

The Italian Neo-Idealists and Federigo Enriques

The Dispute Between Benedetto Croce and Federigo Enriques: a Defeat for Enriques?

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Abstract: The controversy that between 1908 and 1912 saw Benedetto Croce and Giovanni Gentile opposed on one side and Federigo Enriques on the other did not actually have a conclusive episode, but its end was perceived, for its results on culture, on society and teaching in Italy, as a "defeat" of Enriques. A more careful examination of the events and of the historical context in which it took place seems, however, to clearly demonstrate that we can speak not of a personal defeat of the great mathematician from Livorno, but rather of a defeat of the commendable attempts at cultural and social modernization of Italy in an international perspective, of which Enriques was not the only actor but certainly the most exposed. Such intentions were crushed by the myopic provincial conservatism of Italian neo-idealism, favored by the fascist regime, concerned only with affirming in the world an alleged autarkic national cultural superiority, based on the traditional literary-humanistic culture, ignoring the progress of the new technical-scientific thought, due to its nature instead placed in an international context.

1 – FEDERIGO ENRIQUES: AN INTELLECTUAL IN ALL AREAS

Federigo Enriques was one of the leading figures in the cultural panorama, not only in Italy but also in Europe, in the first half of the 20th century. Mathematician, philosopher and historian of science, he wrote works in each of these fields which – as Guido Castelnuovo¹ said – «would alone be enough to fill and illustrate the entire life of a scientist». Although it is not possible to separate the three directions mentioned by Castelnuovo in the intellectual activity of Enriques, it is possible to distinguish them into three periods in each of which one or the other of the three directions prevailed: 1893-1906 (mathematics), 1906-1922 (philosophy) and 1922-1946 (history of science). In

¹ Castelnuovo (1947).

reality Federigo Enriques was not only a mathematician, philosopher and historian of science, as recalled by his brother-in-law Guido Castelnuovo, in his commemoration held at the Accademia Nazionale dei Lincei on 11 January 1947. Due to the extraordinary variety of his cultural interests - of which will be explained later - Enriques was an all-round intellectual, and in particular one of the most notable references for overcoming the barriers between the "two cultures".

Abramo Giulio Umberto Federigo Enriques - this is his full name - was born on the 5th of January 1871 in Livorno from Giacomo Enriques, of Jewish origins with Portuguese descent, and Matilde Coriat, born in Tunisia and bilingual (Italian and French). In 1882 he and his family moved from Livorno to Pisa, where Federigo attended secondary school. In 1887 he finished high school and enrolled at the University of Pisa, also attending the highly prestigious Scuola Normale Superiore, where he was taught by Enrico Betti (1823-1892), Ulisse Dini (1845-1918), Luigi Bianchi (1856-1928), Vito Volterra (1860-1940) and Riccardo De Paolis (1854-1892, the leading Italian mathematicians of the time.

Even before graduating, in 1890 he published his first academic scientific memoir: *Alcune proprietà dei fasci di omografie negli spazi lineari ad n dimensioni* (*Some properties of homograph bundles in linear spaces with n dimensions*).² But Federigo Enriques' first (non-academic) publication dates back to 1885, when he was just 14 years old: Table of perfect integer squares and cubes contained in 100000 (Pisa: Nistri, 1885), a 10 page file in 16-ths.

In the summer of 1891, at the age of twenty, he graduated in mathematics with De Paolis, defending a thesis entitled *Alcune proprietà metriche dei complessi di rette ed in particolare di quelli simmetrici rispetto ad assi* (*Some metric properties of complexes of lines and in particular of those symmetric with respect to axes*), published four years later.³

In November 1892, after a few months spent in Pisa, he arrived in Rome to continue the specialization course in algebraic geometry held by Luigi Cremona who, with his "birational transformations",⁴ he had effectively introduced in Italy that new line of research, already promoted by Corrado Segre. On this occasion, in Rome he got acquainted with Guido Castelnuovo, who, together with Corrado Segre and Luigi Cremona, was the leading representative of the Italian school of algebraic geometry, of which Enriques himself would later join as the main protagonist. Subsequently he spent a few months of 1893 in Turin completing his specialization course with Segre. During the period of the specialization course in Rome, Enriques published various academic works⁵ which earned him in 1894 the position of teaching projective geometry at the University of Bologna. The first important results of his studies in algebraic geometry were the article *Ricerche di geometria sulle superficie algebriche* (*Geometry research on*

² Enriques (1890).

³ Enriques (1895).

⁴ Cremonian transformations generalize homographies, as, for example, in the plane straight lines no longer change into straight lines but into curves of a higher order. They are called "birational transformations" because to any point of the initial space they associate another point of the transformed space whose coordinates are rational functions of those of the starting point.

⁵ In 1892: *Le omografie cicliche negli spazi ad n dimensioni*; *Le omografie armoniche negli spazi lineari ad n dimensioni*. Nel 1893: *Sui gruppi continui di trasformazioni cremoniane nel piano*; *Sopra un gruppo continuo di trasformazioni di Jonquières nel piano*; *Una questione sulla linearità dei sistemi di curve appartenenti ad una superficie algebrica*; *Sui sistemi lineari di superficie algebriche le cui intersezioni variabili sono curve iperellittiche*; *Sugli spazi pluritangenti delle varietà cubiche generali appartenenti allo spazio a quattro dimensioni*; *Ricerche di geometria sulle superficie algebriche*; *Le superficie con infinite trasformazioni proiettive in se stesse*.

algebraic surfaces)⁶ of 1893 and his university textbooks *Lezioni di Geometria Descrittiva (Lesson of Descriptive Geometry)*⁷ and *Lezioni di Geometria Proiettiva (Projective Geometry Lessons)*⁸ published the following year. In 1896, at the age of 25, he was appointed full professor of projective and descriptive geometry at the University of Bologna. In 1903 the first edition of a highly successful series of mathematics textbooks for upper secondary schools, which were adopted throughout Italy until the 1970s, was published with the title *Ementi di geometria (Elements of geometry)*, written with Ugo Amaldi. In 1906 he published the volume *Problemi della Scienza (Problems of Science)*,⁹ which due to its contents can be considered twinned with the famous books by Henry Poincaré: *La science et l'hypothèse* (1902), *La valeur de la science* (1905) and *Science et methode* (1908). The book, written with material taken from previous articles by Enriques, contains his scientific philosophy, his psychological approach to the principles of geometry and anticipates Albert Einstein's views on the concepts of time, space, motion, force. In the same year he founded the "Società Italiana di Filosofia" (Italian Philosophical Society - SFI) in Bologna and chaired it until 1913. The following year, in 1907, he founded the «*Rivista di Scienza*» (*Science magazine*), which would then take on the name «*Scientia*» in 1910. In 1908 he participated in the III International Congress of Philosophy in Heidelberg and there he received the task of organizing and presiding over the IV Congress to be held in Bologna in 1911. In 1912 he published *Scienza e razionalismo (Science and rationalism)*,¹⁰ the book that contains more than any other the philosophical thought of Enriques, in which current philosophical views are compared with ancient ones. In the years from 1912 to 1914, the second edition in two volumes of the *Questioni riguardanti le matematiche elementari (Questions concerning elementary mathematics)*¹¹ was published, written together with other distinguished Italian mathematicians, which constitutes his major work dedicated to the teaching of mathematics. As President of the National Association of University Professors, in the years 1913-1915 he formulated a reform project for the Italian university, which however was not approved. In 1919 he was elected President of the "Mathesis Society" (founded in 1895), a position he held until 1932. In 1921 he assumed and maintained the direction of the «*Periodico di Matematiche*» (*Mathematical Periodical*) until 1938, being removed due to the racial laws. He will take over the direction from the fall of fascism until the year of his death, 1946. The following year, in 1922, he moved from Bologna to Rome where he became full professor first of Higher Mathematics and then of Higher Geometry at the University "La Sapienza". In the same year his book *Per la storia della logica (For the history of logic)*¹² was published and the following year he founded the "National Institute for the History of Physical and Mathematical Sciences" in Rome, within which the "School of the history of sciences" was created. In 1923 the first volume of *Gli Elementi d'Euclide e la critica antica e moderna (Euclid's Elements and ancient and modern criticism)*¹³ was published, the first Italian critical edition of Euclid's work, written with other collaborators. It will be completed in 1935 with the fourth volume. In 1925 he was appointed director of the Mathematical Section of the

⁶ Enriques (1893).

⁷ Enriques (1894a).

⁸ Enriques (1894b).

⁹ Enriques (1906).

¹⁰ Enriques (1912).

¹¹ Enriques (1912, 1914). In 1927 the third edition in 4 volumes was published. The first edition had come out in 1900 with the title *Questioni riguardanti la geometria elementare (Questions concerning elementary geometry)*.

¹² Enriques (1922).

¹³ The second, third and fourth volumes were published in 1930, 1932 and 1935.

"Enciclopedia Italiana" by Giovanni Gentile, a position he would hold until 1937. In 1932 the first volume of the *Storia del pensiero scientifico (History of Scientific Thought)*,¹⁴ written with Giorgio de Santillana, dedicated to Antiquity, was published. The work remained unfinished, but in 1937 the *Compendio di storia del pensiero scientifico (Compendium of the history of scientific thought)*¹⁵ was published (with Giorgio de Santillana), which contained the periods not included in the previous work. In 1934, in Paris, his book *Signification de l'histoire de la pensée scientifique*¹⁶ was published, in which Enriques reaffirmed the theoretical value of science. Following the introduction of the racial laws also in Italy, in 1938 he was removed from university teaching and relieved of all public offices. However, he continued to have relations with France, where in 1941, in Paris, his book *Causalité et déterminisme dans la philosophie et l'histoire des sciences* was published, which contains a critical examination of the problem of determinism. With the fall of fascism, in 1944, he finally returned to teaching at the University of Rome, until his death following a heart attack on 14 June 1946 in Rome.

2 - A CONTROVERSY WITH MULTIPLE INTERPRETATIONS

The controversy between Federigo Enriques and the major representatives of Italian neo-idealism, Benedetto Croce and Giovanni Gentile, began in 1908, reached its climax in 1911 and ended up being exhausted without a well-defined solution in 1912. There was, therefore, no document or an event that can be considered as the final "battle" that with its outcome has somehow decreed the winner and the loser. «However, Croce's authority had the practical effect of making a large part of the philosophical and cultural circles line up on positions that were hostile to Enriques, so that the end of the controversy was commonly perceived as a "defeat" of the Enriques».¹⁷

There are many questions that, after more than a century, it is legitimate to ask today about the meaning and outcome of that "clash". It was really only an unfortunate "academic controversy" or rather a real "conspiracy" concocted by Croce and Gentile to eliminate their most formidable opponent from the Italian cultural scene and, with him, everything that was linked to his efforts of renewal and cultural and social modernization of Italy at the beginning of the 20th century? How much "personal" and how much "academic" was the controversy which, in any case, took on an official public dimension? If we want to give the sense of a "personal" defeat to that story, was Federigo Enriques really the only defeated? Weren't there other scientists and philosophers who shared his same aspirations for cultural renewal in Italy and the idea of a scientific philosophy that would bring science and philosophy closer together? And if, on the other hand, we want to see it in impersonal terms, it was only the scientific world that capitulated under the conceit and arrogance of a so-called superior culture or, rather, it was not the defeat of the aspiration to modernity, into which Italy could enter on the threshold of the new century like other more advanced European nations?

To try to give an answer to these questions, as objective as possible, in the sense of coherent with the facts that can be established, it is necessary to analyze the multiple meanings that that clash assumed: between provincial conservatism and international modernism; between a secular traditional literary-humanistic culture (which erroneously included philosophy too) and a scientific culture with its new scientific

¹⁴ Enriques (1932).

¹⁵ Enriques (1937).

¹⁶ Enriques (1934).

¹⁷ Israel (1993).

philosophy; between neo-idealism and positivism/neo-Kantism; between different ways of conceiving society; between the personal aspirations of the contending parties for the philosophical and cultural hegemony in Italy.

All these facets of the controversy saw Enriques as protagonists in the forefront, on the one hand and Gentile and Croce on the other, these however with often overlooked but in reality, substantial differences, above all in their personal different consideration of science.

Furthermore, it should be noted that Enriques was not the only protagonist of that controversy, which in reality, in a more latent and discrete form, had already begun much earlier, through the work of a large group of other prominent personalities of science and in particular of Italian mathematics of the second half of the nineteenth century. Enriques, however, was undoubtedly the major champion of that clash, assuming the most exposed position to the attacks of neo-idealist philosophers. If, therefore, we want to speak of personal defeat, the only defeated was not Enriques but, with him, also all the Italian mathematicians, physicists, chemists, naturalists and philosophers who, albeit in different ways, shared his aspirations of cultural and social renewal of post-Risorgimento Italy and the beginning of the 20th century.

From the brief outlines that follow, two characteristics emerge, essential for better understanding both the meaning of the clash between Enriques and Croce-Gentile and the consequences, normally attributed to its outcome, on the difficulties of a solid affirmation of scientific culture in Italy: the connotation of Italian science at the end of the 19th century and at the beginning of the 20th century, on the one hand, and the strong presence of Italian scientists in leading government positions until the rise of fascism, on the other, a phenomenon which would disappear in the following years until nowadays.

3 - SCIENCE IN ITALY BETWEEN THE 19TH CENTURY AND THE EARLY 20TH CENTURY

To understand the cultural background of Federigo Enriques, and the same controversy that saw him engaged against the Italian neo-idealists, it is useful to look at the Italian scientific context over the period from the mid-nineteenth century to the early twentieth century. From the following pages emerges a picture of Italian science which, in the years between the 19th and 20th centuries, places it in the first places internationally, with some interesting characteristic features. This primacy of Italian science at an international level, which also extends to national political life, strengthens in Federigo Enriques the conviction of being able to assign to science, also in Italy, a leading place alongside literary-humanistic culture.

A first characteristic of our scientific community of the time was the desire to enter an international context, which at the time was essentially identified with the European one.¹⁸ This aspiration is part of the modernization process that had already affected the most industrialized and technologically advanced countries of Europe. The modernization of society also involves scientific research, which requires being informed of the most advanced research conducted in other Countries,¹⁹ so

¹⁸ The United States of America at that time had not yet conquered the international cultural leadership that has characterized them from the end of the Second World War to the present day.

¹⁹ In particular «in the years of Enriques the culture of a philosophical-scientific-historical orientation was more significant in France and Germany than in England. Enriques was very attached to France and Germany» (Lombardo Radice, 1982).

modernization and internationalism are two inseparable faces of the science of the time. International competition led Italian science, at that time, to reach top positions, engaging it in frontier research which gave fundamental results in mathematics, physics and chemistry.

3.1 - THE FIRST ITALIAN SCIENTIFIC COMMUNITY

The conscience of a national scientific community, in Italy, can be traced back to the creation of the "Union of Italian Scientists", wanted by the zoologist Carlo Luciano Bonaparte, (son of Luciano, younger brother of Napoleon I) and by Vincenzo Antinori, Giovanni Battista Amici, Gaetano Giorgini, Paolo Savi and Maurizio Bufalini. However, its main promoter was Prince Carlo Luciano Bonaparte, who, animated by nationalist fervor, convinced the Grand Duke of Tuscany Leopold II to promote the first meeting of Italian scientists in Pisa from 1 to 15 October 1839, hosting scholarly memoirs in six sections: Physics, Chemistry and Mathematical Sciences; Geology, Mineralogy and Geography; Plant Botany and Physiology; Comparative Zoology and Anatomy; Medicine; Agronomy; Technology. The choice of Pisa seems the most suitable, both due to the fact that it is located in Tuscany, where Leopold II is known for his scientific interests, and due to the fact that it was the birthplace of Galileo Galilei, universally recognized as the father of modern science. The meetings were first held on an annual basis until 1847, each meeting being made up of several meetings held on different days over a period of 15 days. Subsequently they resumed in unified Italy in 1861 in Florence with an extraordinary edition in 1862 in Siena (X meeting) and in 1873 in Rome (XI meeting). They conclude with the last one of 1875 in Palermo (XII meeting), on the occasion of which the regulation of the "Italian Society for the Progress of Sciences (SIPS) is approved, which therefore is to be considered the continuation of the "Union of Italian Scientists". Already in these meetings it is possible to glimpse the spirit of international openness that will increasingly characterize the activities of our national scientific community. Indeed, some famous foreign scientists were also invited to the meetings, among which the names of William Herschel and Charles Babbage stand out, and the proceedings of the meetings were sent to the most important foreign scientific institutions.

3.2 - MATHEMATICS

In the first half of the 19th century, mathematics, both in teaching and in research, had suffered a long period of decline in Italy compared to the rest of Europe. But after the proclamation of the Kingdom of Italy, thanks to the work of many Risorgimento and post-Risorgimento mathematicians, the situation changed radically, starting a golden age of Italian mathematics. The most prominent mathematicians of this period are Enrico Betti (1823-1892), Francesco Brioschi (1824-1897), Giuseppe Battaglini (1826-1894), Felice Casorati (1835-1892), Luigi Cremona (1830-1903) and Eugenio Beltrami (1836-1900). These mathematicians also actively participate in the events of our Risorgimento.²⁰ However, despite being "patriots", they did not choose blind nationalism, but worked to give the mathematical research of a unified Italy an international connotation, establishing ties with the rest of Europe. Battaglini's students were several illustrious specialists in algebraic geometry: Enrico D'Ovidio, Riccardo De

²⁰ Bottazzini, Nastasi, (2013).

Paolis, Ettore Caporali, Domenico Montesano, as well as the algebraists Alfredo Capelli and Giovanni Frattini. In 1858 Betti, Brioschi and Casorati visited the universities of Göttingen, Berlin and Paris. On November 29, 1863 Brioschi, with his student engineer Giuseppe Colombo, founded the Royal Higher Technical Institute in Milan (which will later take on the name Polytechnic), taking analogous German institutions as a model. Bernhard Riemann, invited to teach at the “Scuola Superiore Normale” in Pisa, rejected the proposal for health reasons, but remained in Italy from 1863 to 1866, the year in which he died in Selasca, on Lake Maggiore, on 20 July. Those years were therefore an unrepeatable occasion for fruitful exchanges of ideas between the great German mathematician and our Pisan mathematicians. The work of Betti, Brioschi, Casorati, Cremona and Beltrami gives extraordinary results, not only for their research but also for the formation of new generations of brilliant mathematicians, who bring Italian mathematics to the highest international peaks in the period from 1880 to First World War with: Ulisse Dini (1845-1918), Cesare Arzelà (1847-1912), Salvatore Pincherle (1853-1936), Gregorio Ricci Curbastro (1853-1925), Giuseppe Veronese (1854-1917), Luigi Bianchi (1856-1928), Giuseppe Peano (1858-1932), Ernesto Cesàro (1859-1906), Vito Volterra (1860-1940), Corrado Segre (1863-1924), Guido Castelnuovo (1865-1952), Federigo Enriques (1871-1946), Tullio Levi-Civita (1873-1941), Guido Fubini (1879-1943), Francesco Severi (1879-1961), Leonida Tonelli (1885-1946), Guido Ascoli (1887-1957). The fame of these mathematicians is international, so much so that Felix Klein, for his great *Enzyklopädie der mathematischen Wissenschaften (Encyclopaedia of Mathematical Sciences)*, entrusts the drafting of many entries to Italian mathematicians, including Salvatore Pincherle, Luigi Berzolari, Orazio Tedone and Federigo Enriques. In 1907 Klein asked the latter to draft the article *Prinzipien der Geometrie*, dedicated to the principles of geometry, which would turn out to be a real monograph on the subject. Algebraic geometry, due to the preponderant contribution of Italian mathematicians (and Enriques will be one of its fathers together with Corrado Segre, Luigi Cremona, Guido Castelnuovo and Francesco Severi) will be known in Germany as *l'italienische Geometrie*, the Italian geometry. There are also international awards. In 1907 Federigo Enriques and Francesco Severi received the Bordin prize from the Academie des Sciences in Paris. In 1909, the same prize was awarded to Giuseppe Bagnera (1865-1927) and Michele de Franchis (1875-1946) for their work on the classification of elliptical surfaces. The philosopher and logical-mathematician Bertrand Russell defines Peano as «the great master in the art of formal reasoning» (Russell, 1970, p. 74) and Henry Poincaré, in the French newspaper «*Le Temps*», refers to the “Palermo Mathematical Circle” as to the largest mathematical organization in the world. And he has every reason to affirm it: out of 924 members, 618 are foreigners, that is almost 70%! On the proposal of Vito Volterra, the IV International Congress of Mathematics was held in Rome from 6 to 11 April 1908. There were 700 participants in the congress. Italy is present with the highest number (213), followed by Germany (174), France (92) and Austria-Hungary (74). Volterra, in his inaugural speech, confirms the international character of science, which also informs the Italian one.

3.3 - PHYSICS

Pietro Blaserna, Antonio Pacinotti, Damiano Macaluso, Galileo Ferraris, Augusto Righi, Orso Mario Corbino, Domenico Pacini, Antonino Lo Surdo and Guglielmo Marconi are the leading figures in Italian physics from the mid-19th century to the beginning of

the 20th century.²¹ Physics, until about 1870, was essentially conceived as Galileo intended it: an experimental science, in which mathematics was reserved an auxiliary and instrumental function, a means of expressing quantitatively relationships between the physical quantities object of the experiment. Language and heuristic tool, then. But in the last thirty years of the nineteenth century, experimental physics was joined by the mathematical physics of Betti, Volterra and other physicist-mathematicians and engineers, such as Luigi Federico Menabrea and Alberto Castigliano, whose research converged into the rising Building Science. Only in 1926 Orso Mario Corbino explained very clearly the need to introduce theoretical physics, in addition to mathematical physics, to re-establish the lost contact between mathematical physicists and experimental physicists: he will introduce the first chair of theoretical physics in Italy, held by Enrico Fermi. The first-degree thesis in theoretical physics is that of the homonymous son of the philosopher Giovanni Gentile, Giovanni Gentile Jr (1906-1942), achieved in Pisa in 1927. The differences of methodological approach in the research of mathematical physics and theoretical physics²² also explain the different professional connotations of the authors: mathematicians the authors of mathematical physics research and physicists the authors of theoretical physics research. But in the period considered here, prior to the famous dispute between Enriques and the neo-idealist philosophers, which began in 1908, theoretical physics does not exist as a separate discipline, being identified with mathematical physics. This explains why many mathematicians of the time were also physicists.

In 1844 Carlo Matteucci and Raffaele Piria founded the journal «*Il Cimento, giornale di fisica, chimica e storia naturale*» (*The Cimento, journal of physics, chemistry and natural history*) in Pisa, which in 1855 became «*Il Nuovo Cimento, giornale di fisica, chimica e storia naturale*» (*The New Cimento, journal of physics, chemistry and natural history*), often abbreviated to «*Il Nuovo Cimento*,». Forty-two years later, in 1897, it became the official press organ of the "Italian Physics Society" and one of the most authoritative and famous physics journals.

The first great reformer of Italian physics is Pietro Blaserna (1836-1918), who graduated in physics with honors at the age of 21 from the University of Vienna and then assistant to Henri-Victor Regnault at the University of Paris, where he dealt with theory gas kinetics. In 1862 - at the age of just 26 - he was called to fill the chair of Experimental Physics first at the Institute of Higher Studies in Florence and then, the following year, at the University of Palermo. In 1872 he went to Rome to hold the chair of Experimental Physics. Blaserna radically reformed the teaching of physics by introducing the institution of the "practical school", i.e., the physics laboratory. Furthermore, in 1881, on the model of the most advanced European university centres, Blaserna established a

²¹ Giuliani (1996, 2013).

²² The works in mathematical physics and theoretical physics are characterized by a strong presence of mathematics, but with a different use of it. Mathematical physics works place the main interest in solving the mathematical problem faced and the comparison between mathematics and experience is not generally foreseen. The physical aspects of the problems addressed influence only the choice of the starting postulates, limiting their generality. Their goal is not so much the acquisition of new physical results but that of obtaining a rigorous formalization of already existing physical theories, following a hypothetical-deductive approach. On the contrary, in theoretical physics works, the role of mathematics is auxiliary and instrumental, being used as a language and tool to quantitatively express relationships between physical quantities and to formalize the physical theory which remains, however, the true object of the research. Theoretical physics works involve the comparison with the experiment and are often themselves generated by seeking an interpretation to previous experimental results. Furthermore, theoretical physics research does not always follow a rigorous hypothetical-deductive method.

more modern physics institute in via Panisperna in Rome. In this same institute, a few decades later, Enrico Fermi's famous Roman physics school was born. Blaserna's research spans various fields of physics: properties of real gases, study of the ionization of air, thermodynamics, optics, geophysics, electrotechnics, acoustics, musical physics.

Antonio Pacinotti (1841-1912) has remained known in the history of science for the conception of the famous ring that bears his name, which is none other than the first rudimentary realization of the direct current dynamo, the first dynamic machine generating electricity.²³ As he himself recounts, he had the idea one evening during the Second Italian War of Independence in 1859 in which he participated as a volunteer sergeant, and it was published for the first time in the June 1864 issue of «*Il Nuovo Cimento*», in a paper entitled *Descrizione di una macchinetta elettromagnetica* (*Description of an electromagnetic machine*). Unfortunately, as with other discoveries made by Italians, even that of the direct current dynamo was plagiarized by foreigners. The paternity of the invention of the dynamo was publicly acknowledged to Pacinotti by Galileo Ferraris but never in France. The official priority of the invention of the direct current dynamo was recognized to him long after his death, at the Chicago Universal Exposition of 1933 and in 1934 at the Congress of Electrotechnical Scientists, on the occasion of the 75th anniversary of his conception.

In 1900, there were just 71 physicists in Italian universities, making up a scientific community that was too small and poorly equipped to deal with the new experimental discoveries and new ideas of the decade 1895-1905. However, original research was also recorded in this period, such as, for example, those on magneto-optical effects. In 1885, the engineer Galileo Ferraris (1847-1897) discovered the principle of the rotating magnetic field, which is the foundation of the alternating current electric motor. In 1898 Damiano Macaluso (1845-1932) and Orso Mario Corbino (1876-1937), experimenting on vapors of alkali metals, discovered that the Faraday effect takes on particular characteristics when the wavelength of light approaches that of the absorption lines of the atoms constituting the vapour: the Macaluso-Corbino effect is still today the object of experimental and theoretical study. Corbino also studies the *Hall effect* in bismuth discs, in which a circular symmetry is maintained: the original radial current, produced by a potential difference applied between the center and the periphery of the disc, is partially transformed into circular current by the magnetic field applied perpendicular to the disk. This line of research intertwines with that of mathematical physics of which Vito Volterra is the greatest representative, thus constituting a real Italian tradition of research.²⁴

A leading position in Italian physics of this period is held by Antonio Garbasso (1871-1933). His research concerns primarily, since the time of his degree in physics at the University of Turin, electromagnetism and its relationship with optics and in a more advanced age also spectroscopy. After graduation, he follows master classes with Heinrich Rudolf Hertz at the University of Bonn and with Hermann von Helmholtz and Emil Aschkinass at the University of Berlin. He carries out studies and research on X-rays, just discovered by Wilhelm Conrad Röntgen in 1895. Winner of two competitions for the chair of mathematical physics and experimental physics, he chose the latter, teaching experimental physics at the famous "Istituto di Studi Superiori, Pratici e di Perfezionamento" in Florence,²⁵ succeeding the illustrious mathematician and physicist

²³ Previously, the only way to generate electricity was the electro-chemical static one of the electric cells or batteries.

²⁴ Nicotra (2021a).

²⁵ Which will later become the University of Florence.

Antonio Roiti (1843- 1921).²⁶ In Arcetri Garbasso creates the Italian school of cosmic ray physics (Arcetri school), which conquers leading international positions in this line of research thanks to Enrico Persico (1900-1969), Giorgio Abetti (1882-1982) and the students of Garbasso (Antonino Lo Surdo, Rita Brunetti, Giuseppe Occhialini, Bruno Rossi, Franco Rasetti, Francesco Rodolico, Vasco Ronchi, Gilberto Bernardini, Daria Bocciarelli, Lorenzo Emo Capodilista). Garbasso also actively devoted himself to politics as a senator of the Kingdom of Italy from 1924 to 1933 and mayor of Florence from 1920 to 1928 with some brief interruptions. He adheres to the fascist regime but disagrees with the Gentile reform which penalizes scientific teaching.

In 1908 Blaserna called to Rome the Sicilian physicist Orso Mario Corbino, professor of Experimental Physics at the University of Palermo, to hold the chair of Complementary Physics. It will be Corbino who will continue Blaserna's work of reforming Italian scientific research, leading it to deal with frontier research of the time. Ten years later, in 1918, Corbino will hold the chair of Experimental Physics at the Royal Physical Institute left vacant by the death of Pietro Blaserna and will also replace him in the direction of the Institute. Corbino, in Sicily, had dedicated himself to cutting-edge research in the field of "modern physics" and wants to transform the Physics Institute in via Panisperna into a center of excellence at the European level, which it will later become with the "ragazzi di Fermi" (Fermi's boys). Corbino is a scientist in the modern sense of the term. His activity is not limited to pure research, but also involves applied research, the industrial world, and politics.

In 1909 the Nobel Prize for Physics was jointly awarded to Guglielmo Marconi (1874-1937) and Karl F. Braun (1850-1918) in recognition of their contribution to the development of wireless telegraphy. It is the first Nobel awarded to an Italian scientist.²⁷

The researches of the Italian physicists Antonino Lo Surdo (1880-1949) and Domenico Pacini (1878-1934) are the basis for the researches that will yield the Nobel Prize for Physics respectively to Johannes Stark (1874-1957) in 1919 and to Victor F. Hess (1883-1964) in 1936.

Vito Volterra²⁸ he is undoubtedly the undisputed leader of the Italian scientific community in the second half of the 19th century and the first decades of the following 20th, until his isolation by fascism after 1926. His contributions to mathematics and physics are so numerous and known at international level to be called by the US newspapers "Mister Italian Science". The public and academic offices of Volterra are numerous and at an international level. His specialty is mathematical physics, but his interests range well beyond scientific ones, generously embracing humanistic and historical culture in particular, thus giving a shining demonstration of how false the separation between the so-called two cultures is, the humanities and science. He is also a tireless scientific organizer. Volterra is co-founder and first president of the "Italian Physical Society" in 1897 and does not miss an opportunity to relate Italy with the most qualified international scientific circles, through the exchange of researchers between the scientific communities of different countries, showing an incredible modernity of views on science policy. In 1900 Volterra was called by Blaserna to teach Mathematical Physics at the Royal Institute of Physics of the "La Sapienza" University of Rome, in via Panisperna. We owe him and Orso Mario Corbino the creation of the famous physics

²⁶ The precarious economic conditions of the young Vito Volterra would have forced him to abandon his studies, if he hadn't been helped by Roiti, who offered him a position as preparatory assistant at the "Institute of Advanced, Practical and Improvement Studies" in Florence in 1877 (Nicotra, 2021a).

²⁷ For the background of this Nobel, see Bischi (2017).

²⁸ Nicotra (2021a).

school in via Panisperna, which will be led by Enrico Fermi, of whom Volterra follows the first steps of the scientific career by giving him a scholarship from the Rockefeller Foundation in 1924 at the institute directed by Paul Ehrenfest in Leiden. In 1917 he created the "Inventions and Research Office". In February 1919 the "International Research Council" was established, of which Volterra was appointed a member. In the same year Volterra wanted to replicate the international scientific initiatives on a national level, proposing the establishment of the "National Research Council" (CNR), which should have incorporated various already existing research bodies: the "Inventions and Research Office", the "Committee for the Chemical Industries and the Aeronautical Institute". The project was approved by the Orlando government, but due to bureaucratic difficulties the activity of the CNR began five years later, in 1924, with Volterra as its first president.

Certainly, his example must have had a strong influence on the education of Enriques, who was his pupil in Pisa. Many characteristics of Volterra can be found in Enriques: versatility, the unified conception of culture, the passionate commitment to organizing events and scientific institutes of great prestige.

3.4 - CHEMISTRY

It is the chemistry of the late nineteenth century that demonstrates, even before the physics of the early twentieth century, that the world at a microscopic level is not characterized by continuity but by discontinuity. In 1912, Max Planck himself, who twelve years earlier had discovered the "elementary quantum of action" and therefore discontinuity in physics, wrote:

Physical forces, gravity, electric and magnetic attractions or repulsions, cohesion, act continuously; the chemical forces, on the contrary, according to quanta. This law should be connected with that which permits masses in physics to act on one another in any quantity, whereas in chemistry they can act only in sharply defined, discontinuously variable proportions.

Italian chemistry is represented in this period by two illustrious names, Stanislao Cannizzaro and Giacomo Ciamician, and by another equally illustrious who preceded them: Amedeo Avogadro. All three have made fundamental contributions to this science.

In 1811 Avogadro (1776-1856) proposed the famous law that today bears his name: *Equal volumes of gaseous substances, at equal temperature and pressure, contain an equal number of molecules.* Avogadro gives the molecule the role, followed today, of the fundamental unit of chemistry. For Avogadro, reactions are exchanges between molecules. He gives a simple explanation of the relationship between the microscopic and macroscopic world, or between molecules and volumes, providing, among other things, a very simple way to determine the molecular weight. His ideas, however, are too ahead of their time. They clash with those of the powerful Swedish chemist Jöns Jacob Berzelius, who disputes Avogadro's idea according to which the organic-biological world and the inorganic world are made of the same matter and obey the same physical laws. Furthermore, Berzelius and others contest Avogadro for some anomalies in the application of his law.

We had to wait at least half a century, 1860, before Avogadro's brilliant ideas were accepted by the scientific community, thanks to another great Italian: Stanislao Cannizzaro (1826-1910) from Palermo, a student of the great Calabrian chemist Raffaele Piria (1814-1865), professor at the University of Pisa, considered the founder of modern

chemistry in Italy. Cannizzaro accepts August Kekulé's invitation to participate in the congress of chemists from all over Europe in Karlsruhe, Germany, between 3 and 5 September 1860, during which he once again proposes Avogadro's clear distinction between atom and molecule. On the last day of the Congress, a note of his on atomic weights, written in 1858 and published in the *Sunto di un corso di filosofia chimica (Summary of a course in chemical philosophy)*, was distributed, a synthesis work of his lessons as professor of chemistry in Genoa. In this note, Cannizzaro explicitly refers to Avogadro's Law of 1811. Cannizzaro's report receives the full support of another congressman, the chemist Dmitriy Ivanovich Mendeleev, and thanks to his clarity of exposition, Congress officially accepts Avogadro's hypotheses. Cannizzaro demonstrates very clearly the falsity of the objections posed by Berzelius and others against Avogadro's law: the anomalies they detect in its application are only apparent, because they are due to dissociations of a thermal type. Cannizzaro demonstrates that in every compound every different chemical element is present with at least one atom and finally demonstrates that molecules, despite being compound entities, have their own specific chemical identity and therefore are the constituent units of matter from a chemical point of view. It is a great international affirmation of Italian chemistry. Harold Hartley will write:

The Karlsruhe Conference, thanks to the presence of Cannizzaro, was destined to have a decisive influence on the progress of chemical theory and to be a milestone in its history.

Thanks to the new approach of Avogadro and Cannizzaro, chemistry, just like physics, can apply mathematics and chemists can now write the formulas of molecules with great precision and ease. Cannizzaro himself, thanks to these new instruments, is able to measure the exact atomic weight of 21 different chemical elements.

Emanuele Paternò (1847 – 1935),²⁹ a pupil of Stanislao Cannizzaro, became a professor of chemistry at the University of Turin at the age of just 24 and in 1872 he succeeded Cannizzaro in the same chair at the University of Palermo, later also becoming its Rector from 1886 to 1890. In 1871 he founded the «*Gazzetta Chimica Italiana*» (*Italian Chemical Journal*). His main research concerns photochemistry, in particular the action of light on organic molecules. In 1909, together with George Büchi, he discovered the Paternò-Büchi reaction. Freemason, he held important political offices for many years: mayor of Palermo from 1890 to 1892, senator of the Kingdom of Italy from 1890 to 1935 and vice president of the Senate from 1904 to 1919, as well as numerous high parliamentary offices.

Raffaello Nasini (1854 - 1931),³⁰ after graduating, trained as a chemist in the Roman laboratory of Stanislao Cannizzaro and in the laboratory of Hans Heinrich Landolt in Berlin. Professor of general chemistry first at the University of Padua and then of Pisa, he devoted himself to research on gases, on the theory of solutions, on electrolytic dissociation and then on electrochemistry, of which he launched the first university course in Padua in 1900, probably the first in all of Italy. After the discovery of argon by Lord Rayleigh and William Ramsay in 1894, he develops a particular interest in terrestrial gaseous emanations which will also lead him to be interested in radioactivity. Nasini's research activity spans various and different fields of chemistry with interdisciplinary results: organic, general, inorganic chemistry, physical chemistry and

²⁹ De Condé Paternò di Sessa M., Paternò di Sessa O. (2018).

³⁰ Macchioni (2019).

also industrial chemistry. In the latter field, his studies on the boraciferous fumaroles of Larderello are noteworthy,

Giacomo Ciamician (1857-1922), graduated from the Justus Liebig-Universität of Gießen in Germany, trained as a chemist at the school of Stanislao Cannizzaro in Rome. On 11 September 1912, invited by his American colleagues to the VIII International Congress of Applied Chemistry, he proposed photochemistry as a future research direction for chemistry. On 27 September of the same year, in «Science», he published his report: *La fotochimica dell'avvenire (The photochemistry of the future)*. The proposal of the Trieste chemist was revolutionary for those times: fossil solar energy (alluding to fossil coal) was not the only energy source of solar origin useful for the development of civilization. We can learn from plant photosynthesis, using light to carry out a low-temperature chain reaction, thus creating a low-cost industrial photochemistry: an artificial photochemistry, of which Ciamician is considered the founder. A research program that already in 1903, he had begun to implement with a chemical device capable of capturing solar energy and transforming it efficiently and he had spoken about it in a speech given at the University of Bologna on November 7, 1903.

Mario Betti (1875 - 1942),³¹ who succeeded Giacomo Ciamician in 1923 at the University of Bologna, made contributions in organic, naturalistic and hydrological chemistry. In particular, he carries out original studies on organic bases, on the optical antipode doubling of many compounds and on spontaneous oxidation reactions. The general synthesis reaction of heterocyclic derivatives devised by him is known as the "Betti reaction". He has carried out studies on the relationship between the chemical structure and the rotary power of the elements and on the qualities of mineral and thermal waters. From 1939 until his death (1942) he was senator of the Kingdom of Italy.

Original contributions on the study of ternary and quaternary metal alloys and on heterogeneous catalysis are owed to Nicola Parravano (1883 - 1938),³² a pupil of Stanislao Cannizzaro and Emanuele Paternò.

3. 5 - ENGINEERING

Many Italian engineers of this period are responsible for the birth of the Building Science, a set of different disciplines of a physical, mathematical and experimental nature: analytical mechanics, theory of elasticity, continuum mechanics, science of materials.

The Casati law of 13 November 1859 on public education unifies, in the rising Kingdom of Italy, the training of engineers and architects with the establishment of the Engineering Application Schools, separating their studies from those of mathematics, following the model French from the Ecole Polytechnique. Thus, were born the School of Applications for Engineers of Turin in 1860 and the Royal Higher Technical Institute of Milan in 1863. Other pre-existing institutions would follow their example, such as the School of Applications of Bridges and Roads existing in Naples since 1811, the School of Pontifical Engineers in Rome since 1817. Furthermore, new Engineering Application Schools were born in Palermo in 1866 and in Genoa in 1870 and still others in Bologna, Padua, Pisa, Turin. Luigi Federico Menabrea (1809-1896), considered one of the greatest Italian scientists of the 19th century, teaches at the School of Application Engineering in Turin, having left significant contributions in the field of continuum mechanics and building science. He is also the author of the first scientific work on computer science:

³¹ Naso (2017).

³² Fontani, Salvi (2015).

Notions sur la machine analytique de Charles Babbage published in French in 1842. Menabrea was the first to give a formulation of structural analysis based on the principle of virtual jobs, becoming a forerunner in the introduction of energetic principles in continuum mechanics. His theorem of minimum of the elastic potential energy of a deformable body, enunciated in 1858, is well known in the building science. At the same School of Engineering Application in Turin, Giovanni Curioni (1831-1887) would teach from 1865, author of the mighty 6-volume treatise, *L'arte di fabbricare*, which also contains a course on topography. Numerous memoirs on the science of construction assured him international fame. To the engineer Eugenio Barsanti³³(1821-1864) we owe the conception and construction of the first internal combustion engine to an idea of his matured in 1841: illustrating to his students at the Collegio San Michele in Volterra, where he taught mathematics and physics, an experiment on the explosion of a incendiary mixture of air and hydrogen, he had the idea of using the rapid expansion of the mixture to raise a piston. In 1851 Barsanti met the engineer Felice Matteucci (1808-1887) with whom he would collaborate for the rest of his life building various models of internal combustion engines. The two engineers presented the invention of the internal combustion engine on 5 June 1853 at the Accademia dei Georgofili in Florence and, in 1854, obtain the patent in England with the title *Obtaining Motive Power by the explosion of Gases*.

Eng. Quintino Sella (1827-1884) is, together with Luigi Menabrea and Giuseppe Colombo one of the scientist figures who most have a strong presence in post-Risorgimento Italian politics. Repeatedly minister of finance in 1862, in 1864-1865 and in 1869-1873, he contributed to the work of transformation and enhancement of Rome not only as the capital of Italy but also as a European scientific centre. His expertise as an engineer in the mining field earned him various public positions in the sector and his studies in mineralogy various international awards as a scientist. In 1855 he designed and built a machine, the "electromagnetic sorter", based on the principle of electromagnets, to separate magnetite from cupriferous pyrite, obtaining the patent, which was awarded a gold medal at the Universal Exhibition in London in 1862.

Eng. Giuseppe Colombo (1836-1921) was one of the first professors at the Royal Technical Institute of Milan, becoming in 1865 holder of the chair of Mechanics and Industrial Engineering, that he would hold until 1911. In 1897, after Brioschi, he became the second rector of the Milan Polytechnic. He was also a passionate scientific communicator, much appreciated by an audience of all social classes, collaborator and then director of the technical magazine «L'industriale», published from 1871 to 1877. Elected a member of parliament in 1886, he was appointed minister of Finance in 1891, Treasury Minister in 1896, first Vice President and then President of the Chamber of Deputies from 1899 to 1900, finally Senator of the Kingdom of Italy in 1900. Giuseppe Colombo also possesses a brilliant and courageous entrepreneurial spirit: he understands the application potential of Edison's dynamos to produce electric lighting and electricity in distributable form, as were gas and water. He asks for and obtains from Edison the exclusive right for Italy to use his method. With John William Lieb, a technician of the Edison Company, under his guidance, on June 28, 1883, in Milan, next to the Duomo, in a building built on the site of a former theater in via Santa Radegonda, he inaugurated the first power plant of the 'Continental Europe.

His most famous writings certainly remain his numerous technical manuals, in particular the *Manuale dell'Ingegneria Civile ed Industriale (Manual of the Civil and*

³³ His real name was Nicolò. Eugene is the name he took as a priest in the Scolopi order.

Industrial Engineer) (more familiarly known as " *il Colombo*") whose first edition, from the publisher friend Ulrico Hoepli of Milan, dates back to 1877. It will remain for decades, with numerous reissues and updates, the practical guide of generations of engineers, still on the market today.

A place of honor in the construction of the theory of elasticity, to which many mathematical engineers-physicists of the time made fundamental contributions, is undoubtedly occupied by Carlo Alberto Castigliano (1847-1884), a pupil of Curioni. Born into a family of humble origins, during his studies he had to face economic difficulties due to the loss of his father and then also of his stepfather, who had married his mother who was widowed for the second time. In 1871 Castigliano obtained a degree in pure mathematics and in 1873 a degree in civil engineering, discussing the thesis *Intorno ai sistemi elastici. Dissertazione (On elastic systems. Dissertation)*, published in Turin in the same year. It contains the proof of the principle of elasticity or theorem of minimum work stated, but not proved, by Menabrea in 1858:

Let us consider an elastic system made up of parts subject to torsion, bending or transversal sliding, and of rods jointed to those parts and to each other: I say that if this system is subjected to the action of external forces so that it deforms, the tensions of the rods after deformation are those which minimize the expression of the molecular work of the system, taking into account the equations that exist between these tensions, and assuming constant the directions of the rods and of the external forces.

This theorem proved Menabrea's principle in more general terms and will be known later as Primo Teorema di Menabrea (or "Menabrea's First Theorem"). This was the object of dispute between Menabrea and Castigliano, who accused Menabrea of plagiarism having not explicitly acknowledged his work. Indeed, in 1875, Menabrea, in another attempt to prove his principle of minimum energy, made use of Castigliano's demonstration, which he simply quoted in a footnote.

Another result that made Castigliano famous all over the world is another theorem at the foundation of the theory of elasticity, the theorem of derivatives of work, known as *Castigliano's Theorem*,³⁴ used for calculating the displacements of a structure and therefore its stiffness with a test load. Once the elastic deformation energy has been calculated with the beam theory, it is sufficient to calculate its partial derivatives with respect to the applied forces to obtain the displacement. Finally, stiffness is the ratio between the applied force and the displacement it causes.

Castigliano was appointed a member of the Accademia Nazionale dei Lincei and of the Academy of Sciences of Turin and in 1861 received the title of count. His results on the theory of elasticity, published in various works, were published in French in Turin by the publisher Negro in 1880, in the work *Théorie de l'équilibre des systèmes élastiques et ses applications*. This work, more than any other, made him known throughout the world.

³⁴ The Author formulated it as follows: «... the displacement (or rotation) of an elastic solid element is defined by the partial derivative of the deformation work, expressed as a function of the external forces (or moments), performed with respect to one of these forces that is applied to the element considered at the point and in the direction of the desired displacement". In more modern terms: «For a body whose behavior is part of the 1st order theory, with fixed constraints, not subject to temperature variations, the generalized displacement, relative to a generalized force P_i due to all the forces acting on the body, is given by the partial derivative of the elastic potential energy with respect to the same force P_i » (Cartapati, Gallo Curcio, Piccarreta, 1972, chap. IX).

Castigliano owes many works of application of the theory of elasticity to engineering, and also the invention of an instrument, the multiplier micrometer, to measure the deformations produced by loads in metal constructions, which was very widespread in railway operations.

Camillo Gaudi (1853-1941), who succeeded Curioni in 1882, was responsible for the text *Lezioni di Scienza delle Costruzioni* (Lessons on the Building Science) with an axiomatic-deductive approach, which was taken up and perfected by Eng. Gustavo Colonnetti (1886-1968) who took over from him the chair of Building Science in 1928. His book *Principi di statica dei solidi elastici* (*Principles of statics of elastic solids*) dated 1916 was later republished under the title *Scienza delle Costruzioni* (*Building science*) by Einaudi in 1941, remaining a classic for the teaching of that discipline until the seventies of the twentieth century.

3.6 - POLITICS

Another characteristic aspect of Italian science of the period between the 19th and 20th centuries is the political and, in Italy of the Risorgimento, also military commitment by numerous Italian scientists, a phenomenon almost completely absent in the political reality of our country today.³⁵

The Italian scientific community of mathematicians, physicists, chemists and naturalists of the last decades of the nineteenth century and the first decades of the following, on the wave of nineteenth-century positivism, is firmly convinced that science can play a leading role in cultural social and economic development of Italy. The presence of many great Italian scientists in active politics with key governmental positions, bears witness to this. The following became Prime Ministers: the doctor Luigi Carlo Farini and the engineer Luigi Federico Menabrea (three times). The engineer Giuseppe Colombo is President of the Chamber of Deputies. The chemist Emanuele Paternò was vice president of the Senate from 1904 to 1919. The following become ministers: the engineers Luigi Federico Menabrea, Quintino Sella and Giuseppe Colombo, the mathematician Luigi Cremona, the physiologist Carlo Matteucci and the physicist Orso Mario Corbino. The mathematicians Francesco Brioschi and Enrico Betti are undersecretaries. The following deputies or senators are elected: the mathematicians Ottaviano Fabrizio Mossotti, Francesco Brioschi, Enrico Betti, Luigi Cremona; the physicists Orso Mario Corbino, Giovanni Cantoni, Augusto Righi, Antonio Pacinotti, Galileo Ferraris, Antonio Garbasso; the chemists Emanuele Paternò (senator from 1890 to 1935), Mario Betti, Raffaele Piria, Stanislao Cannizzaro; the physiologists Carlo Matteucci, Jacob Moleschott, Giulio Bizzozero, Camillo Golgi.

4 - THE BATTLE OF NEOIDEALISM AGAINST 19TH CENTURY POSITIVISM

On the philosophical level, the main reason for the dispute opened by the Italian neo-idealists against Enriques was the erroneous (or wanted?) identification of Enriques' philosophy with nineteenth-century positivism, opposed by neo-idealism. Enriques, from a young age, strongly and clearly appealed to positivism, but later his criticisms of positivism made him deviate from it clearly, as he himself declared. However, his criticisms were not fully understood by the Italian neo-idealists and his philosophy was superficially branded as positivist. It is therefore appropriate, to understand how much

³⁵ Bottazzini and Nastasi (2013); Nicotra (2021b).

that dispute was animated by other real reasons, to recall the fundamental points of positivist thought and Enriques' reasons for dissent from it.

4.1 - CHARACTERISTICS OF POSITIVISM

Positivism was a philosophical movement that was essentially the result of the Industrial Revolution of the first half of the 19th century and of the rising capitalism of the most industrialized European countries: England, France and Germany. It was founded on the exaltation of scientific and technological progress. Its name derives from the Latin *positum*, the past participle of the verb *ponere*: "that which is placed", that which is founded, that which has its basis in the reality of concrete facts. The founding thought of positivism was expressed by the French philosopher Augusto Comte (1798-1857) in the famous *Discours sur l'esprit positif* (1844) in five points, summarized as follows (Comte, 1985, pp. 47-48): the opposition of real to chimerical; the opposition of the useful to the useless; the opposition of certainty to indecision; the opposition of the precise to the vague; the opposition of the word "positive" to the word "negative", to highlight the opposition of organizing to destroying the new modern philosophy.

4.2 - THE VALUE OF SCIENCE FOR POSITIVISM AND FOR ENRIQUES

Like positivism, Enriques gave science a primary place in the theory of knowledge. On the other hand, the points of divergence between the positivist thought and the philosophical thought of Enriques on the value of science are various and substantial.

The first major point of divergence is the purely utilitarian value of science for positivism,³⁶ while for Enriques it is above all fully theoretical and only subordinately utilitarian.

For positivism, science has absolute value, since its conquests are definitive and fully true; for Enriques, on the other hand, science has only a relative value because it is always approximate, never concluded, being in a continuous evolution and improvement:

... science is a process of successive approximations which indefinitely prolongs its roots in the unconscious inductions of common life, and pushes its branches ever higher, touching on an ever wider, more certain and more precise knowledge.³⁷

and because his purchases imply other previous ones:

Science as well as approximate is also relative. This implies that the meaning of a scientific fact must be subordinated at all times to all the knowledge acquired. Precisely because everything is relative, it is not permissible to take any fact or principle as an isolated one, nor to establish an absolute hierarchy of knowledge which places a primitive knowledge independent of the development of knowledge considered as a whole.³⁸

A consequence of the relative nature of science is Enriques' criticism of the absolute classification of the sciences enunciated by the positivists Auguste Comte and Antoine Augustin Cournot, founded instead on the conviction of the absolute value of scientific knowledge.

³⁶ As for neo-idealism.

³⁷ Enriques (1912, pp. 20,21).

³⁸ There.

Furthermore, Enriques contested positivism for limiting itself to explaining the "how" without seeking the "why" of a phenomenon:

... hypotheses and imaginative representations lead beyond positive science. In this respect the causal explanation implies something more than the simple answer to the question of "how a certain phenomenon occurs". Science goes beyond this explanation when it tries to explain the "why."³⁹

Positivism identifies the "brute fact" with the "scientific fact", attributing a scientific value to experimental or observational data. Comte stated that science must be made up only of ideas, hypotheses and theories that do not go beyond the reality of directly available data, thus affirming the absolute objectivity of the brute fact.

For Enriques, on the other hand, "brute facts" (experimental or observational data) have no meaning in themselves but receive it from the ideas according to which they are interpreted, ordered and correlated, thus becoming "scientific facts".

But this doctrine [positivism], taken literally, would remove all value from science, reducing it to a simple collection of recipes. Because even what we rightly call "facts" receive their meaning precisely from the ideas according to which they are interpreted. [...] A fact is never the brute encounter of certain sensible data, but the connection of several data of a certain order, dominated by an idea: its affirmation always implies recognizing objective and subjective data, separable up to a certain point, but never in an absolute sense.⁴⁰

It is in this passage from the "brute fact" to the "scientific fact" that the construction of scientific knowledge consists of:

Whoever intends to understand the differences between the brute fact in the vulgar sense of the word, and the scientific fact, first of all sees in the latter a much clearer conditional character. [...] So a scientific fact grows, so to speak, from a multitude of brute facts contained in it; it gains in generality as it sums up new, more extensive relationships in itself.⁴¹

Enriques' distinction between brute facts and scientific facts is in perfect agreement with Poincaré's thought:

We cannot be satisfied with pure and simple experience. No, this is impossible; it would be tantamount to completely disregarding the true character of science. The scientist must order; science is made with facts, as a house is made with stones; but a heap of facts is as little a science as a pile of stones is a house.⁴²

From his own words the collocation of the philosophical-scientific thought of Enriques in the field of that experimental rationalism expressly mentioned by him is clear:

But on the other hand, we can see how every observation and every experience has scientific value only insofar as it is based on a reasoning; otherwise he is reduced to

³⁹ Enriques (1945, p.107).

⁴⁰ Enriques (1936 b).

⁴¹ Enriques (1906, pp.101, 102).

⁴² Poincaré (1950, pp. 137-138).

*waiting for nature to be kind enough to instruct us, answering by chance questions that we don't know how to ask or interpret.*⁴³

It is that physical-mathematical method of investigation which Galileo and Newton assumed as a paradigm for the birth of modern science, founded on the symbiosis between experiment and mathematics, which had - it must be pointed out - a brilliant precursor in Leonardo da Vinci:

*I believe that instead of defining what the soul is, which is something that cannot be seen, it is much better to study those things that can be known through experience, since only experience does not fail. And where one of the mathematical sciences cannot be applied, one cannot be certain.*⁴⁴

Enriques' highly interdisciplinary mentality and the particular place he has always assigned to psychology widen the domain of ideas according to which raw facts must be interpreted, ordered and correlated so that they become new acquisitions of science:

*The study of science, conceived as a "fact", must be aided by the teachings of History and the results of Psychology.*⁴⁵

Even more explicitly, he himself mentions the role of psychology in the genesis of scientific theories:

*Now in this second aspect, scientific theory appears to us as a psychological development, which proceeds in a properly inductive sense, that is, it draws new hypotheses from new associations, and from the verification of these it rises to more extensive and more precise associations and hypotheses.*⁴⁶

For positivism, reality is the experimental or observational datum itself, while for Enriques, reality is not identified with the experimental datum, but with what remains invariant in its mathematical representation:

*...the knowledge of a real always implies the coordination of conveniently associated data. In other words, reality is not a pure datum but something constructed thanks to the coordinating rational activity.*⁴⁷

This identification of reality with the invariance of its mathematical representation will be found several years later in Paul Dirac, for whom the Renaissance motto «*pulchritudo splendor veritatis*» was valid, i.e., the identification of the beauty of a mathematical formula with its truth. But why does beauty for Dirac lead to truth? The answer is simple: an equation, for Dirac, is beautiful if it contains invariants and invariance guarantees truth: therefore, beauty leads to truth.

5 - THE SCIENTIFIC PHILOSOPHY OF FEDERIGO ENRIQUES

⁴³ Enriques (1906, p. 126).

⁴⁴ Leonardo da Vinci (Codice Atlantico a 119 v).

⁴⁵ Enriques (1906, p. 79).

⁴⁶ Enriques (1906, p. 150).

⁴⁷ Enriques (1912).

We have seen previously what results of primary importance and what international connotation reached Italian science in the second half of the nineteenth century and in the first years of the new century. Enriques had fallen into that international climate of cultural and social modernization which had science and scientists as its driving force and among these, first and foremost, Volterra. Enriques was perhaps the Italian mathematician closest to the multifaceted scientific and cultural personality of the latter, of whom he had been a pupil. Unlike Volterra, however, he never exposed himself politically and instead, unlike his Master, he cultivated strong philosophical interests. Like Volterra, he had exceptional qualities as an indefatigable cultural organizer and firmly held the idea of interdisciplinarity, as a corrective to the cultural isolation produced by the excesses of specializations. Furthermore, like Volterra, he rejected a clear distinction between pure and applied mathematics and demonstrated a remarkable ability to weave broad and intense cultural relationships with scientists and philosophers from all over Europe: France, Germany, United Kingdom, Belgium, Russia, Sweden. He had a privileged relationship with France,⁴⁸ due both to the fact that French was his second mother tongue (being Federigo's mother of French-speaking origins) and to the particular consonance of his philosophical and scientific thought with that of many French scientists and philosophers. The foreigners with whom he had cultural exchanges form a long list of prominent figures in the scientific and philosophical fields.⁴⁹ Evidence of these contacts can be found in the copious correspondence that Enriques maintained with his brother-in-law and collaborator Guido Castelnuovo, between 1894 and 1905.⁵⁰

Many of his works were written directly in French and published in France before being translated and published in Italy. From 1895 to 1946 (the year of his death) as many as 56 works by Enriques were published in French, and he was also awarded various important positions in France, such as that of corresponding member of the "Académie des Sciences morale et politiques" and that of director of the series "*Philosophie et histoire de la pensée scientifique*" in the series "*Actualités scientifiques et industrielles*" of the publisher Herman of Paris.⁵¹

Federigo Enriques did not recognize the *status* of an autonomous discipline to philosophy, as he considered it a synthesis of critical observations on the sciences, referring to the thought of the pre-Socratic philosophers. He criticized the use of the term philosophy as «... a noun rather than an adjective (philosophical activity or spirit)». ⁵² For this reason it makes no sense to speak of a philosophical system of Enriques, but rather of his cultural program based on philosophy understood as a critical synthesis of the various sciences, a positive gnoseology, a philosophy of knowledge understood as the construction of a system of disciplines in which science (particularly mathematics),

⁴⁸ Nastasi T. (2012).

⁴⁹ Henri Poincaré, Emile Picard, Pierre Humbert, Emile Borel, Paul Emile Appell, Jacques Hadamard, Paul Painlevé, Xavier Léon, Emile Meyerson, Hélène Metzger, Henri Berr, André Laland, Henri Bergson, Léon Brunschvicg, Louis Couturat, Edouard Le Roy, Lucien Lévy-Bruhl, Alexandre Koyré, Georges Sarton, Charles Singer, Wilhelm Ostwald, Max Noether, Felix Klein, Ernst Mach, Albert Einstein, Otto Neurath, Franz Brentano, Gösta Mittag-Leffler, Oscar Zarisky.

⁵⁰ Bottazzini, Conte, Gario (1996).

⁵¹ Enriques published in this series a series of six volumes, which came out between 1936 and 1939, some of which (such as, for example, *Les Ioniens...*) in collaboration with Giorgio de Santillana. In 1936: *Les Ioniens et la nature des choses*; *Le problème de la matière: Pythagoriciens et Eléates*; *Les derniers "Physiologues" de la Grèce*. In 1937: *Le problème de la connaissance*; *Empirisme et rationalisme grecs*; *Platon and Aristotle*; In 1939: *Mathématiques et astronomie de la période hellénique*.

⁵² Enriques (1912, pp. 235-236).

philosophy, history, didactics and educational sciences interact organically in the formation of knowledge. A more concise definition of scientific philosophy can be: unification of knowledge on a scientific basis, with the history of science and the philosophy of science in a central position.

Although not constituted in a philosophical system, it is possible to speak of a philosophical thought of Enriques, characterized by the composition of different antitheses in new syntheses:

1. Reason-Experience in experimental rationalism;
2. Rationalism-Historicism in historical rationalism;
3. Intuition-Logic united in a single active process;
4. Induction-Deduction united in the single inductive-deductive process.

Enriques' scientific philosophy was conceived as a philosophical approach of the scientists themselves to science, and consequently brought together philosophy and science in the same scientist, as at the dawn of philosophical thought.

The idea of a scientific philosophy conceived instead as a collaboration between scientists and philosophers must have been widespread enough perhaps even before the publication of the philosophical writings of Enriques, if already in 1906 the Unione Tipografica Editrice di Torino (UTET) published a large volume of 868 pages, titled *Saggio di Filosofia Scientifica (Pandynamismo) Libri Tre (Physis-Psyche-Ethos)* signed by Roberto Gaetani D'Aragona. In the "Introduction" the Author clearly indicates the meaning he intends to give to scientific Philosophy:

The function of Philosophy, as we have just said, is to coordinate, select, synthesize the products of the individual sciences for a high rational, economic, biological purpose, whereas that of the individual sciences consists in coordinating, selecting, synthesizing in short and comprehensive formulas the results of sensuous experience in order to know the causal link between a group of observed facts. But Philosophy has not always been understood in this way, the individual sciences have not always been distinguished from it. [...] it is also true that [man] has confused the proper function of Philosophy with that of the individual sciences. Indeed, not even today does everyone agree on the goal that Philosophy must set itself, on its limits, on its method; just as there is no agreement on the proper function of each special science.⁵³

D'Aragona dwells extensively on the interdisciplinarity that at the time involved scientists of various disciplines (physicists, chemists, physiologists, mathematicians, etc.) and formulates a clear definition of scientific philosophy, as it was understood at the time:

... the philosophers will bring together the results obtained by all the technical scientists, and, working on this collected, elaborated, selected, coordinated material, they will create a new synthesis, they will build the scientific Philosophy, which will be the true, the healthy, and not the fantastic, convoluted, empty Philosophy, based on nothing. [...] Philosophy will be the heart of the scientific organism, the technical sciences, the single organs.⁵⁴

⁵³ D'Aragona (1906, pp.3,4).

⁵⁴ D'Aragona (1906, p. 5)

The idea of Enriques' scientific philosophy can also be found in the famous *Wiener Kreis (Vienna Circle)*,⁵⁵ founded in Vienna in 1922 by the German physicist and philosopher Moritz Schlick. The Wiener Kreis was a philosophical and cultural club which brought together many prominent philosophers and scientists of the time.⁵⁶ In this circle Schlick founded a new philosophical direction, known by the names of logical positivism or neo-positivism or physicalism, which spread throughout the rest of Europe and in the Anglo-Saxon countries. For his studies in the history of science, for his adherence to the project of a unitary encyclopaedia of science and for his conception of the new "scientific philosophy", Enriques figures, in the *Manifesto of the Club*, a reference thinker alongside Henri Poincaré, Hermann Ludwig Ferdinand von Helmholtz, Bernhard Riemann, Ernst Mach, Pierre-Maurice Duhem, Ludwig Boltzmann and Albert Einstein.

In fact, the philosophical-scientific approach of the Vienna Circle, expressed in its *Manifesto*⁵⁷ written by Hans Hahn, Rudolf Carnap and Otto Neurath, contains all the salient features of Enrique's thought: the unitary conception of science, scientific research as a collective work, the denial of an autonomous existence of philosophy as a discipline in itself, the intelligibility of scientific knowledge, the project of a scientific philosophy.⁵⁸

6 - THE CLASH FOR THE PHILOSOPHICAL AND CULTURAL HEGEMONY IN ITALY

Enriques' philosophical thought could not be appreciated by Gentile and Croce, not because of his presumed adherence to nineteenth-century positivism, as they contested and in reality, denied by Enriques himself, but because it profoundly undermined the cultural leadership of their philosophy.

Federigo Enriques was not only a great mathematician, a philosopher and a historian of science but also a great teacher, a passionate cultural organizer, an innovative reformer of culture: in short, an all-round intellectual of great stature. It is essential to underline this versatility of his figure as an intellectual, because it is closely connected with his cultural ideal of synthesis of the different sciences and more generally of the

⁵⁵ Initially named "Verein Ernst Mach" (Ernst Mach Company) by Hans Hahn in honor of Ernst Mach.

⁵⁶ Ernst Mach, Rudolf Carnap, Otto Neurath, Philipp Frank, Friedrich Waismann, Hans Hahn, Gustav Bergmann, Carl Menger, Herbert Feigl, Viktor Kraft, Ludwig von Bertalanffy, Hans Reichenbach, Kurt Gödel, Carl Hempel, Alfred Tarski, Willard Van Orman Quine, Alfred Julius Ayer, Arne Naess. Ludwig Wittgenstein and Karl Popper did not physically attend the Circle but maintained cultural relations with it.

⁵⁷ H.Hahn, L.Carnap, O.Neurath, *Wissenschaftliche Weltanschauung. Der Wiener Kreis*

(*The scientific conception of the world. The Vienna Circle*) dedicated to Moritz Schlick was published in the first international conference of the Circle held in Prague in 1929. In Italian: H.Hahn, L.Carnap, O.Neurath, *La concezione scientifica del mondo* (1979), edited by A. Pasquinelli Bari: Laterza.

⁵⁸ «The scientific conception of the world is characterized not only by peculiar theses but, rather, by the basic orientation, by the perspective, by the direction of research. It has as its goal the unification of science. Its intention is to connect and coordinate the acquisitions of individual researchers in the various scientific fields. From this program, derives the emphasis on collective work, on intersubjectivity, as well as the search for a global system of concepts. Accuracy and clarity are pursued, dark distances and impenetrable depths rejected. In science there is no "depth"; everywhere is the surface: all experience constitutes an intricate network, sometimes inscrutable and often only partially intelligible. Everything is accessible to man and man is the measure of all things. In this there is an affinity with the sophists, not with the Platonists; with the Epicureans, not with the Pythagoreans; with all advocates of the mundane or the earthly.

The scientific conception of the world knows no insoluble riddles. Clarification of traditional philosophical questions leads, in part, to unmasking them as pseudo-problems; in part, to convert them into empirical questions, subject, therefore, to the judgment of experimental science. Precisely this clarification of questions and statements constitutes the task of philosophical activity, which, however, does not tend to establish specific "philosophical" statements. The method of this clarification is that of logical analysis» (Hahn, Carnap, Neurath, 1979, pp.74,75).

different "knowledge", in the spirit of the unity of culture which he contrasts with the centrifugal tendencies of the various "particularisms", as he called specializations. A cultural ideal opposite to that of Croce and Gentile, for whom it was "vain hope" to believe that the analytic and synthetic tendencies could coexist in a single philosophical perspective.

The international connotation of the scientists' work was not very welcome to fascism, to which Gentile adhered. As Pietro Blaserna said in his introduction to the collective volume *Cinquanta anni di storia italiana (Fifty years of Italian history)*, published on the occasion of the first fiftieth anniversary of the unification of Italy, it «flies like an eagle and knows neither limitations nor frontiers, nor customs tariffs and differentials». This absence of «frontiers» certainly could not have pleased fascism, which in fact always exerted a control action on the activities of our scientists, contributing to the dismemberment of Fermi's group of physicists.⁵⁹ The emigration of almost all the "boys of via Panisperna" was influenced not only by the racial laws of 1938 but also by the usual reasons for the lack of funds destined for research, which became very strong with the death of Corbino and Marconi, their "patrons", both passed away in 1937. In contrast to this international connotation of our scientific community, also aimed at pursuing a modernization and progress of Italian society, we find instead the culture of the neo-idealism of Croce and Gentile characterized by a provincial attachment to the cultural traditions of our country, strongly biased towards the literary-humanistic disciplines.⁶⁰

Furthermore, his affirmed and acclaimed versatility placed Enriques, in the eyes of the two greatest Italian philosophers of the time, as a formidable opponent in the conquest of cultural hegemony in our country, unlike other men of science of great fame and prestige, such as Giuseppe Peano, Giovanni Vailati and Vito Volterra, but much more "confined" in their respective scientific programs and, therefore, considered harmless by Croce and Gentile,⁶¹ since culture in Italy is traditionally only humanistic:

Croce and Gentile are not worried by those "two or three modest and withdrawn logicians who cultivated an English garden next to their house".⁶²

The «two or three modest and withdrawn logicians» are Peano, Vailati and Volterra in the allusive words of Giovanni Papini, quoted above. Enriques, then, combined with his cultural versatility an extraordinary ability to organize events and cultural institutes

⁵⁹ Franco Rasetti (1901-2001) emigrated to Canada in 1939, where he taught at the Laval University of Québec; Emilio Segrè (1905-1989) in 1938 was at the University of California, "Berkeley". In that same year, the enactment of the fascist racial laws forced him to stay there for the rest of his life; Since 1936, the year in which he went to Paris to carry out studies with Irène Curie and Frédéric Joliot, on the collisions of neutrons with protons and on the electromagnetic transitions between isomers, Bruno Pontecorvo never returned to Italy, living and working in various foreign countries (USA, United Kingdom, Finland and finally USSR); Enrico Fermi (1901-1954) after receiving the Nobel Prize, at the end of 1938, moved directly to the USA with his wife of Jewish origins, and remained there until his death.

⁶⁰ Lombardo Radice (1982).

⁶¹ Vailati, who could have been a potential opponent in the conquest of philosophical hegemony in Italy, died in 1909. Peano was now on the threshold of retirement and his philosophical interests were limited to formal logic understood as an integral part of mathematics. While Volterra firmly shared - together with others such as Enrico Betti, Ulisse Dini, Luigi Bianchi, Giuseppe Peano and Enriques - the aversion and concern for the separation between humanistic studies and mathematics, however, he devoted a large part of his activity to the applications of science aimed at socio-economic progress of Italy.

⁶² Guerraggio, Nastasi (1993, p. 58).

of the highest order, which reflected the absence of boundaries of specialization in his fervor for unitary culture.

Enriques' main opponents in the battle for philosophical and cultural hegemony in Italy were certainly Giovanni Gentile and Benedetto Croce, but the style, intensity and results of the controversies that characterized that battle were very different for the two greatest Italian philosophers of the era. Therefore, it is convenient to treat Enriques' relations with Gentile and with Croce separately.

Furthermore, the controversy that saw them as protagonists for the philosophical and cultural hegemony in Italy included different aspects: on the surface they only seem to be ideological differences, but behind the scenes clear personal jealousies emerge on the part of the two idealist philosophers, who took the form of a real "conspiracy" against the Livorno mathematician.

6.1 – ENRIQUES AND GENTILE

A useful source for forming an idea of the evolution of the personal relationships between Enriques and Gentile are the 24 letters sent by the Livorno mathematician to the Sicilian philosopher in the period from 14 June 1907 to April 1942.⁶³

Gentile's criticisms of Enriques always remained within the orthodox limits of ideological differences, expressed in articles, without ever bordering on indecorous denigration, as instead happened with Croce. There was always a relationship of mutual esteem between the two, despite the "difference of views", which strengthened after 1923 to the point of assuming the connotation of a true friendship, which can be explained by Gentile's undisputed intellectual honesty which allowed him to recognize other people's commendable goals, beyond differences of views, both in the cultural and political fields.⁶⁴ The heading of the letters mentioned reflects and confirms this evolution of the interpersonal relationships between Enriques and Gentile, passing from the « Distinguished Colleague», of the letters from 14 June 1907 to 12 June 1910, to the «Dear Minister», of 23 December 1922 and 15 April 1923, to Dear Gentile», of the letters between 20 December 1924 and 8 December 1940, ending with a «Dearest Friend» in the letter of April 1942, written by Enriques to share with Gentile his «affectionate participation» in the «immense pain» for the loss of his son, the theoretical physicist Giovanni Gentile junior, known as Giovannino. Gentile's attitude towards science changed radically after the First World War, probably due to the influence of both his pupil Ugo Spirito and his sons Gaetano (doctor) and Giovannino (theoretical physicist). Science had fully entered the Gentile family, as transpired, in 1935, from Giovanni Gentile's own words:

Which [Italian scientists] have therefore opened the doors of their Congresses to philosophy. And it is to be hoped that the philosophers will abandon their tradition of their special Congresses.⁶⁵

The controversy between Enriques and the Italian neoidealism began in 1908 with Giovanni Gentile, following his severe criticism of Enriques' volume *Problems of science* (1906), which appeared in «La Critica» (1908, VI, pp. 130-146). , in which the Sicilian

⁶³ Guerraggio, Nastasi (1993).

⁶⁴ During the Republic of Salò, when, on 21 November 1943, he was nominated by Mussolini as president of the Italian Academy transferred from Rome to Florence, Gentile proposed to the Duce the appointment of academics, including non-fascists.

⁶⁵ Guerraggio, Nastasi (1993, p.68).

philosopher denied Enriques' "scientific philosophy" the value of a true philosophy, "oscillating between philosophy, never achieved, and the particular science hardly philosophized, with I don't know what advantage of the scientific spirit". Gentile rejects Enriques' conception of a science that is never complete and always perfectible, which he attributes to the incorrect identification between the history of knowledge and knowledge: «The progressive correction of knowledge is the history of knowledge», while knowledge is a «vision of the eternal» since the «formal theory of knowing» is out of time. Furthermore, Gentile disputes the unitary recomposition capacity of individual scientific acquisitions, which is the heart of the spirit of the scientific philosophy advocated by Enriques thanks to the «substitution [...] of social work for individual efforts». He considers it a contradiction and a «vain hope»:

What is this All of the enthusiasts of the new scientific philosophy? [...] The contradiction [...] between the analytic tendency and the synthetic tendency, which today fatally oppose each other in the mind of every scientist, is a true contradiction, and more profound than Enriques thought because it is basically the fundamental contradiction of thought.⁶⁶

The denial that the analytic and synthetic tendencies of science can coexist in a single philosophical perspective, in the new scientific philosophy, leads Gentile to harshly criticize also the validity of the «*Science magazine*» founded by Enriques the year before, in 1907, with the engineer-philosopher Eugenio Rignano, the chemist Giuseppe Bruni and the doctors Antonio Dionisi and Andrea Giardina:

A magazine which discusses, in the same issue, the electromagnetism of the universe, mediumship, the relationship between chemistry and biology, the need for light that plants have, consciousness, the Austrian economic school, the main laws of sociology, of the origins of religious celibacy, of the reform of the teaching of elementary mathematics, etc., in my opinion, can only encourage scientific amateurism, of which I don't know how much science can benefit.⁶⁷

An accusation, that of "scientific amateurism", which clashes with the plethora of excellent names of the collaborators of the Journal. Among the Italians: Vito Volterra, Giuseppe Peano, Guido Castelnuovo, Giovanni Vailati, Orso Mario Corbino, Enrico Fermi, Edoardo Amaldi, Camillo Golgi, Gino Loria, Ludovico Geymonat. Among the foreigners: Bertrand Russell, Ernest Rutherford, Sigmund Freud, Henri Poincaré, Emile Picard, Albert Einstein, Arthur Eddington, Werner Heisenberg, Rudolph Carnap, Otto Neurath, Ernst Mach, Hans Driesch, Pierre Janet, Jules Tannery.

Gentile, however - as Enriques challenged him in 1909 in the preface to the second edition of the Problems of Science - dwells only on chapter III ("The problems of logic") of the book, criticizing Enriques' empirical reduction of logic to psychology. Gentile ignores the remaining chapters IV, V, and VI dedicated to geometry and mechanics, not having the preparation to be able to understand their content, as he himself confessed in a letter to Croce:

⁶⁶ «*La Critica*», a. VI 1908, pp. 130-146; also in Paolo Casini, *Federigo Enriques e i filosofi neoidealisti*.

⁶⁷ «*La Critica*», a. VI 1908, p. 130-146; also in Guerraggio, Nastasi (1993, p. 59).

*Tomorrow, I hope to write the review of Enriques, which is a book that I don't know which way to take, not to say too badly with the fear of not having understood, through my fault, what good there may be.*⁶⁸

Enriques replies to Gentile's criticism, without however quoting it, in the "Preface to the second edition" of *Problems of Science* (1909), claiming the originality of his research in the gnoseological theme:

But most of the more superficial critics, among the philosophers who have examined my work, have believed they could limit themselves to the first two chapters, and have not seen at all the new solution to the problems of Kantian criticism developed in the subsequent ones.

The following year, in 1910, Enriques polemically tackled the Hegelian dialectic in the article *Hegel's metaphysics considered from a scientific point of view*,⁶⁹ published in the «*Rivista di Filosofia*»⁷⁰ in which he qualified Hegel «as a great fantasy and a *pauvre intellect*» while recognizing in him «an extraordinary imagination, poetic genius, coherence of sentimental inspiration».

Hegel's style, continues Enriques, «... already reveals to us a fundamental aspect of the Hegelian psyche which is adverse to scientific thought». Enriques defined the Hegelian dialectic as an «interesting psychological document, or a tissue of empty verbal associations of formalism», making fun of some obvious "horrors" of the Hegelian dialectic: the absurd a priori deduction of the law of gravitation; the definition of light as a pure ideality, which is particularized in the star and recovers its universality in the sun; the dialectical figure who assimilates the obligatory trajectory of the moon to the "rigidity" of the concept and the free trajectory of comets to the "dissolution" of the same logical entity; the magnet seen as a syllogism, where the poles are joined in the middle term.

Croce reads Enriques' article on Hegel and urges Gentile to reply:

*You will have seen Enriques's nonsense on Hegel's Metaphysics, published in the place of honor in the "Revue de métaphysique". It is also full of insolences against the Hegelians. If you want to dedicate a review or a small variety (but short: 3 or 4 pages at the most) go ahead and send it to me soon.*⁷¹

But he adds in the subsequent letter to Gentile dated February 3, 1910:

*do not accentuate too much the polemic against his person and against his Society.*⁷²

Gentile follows Croce's "advice" by writing the article *Scherzi innocenti intorno alla metafisica hegeliana* in «*La Critica*», reacting harshly to those that:

they seem insolent and they are not. They are the only way in which Professor Enriques is capable of expressing his quite dispassionate historical judgment about

⁶⁸ Letter dated Palermo, July 26, 1908, in Giannantoni (1974, p. 253).

⁶⁹ Enriques (1910).

⁷⁰ Immediately afterwards translated into French: *La métaphysique de Hegel considérée d'un point de vue scientifique* in the review «*Revue de métaphysique et de morale*», 1910, VIII, pp. 1-24).

⁷¹ Croce A. (1981).

⁷² Croce A. (1981, pp. 368-370).

the value of Hegelianism considered from his point of view: they are the forthright, naively accepted, written and published expression of of what Professor Enriques feels. Enriques reading the Hegelian Encyclopedia.⁷³

This is the only occasion in which Gentile crosses the ideological terrain of contrast, indulging in hostile personal appreciations:

Let's say it frankly: Prof. Enriques demonstrates in a thousand ways the most commendable practical zeal for the increase of philosophical studies in Italy, and has even come to create the name, if not yet the reality, of an Italian Philosophical Society. But shouldn't he also do something to his own advantage, endeavoring to educate himself mentally and form a clear concept of the present state of philosophy, conscientiously studying its history?⁷⁴

6.2 – ENRIQUES AND CROCE

Even Benedetto Croce with regard to the «*Rivista di Scienza*» expresses, in «*La Critica*», a negative judgment on its multidisciplinarity:

There is and cannot be anything in common except the material unit of the periodical, a unit which is not that advantage (when it is an advantage) that one can believe: because it can also be a damage, and a serious one.

The controversy became more bitter with the subsequent intervention by Benedetto Croce in his interview given to Guido De Ruggiero in "*Il Giornale d'Italia*" on April 16, 1911, immediately after the IV International Congress of Philosophy in Bologna:

willing professor Enriques, who with zeal but little preparation dabbles in philosophy" [...] "and takes on the burdens of the philosophers' congresses, as meritorious as mine would be meritorious and disinterested, if I organized mathematics congresses.

His resentment at the intrusion of the mathematician Enriques into his field of study, philosophy, which he believes should be cultivated only by professional philosophers, is evident in Croce's words.

Croce, unlike Gentile, denies any cognitive value to science, considered a set of "pseudo-concepts" (abstractions derived from empirical data) as opposed to the "pure concepts" of philosophy (specific cognitive forms of reality as a *continuum* of infinite individuations), recognizing them only as a practical utility. Position, therefore, in stark contrast to that of Enriques.

The controversy soon degenerates into personal attacks by Croce against science:

Scientific knowledge is not true knowledge, but devices of a practical order. The related concepts are pseudo-concepts, suited to tiny minds not to the universal minds of idealist philosophers.

⁷³ Gentile (1910).

⁷⁴ Gentile (1910, p.145).

*Men of science [...] are the embodiment of mental barbarism, deriving from the substitution of schemes for concepts, of piles of information for the philosophical-historical organism.*⁷⁵

On the contemporary discoveries and conceptual arrangements of Frege, Peano and Russell, Croce expresses himself as follows:

*The new devices [of mathematical logic] are to be recommended, if anything, to traveling salesmen [so that] they persuade customers and merchants of the usefulness of the new commodity and buy it [...] their philosophical nullity remains [...] fully proven.*⁷⁶

And against Enriques:

*With the procedures of prof. Enriques one can, at most, when one is lucky [...], drag along a crowd of the ignorant [...] nothing more treacherous than the crowds of the ignorant [...] like nothing more faithful and persistent than the little chosen ones who, feeling joined by truths, they know they have the present and the future for themselves.*⁷⁷

As Giorgio Israel states, the polemic «continued with decreasing intensity until 1912 without definite conclusions. However, Croce's authority had the practical effect of making a large part of the philosophical and cultural circles line up on positions hostile to the E., for which the end of the controversy was commonly perceived as a "defeat" of the E. ».⁷⁸

Croce does not even spare Francesco Severi, who had criticized the intolerance of idealism, admonishing him in a poisonous way:

*To the prof. Severi who is a man of study I would like to address a prayer; and it is not to risk discussing concepts that belong to a field foreign to him, and to enter in which I don't know if he has the inclination (everyone has their own inclinations), but he certainly doesn't have the preparation.*⁷⁹

7 - THE CONSPIRACY OF CROCE AND GENTILE

It has been said previously that the presence, in the "controversy" between Croce, Gentile and Enriques, of a strong personal component raises the suspicion of a real "conspiracy" concocted by the two philosophers, to eliminate from the Italian cultural scene their most fearsome opponent. The correspondence between Croce and Gentile seems to corroborate this further reading of the clash.

Gentile's scientific lack of preparation confessed to Croce, in preparing to write «La Critica» the review, warmly supported by Croce, of the *Problems of science*, suggests that more than the intellectual need for an "honest" critique of the book by Enriques has guided the pen of Gentile the will of a personal attack instigated by Croce. A clash probably matured from certain jealousies shared with his friend Croce, which arose from the alternation, within the space of only two years of important events which constituted

⁷⁵ Croce B. (1908).

⁷⁶ Croce B. (1909).

⁷⁷ Therein.

⁷⁸ Israel, (1993).

⁷⁹ Croce B. (1914).

many dangerous signs of encroachment by Enriques in the field where Croce and Gentile felt undisputed protagonists. In 1906 the "mathematician" Enriques had created the "Italian Philosophical Society" and made his debut in the philosophical field with the *Problems of science*. The following year, in 1907, he had founded «*Rivista di Scienza*» and organized the 2nd congress of the "Italian Philosophical Society" in Parma, in which Enriques, with his inaugural speech *Il rinascimento filosofico nelle scienza contemporanea e il valore della scienza* (*The philosophical renaissance in contemporary science and the value of science*)⁸⁰ underlines the importance of the debate that logicians, physicists and mathematicians have opened or intend to start with philosophers. Finally, in 1908, at the III International Congress of Philosophy, Enriques was invited to participate as president of the Italian Philosophical Society, receiving the task of organizing the 1911 IV International Congress in Bologna.

Enriques always made himself very available for a serious and constructive dialogue with Gentile and Croce, despite the declared strong ideological differences, showing on several occasions his willingness to involve them in all his initiatives of a philosophical nature. But he always receives, in response, attitudes of total closure and hostility.

In a letter dated June 14, 1907, Enriques explicitly invites his "colleague" Gentile to participate in the 2nd Congress of the Italian Philosophical Society (SFI), to be held in September in Parma, in conjunction with the Congress of the Italian Society for the Progress of Sciences:

Distinguished Colleague,

... Now it would be desirable for our meeting to be attended largely by the most valiant philosophers. [...] The purpose of this letter is precisely to ask you to come to the Congress and to bring you some communication, eg. on the new Hegelian movement in Italy or on any other theme you prefer.

I will add that I would also gladly invite Croce; but I am held back by the doubt that my question does not please him, since he is a stranger to our Society.⁸¹

But Gentile refused Enriques' invitation, as can be seen from the subsequent letter dated 15 July written to Gentile from Riccione, where Enriques was on holiday. In the same letter, Enriques' willingness to establish a wider collaboration with Gentile also clearly appears, which concerned both the management of the SFI itself and the participation in the III International Congress of Philosophy scheduled for the following year, in 1908, in Heidelberg:

Dear Colleague,

... I am very sorry that you cannot intervene also because I was counting on consulting with you on many issues that concern our social action [that of the SFI], and on what we can do to prepare for the next congress in Heidelberg.⁸²

Furthermore, Enriques tries to involve Gentile in the project of a series of philosophical texts to be produced with the Sandron publishing house:

With Sandron we are in principle in agreement for a collection of works under the title: Library of the Italian Philosophical Society. Now we need to think about putting this into action by presenting respectable names to the public. Please think

⁸⁰ Enriques (1908).

⁸¹ Guerraggio, Nastasi (1993, p. 143).

⁸² Guerraggio, Nastasi (1993, p. 144).

*about it too. We are very grateful to you for the report on German philosophical societies which we await with keen interest. Have me, dear Colleague, cordially with the highest esteem
Yours F. Enriques.⁸³*

In a letter dated February 1910, Gentile expresses to Croce all his disagreement with Enriques' role as "protagonist" in the organization of the IV International Congress of Philosophy to be held in Bologna the following year:

Dearest Benedetto, I have rethought the matter of the Philosophical Congress of Bologna; and I am convinced that we must absolutely resign from the Organizing Committee, if prof. Enriquez does not recognize the advisability of leaving the main position which he has taken on himself, and he does not defer to the whole Committee, or at least to the first nucleus of it, as designated by the Heidelberg congress, and of which, if I am not mistaken, you too take part in the deliberation on the ways and methods of organizing the Congress, reserving for yourself only the part that the Committee itself will assign to you, naturally considering your special condition of being in Bologna.⁸⁴

In the same letter, Gentile's jealousy and resentment for the notoriety evidently enjoyed by Enriques as an all-round intellectual, therefore not only as a mathematician, but also as a philosopher and, not negligibly important, as a cultural organizer are clearly expressed:

If the newspapers must continue to talk and gossip about the Congress as a personal work of prof. Enriquez; ⁸⁵[...] if the prof. Enriquez must present himself to the Congress as the most competent representative of the Italian studies of Logic and General Philosophy, and then speak at the inauguration as the President of the Italian Philosophical Society; I do not agree. [...] and, in any case, I believe that this role, which it seems to me that they are arrogating, of head boy does not benefit him or the Italian studies.⁸⁶

8 - THE LEGACY OF THE "DEFEAT" OF ENRIQUES

When speaking of the consequences of Croce's philosophy on events in Italy, I think we must distinguish three aspects: Croce's anti-scientism, the failure of Enriques' cultural program, the difficulties of affirming scientific culture in Italy with the consequent delay of its industrial development compared to other countries.

Croce's anti-scientism

Opinions on Croce's anti-scientism are very different: those who, like Giulio Giorello, affirm it without any doubts and those who, like Corrado Ocone and Giuseppe Giordano instead consider it a false reading of Croce's thought.⁸⁷

On Croce's anti-scientism, I confess that I know nothing about science, his expressions of contempt for mathematics, science and scientists themselves are unequivocal and numerous. It is only a sleight of hand, of which certain philosophers are

⁸³ There.

⁸⁴ Guerraggio, Nastasi (1993, pp. 60-61).

⁸⁵ This is the (incorrect) spelling of the original.

⁸⁶ Guerraggio, Nastasi (1993, pp. 60-61).

⁸⁷ Giorello, Ocone (2012); Giordano (2016).

masters, wanting to overturn them and disguise them with the usual empty whirlwinds of meaningless words. Giulio Giorello, in his dialogue with Corrado Ocone on 19 November 2012 *È vero che Croce odiava la scienza? (It is true that Croce hated science)* published by Reset,⁸⁸ quotes a passage from Croce's work *La storia come pensiero e come azione (History as thought and as action)*, where the philosopher from Pescasseroli says that science performs its "useful office" certainly not when it «makes abstractions, builds classes, establishes relationships between classes which he calls laws, mathematical formula and the like. All of these are works of approach aimed at saving acquired knowledge and procuring new ones, but they are not the act of knowing». And what else is the act of knowing? I agree perfectly with Giorello when he observes:

I would like to know what this act of knowing is for the scholar from Pescasseroli! In 1938 we are now far from Newton; in 1900 Planck introduced the first quantum hypothesis, in 1905 Einstein revived quantum theory, reshaped statistical mechanics and laid the foundations of relativity; in 1915-16 general relativity was born; quantum physics went on with Bohr and his model of the atom to the formulations of what will be called quantum mechanics in the strict sense. The science is this: calculus, general topology, algebraic topology, functional analysis, differential geometry, etc.

Where is the act of knowing if not in mathematics? It is significant that at the very beginning of the 1930s Paul Dirac insisted that mathematics surpasses the empirical information of the world and defines the new objects which will then be explored and controlled in the laboratory.⁸⁹

An attempt to redeem Croce's anti-scientism was made by Giuseppe Giordano,⁹⁰ who drew attention to a 1940 work by Croce, *Il carattere della filosofia moderna (The Character of Modern Philosophy)*, republished in 1991, in which the philosopher recognized science as a human product, having its own history and therefore its own author:

Not unlike poetry, a scientific theory is born from a dark background, almost a glimmer that gradually grows in strength and creates clarity, or like a very lively lightning that cuts through the darkness and then seems to get lost and requires long tension and patience waiting for it to return and for the clear light to remain still. Sometimes this process lasts chronologically for a long time, and of the great works of science as of those of art we can say equally what has been said sometimes of one or the other, which are youthful thoughts implemented in manhood.⁹¹

In the same work Croce, very clearly, recognizes the same genius in the scientist that instead Kant considered the exclusive gift of the artist:

But one is not a Newton without a gift of genius equally generous from nature as the one it bestowed on the poet.⁹²

The thought that Croce expresses in his 1940 volume, *Il carattere della filosofia moderna (The character of modern philosophy)*, is unfortunately too late to correct the

⁸⁸ Giorello, Ocone (2012).

⁸⁹ Therein.

⁹⁰ Giordano (2016).

⁹¹ Matrogregori (1991).

⁹² Therein.

widespread idea of his anti-scientism. However, it is very interesting, because it overshadows the same historicism that belonged to Enriques, with which he instead argued at the beginning of the twentieth century.

The failure of Enriques' cultural program

Many words have been spent on the question of the outcome of the controversy between Enriques and Croce-Gentile, hypothesizing very different scenarios.

However, one fact seems certain, from what we have been able to reconstruct of those events: Enriques was left substantially alone in that battle.

Yet, in 1908, there were still leading scientific personalities who, with their authority, could have teamed up with Enriques. Among the mathematicians, the aforementioned Ulisse Dini, Cesare Arzelà, Salvatore Pincherle, Gregorio Ricci Curbastro, Giuseppe Veronese, Luigi Bianchi, Giuseppe Peano, Corrado Segre, Guido Fubini, Leonida Tonelli, Guido Ascoli and Guido Castelnuovo himself, Enriques' brother-in-law. Only Severi and Volterra had the audacity to enter into conflict with Croce, denouncing the intolerance of his philosophy towards science. Among the physicists, Damiano Maçaluso and the distinguished Orso Mario Corbino, Pietro Blaserna, Antonio Pacinotti, Guglielmo Marconi, Domenico Pacini, Antonino Lo Surdo were still alive. In short, there was an Italian scientific community of the highest order, internationally established, which could have intervened in favor of Enriques. Why didn't this happen? There was probably an incapacity of our scientific community to know how to face Croce's dialectic on a philosophical and cultural level with equal vis-à-vis. Only Enriques could oppose it, but while Croce had a multitude of supporters on his side, Enriques was essentially alone.

A first cause of the failure of Enriques' cultural project, centered on the collaboration between philosophers and scientists, or rather on the application of the scientific method to philosophy, with the birth of scientific philosophy, is certainly the bitter dispute between Enriques and the Italian neo-idealists, whose it was said. But Ludovico Geymonat adds two more to it.

One is Enriques' misunderstanding of the importance that modern mathematical logic and mathematical formalism were increasingly assuming, which according to Geymonat transpires from the same work *Per la storia della logica (For the history of logic, 1922)* and which manifested itself openly in the contrasts with Giuseppe Peano:⁹³

Unfortunately, there were many mathematicians in those years, in Italy and not only in Italy, who viewed research in logic with strong suspicion; but it was certainly particularly serious that this attitude was also shared by a scholar like Enriques who did not want to be and was not a pure technician of science. It ended up by throwing a considerable discredit, among "pure mathematicians", towards mathematicians who also dealt with other problems (logical, historical or philosophical). [...] the aforementioned closure with regard to logic has notably weakened the position taken in favor of rationalism, the claim to defend, in our century, the rights of reason without basing this defense on full recognition of the merits acquired in this field by the most refined logical-formal research. However, it is certain that the serious gap did not contribute to making the criticisms raised by the two authors in question effective (or at least immediately effective) [alluding to Enriques and the French epistemologist Gaston Bachelard] against the intrusive idealistic, spiritualistic, irrationalists.⁹⁴

⁹³ Who also saw Vito Volterra on Enriques' side.

⁹⁴ Geymonat (1976, vol. VII, pp .690-691).

The other reason for the failure of Enriques' program is, according to Geymonat, its psychological orientation (common to Bachelard) clearly expressed in his work *Il significato della storia del pensiero scientifico* (*The Meaning of the History of Scientific Thought*, 1936) where:

*We read that the task incumbent upon it is to enucleate the genesis of scientific ideas, of the great changes they underwent, of the "natural errors" and of the "non-senses" which even the greatest scientists incurred. It is a study that demonstrates to us the coexistence of both the rational and the empirical factor in cognitive processes, and therefore the irreducibility of science to only one of them.*⁹⁵

Geymonat's hypotheses are certainly plausible and apparently very restrictive. Indeed, however, the lack of a united front on the part of the scientists and philosophers who were on their side must have constituted an element of weakness against the much more solid and united opposing front of the neo-idealists.

I believe another hypothesis on the failure of Enriques' cultural program could be, more generally, the incomprehension of Enriques' philosophical thought by the entire Italian cultural *establishment* of the first half of the twentieth century. A clear manifestation of that hiatus between humanistic culture and scientific culture which, a few decades later, would be stigmatized by the English physicist-writer Sir Charles Peirce Snow in his famous lecture *The Two Cultures*, held at the University of Cambridge on 7 May 1959 and then republished, with some additions, in the small volume of the same title in 1963.

There was probably a lack of preparation on the broader cultural level, on the part of the basic Italian scientific community (the secondary school science teachers), unlike those who instead gravitate in the humanistic field. For a long time, the third pages of newspapers were always dedicated to topics of a literary, philosophical (but not philosophy of science) and artistic nature, rarely to scientific topics and when this happened it was only with reference to sensational practical applications of scientific discoveries. I think Richard Feynman has nailed this problem right by writing:

*And I believe that science has remained a marginal phenomenon because we scientists are waiting for someone to ask us questions or invite us to explain Einstein's theory to people who don't even understand Newtonian mechanics, while nobody ever invites us to attack miraculous healings nor does he ask us what the science of astrology thinks today. I think we should mostly write in newspapers.*⁹⁶

Furthermore, the lesser ability, compared to the Risorgimento and post-Risorgimento past, to "combine scientific research and civil commitment" should not be underestimated.

*But, after the war, it was the philosophers, first with Croce and then with Gentile, who settled in the Palazzo della Minerva where mathematicians had been at home for decades as well as in parliamentary halls. With the isolated exception of Volterra [...] the mathematical community no longer has a voice in the political institutions of a country that had seen them among the protagonists for so many decades.*⁹⁷

⁹⁵ Geymonat (1976, vol. VII, p. 691).

⁹⁶ Feynman (2002, pp. 121-122).

⁹⁷ Bottazzini, Nastasi (2013, p. 416).

Even the influence of the Catholic Church, traditionally not prodigal towards science, has certainly held back the spread of a scientific mentality and culture in our country, where its presence is greatest. It should be kept in mind that in post-Risorgimento Italy secularism and anti-clericalism were much stronger than at the beginning of the twentieth century.

In a more realistic vision that takes into account the real complexity of human events, probably all the scenarios mentioned above should be taken into consideration, without excluding anyone.

The influence of Croce on the scientific and industrial development of Italy

As for the difficulties of affirming scientific culture in Italy, I believe that they are not to be attributed only to Crocianism and the infamous Gentile Reform, although they had a considerable weight. Giorello says:

Italy would be scientifically backward due to the fault of Benedetto Croce: this is a historiographical myth that even an anti-Crociano like Geymonat has repeatedly contested and which was the subject of the issue 4/2012 of Il Mulino by an intervention by Alessandra Tarquini. Italy's backwardness in the scientific field is the result of bad choices by politicians on the one hand and of cultural resistance and the inability of the scientists themselves to communicate on the other and which are therefore independent of Croce's idealism. At the cultural level, if anything, there are other forces that could be attributed to the scientific delay, see for example the nefarious influence of the Church on some aspects of bioethical research.⁹⁸

Opinions on this issue are also very varied and conflicting.

Particularly curious is the opinion of the physicist Carlo Bernardini, who attributes the difficulties of development of scientific culture in Italy to none other than our own language, penalized compared to English, in the ability to communicate science.⁹⁹ And to think that modern science was born in Italy with the beautiful vernacular of Galilei!

Returning, however, to the topic already treated by Bottazzini and Nastasi (2013) of an insufficient presence of men of science in political and social life compared to the Risorgimento era, I like to close these pages with the thought of Gaspare Polizzi, which I fully share:

But even in our republican Italy the presence of mathematicians, and more generally of scientists, in the public and political scene will no longer be as consistent as in the nineteenth century, and above all science will no longer be seen as a decisive orientation for cultural and productive development of the country. And this is perhaps one of the underlying problems that do not allow Italy to return to being a great nation of culture and science.¹⁰⁰

ACKNOWLEDGMENT

⁹⁸ Giorello, Ocone (2012).

⁹⁹ Bernardini, De Mauro (2003).

¹⁰⁰ Polizzi (2014).

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