) has the invaluable, objective advantage, for our purposes, of being statistically, i.e. numerically, *auto-referenced*. Social facts are consolidated as such, historically, precisely in the measure in which *they gradually achieve* statistically this regularity, in the relationship between the most common crimes which are produced in the practice of these social facts, and the corresponding punishments which are imposed.
It therefore depends only on the *specific* content of such social facts, if it is necessary or not to write down a list of *such* crimes and *such* punishments:

Crimes	Punishments
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We have here then *our* principle of empirical reference, of general validity, whose observation, possible formulation, and probabilistic prediction, leads us directly to the heart of group feelings and ways of thinking, to those "habitual modes of thought and feeling" where Weber (1978: 11) wanted to find in the end the sociological understanding to which we aspire.

III. To finish off, let us say something about the *real* analogy which Majorana seems to wish to establish (at the end of his article) between the death-rates or marriage-rates of a modern society and the disintegration of a radioactive atom. Many are the contemporary sociologists who have felt the attraction of this comparison, though we have always worked along Carlos Moya's line:

> "Since the sixties and early seventies, we have been experiencing a seismic collective break-up of the old patriarchal/national regime based on the taboo (patriarchal) on incest. The new set-up, of the domestic privacy in legitimate erotic relations and in possible family intimacy, emerges over the fissures of this revolutionary metamorphosis in the fundamental nucleus of Western social order. The new set-up *does not imply the abolition of the old* but rather its mutated emergence based on a wide range of 'domestic' and 'family' alternatives. These are coherent with the new forms of relationships: those based on friendship, neighbours or alliance, which are typical in the highly urbanised and technologically advanced Western countries." (Moya 1984: 29) (our italics)

An especially about this:

> "The mechanisms *themselves* of social reproduction become collective mechanisms of social change when the ambivalent relations between youths and adults explode in a massive conflict of one generation with the other." (Moya 1984: 31) (our italics)

This is the sociological origin of law, of any law, which for the sociologist is nothing other than mere statistics. We say that the statistical regularity in the application of the crime/punishment relationship is a *universal* characteristic of any *institutionalized* social practice; bureaucracies, due to their content, have had to fully recognize such a characteristic when elaborating their regulations. For this reason Simmel (2009: 50) saw in them "an analogous image of society in general, but in miniature, rather simplified words…".

It is certainly far from small the task which awaits us sociologists if we wish to give our rigorous opinion about to what extent such an analogy is valid, and when it ceases to be so. First it will be necessary to formulate mathematical equations capable of predicting (in probabilistic terms) sexual and rearing behaviour in any part whatever of the highly capitalized societies. Only *after* will we truly be in conditions to see to what extent these equations have or do not have an exponential mathematical configuration, similar to that of the equations for the disintegration of the atom, *which Physics already possesses*.[14]

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[14] For obvious reasons, in this small commentary we have limited ourselves to pointing out some difficulties, opportunities, and hopes that this possible orientation of Sociology presents, without being able to refer to the procedures of the method which considers them to be relevant. The interested reader can find them in ALLONES (1999; 2019) and ALLONES (2005).