UNIVERSITAS

Newsletter of the International Centre for
THE HISTORY OF UNIVERSITIES AND SCIENCE

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UNIVERSITAS is the newsletter of the International Centre for the History of Universities and Science (CIS) at the University of Bologna. It is an occasional publication, with at least two issues a year. Its aim is to circulate news of work in progress in the fields of the history of universities and the history of science and technology. UNIVERSITAS, like CIS, is designed to promote the exchange of information between Italian historians and the international community of scholars. It will be sent free of charge to those interested.

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The roots of invention: new sources on young Marconi

by Barbara Valotti

Just months before the celebration, in Spring 1995, of the centenary of the invention of radiotelegraphy, historians of science are able to shed new light on Guglielmo Marconi's formative years in Bologna thanks to the recovery of some extremely interesting documents: a series of notebooks and loose papers written by Marconi when he was 17-19 years old [1].

Analysis of this new material is helping to clarify the roots of Marconi's creativity, often described in the literature as characterized by chance and sudden flashes of inspiration, or by mere imitation.

In the introduction to *Bibliografia marconiana*, published in 1974, Giorgio Tabarroni pointed out that biographers dealing with the formative years of the inventor of wireless telegraphy emphasized with a degree of satisfaction that Guglielmo Marconi had not pursued regular studies: this helped foster the image of a completely self-taught Marconi [2]. This image, together with a lack of direct evidence, hindered research on young Marconi.

The new documents give us important new information on the context in which Marconi grew up and carried out his first experiments: his family, his Italian and Irish origins, the contacts he was able to set up in various cities, his teachers, his early scientific readings. The data — currently being researched by Maurizio Bigazzi, Anna Guagnini, Giuliano Pancaldi and the author of this article — allow us to better reconstruct the environment young Marconi worked in and seem to confirm that, as Hugh G. J. Aitken remarked, «the emergence of something new is rooted in a field of the known and the familiar» [3].

Before outlining the salient characteristics of this documentation, let me point up the emotion felt by historians in seeing and being able to analyse notebooks and papers written by young Marconi that have remained unknown for over a century.

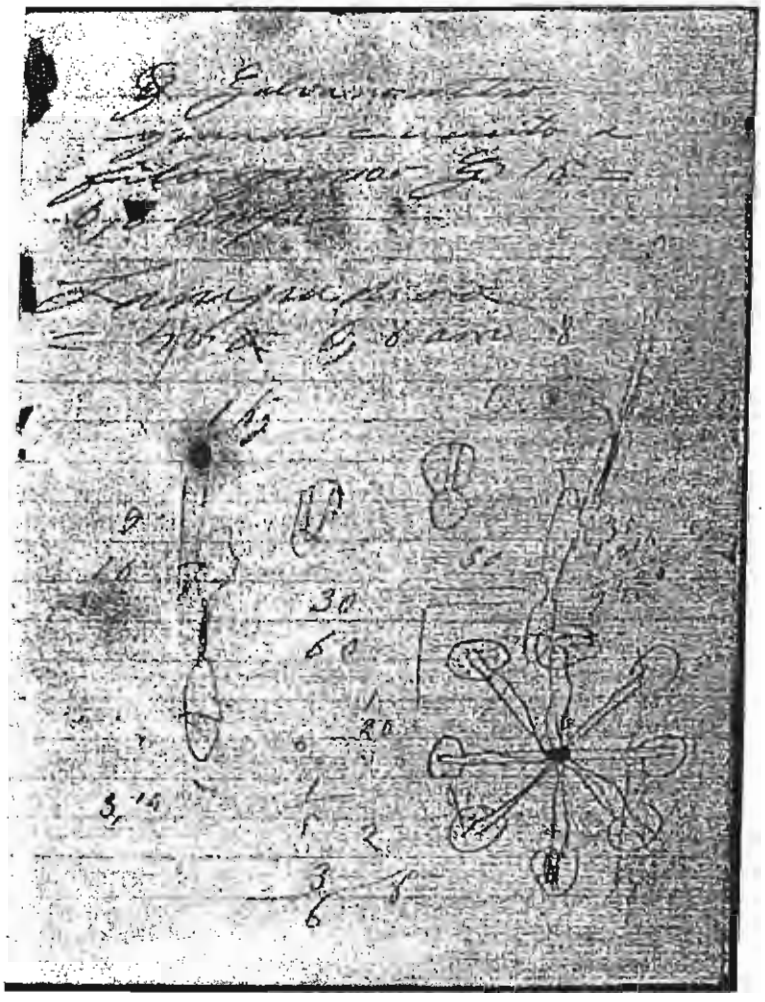
The most interesting parts of the new material are those contained in four notebooks Marconi kept to record his early experiments in electricity and draft letters he sent to his relatives

Young Marconi's experiments

by Maurizio Bigazzi

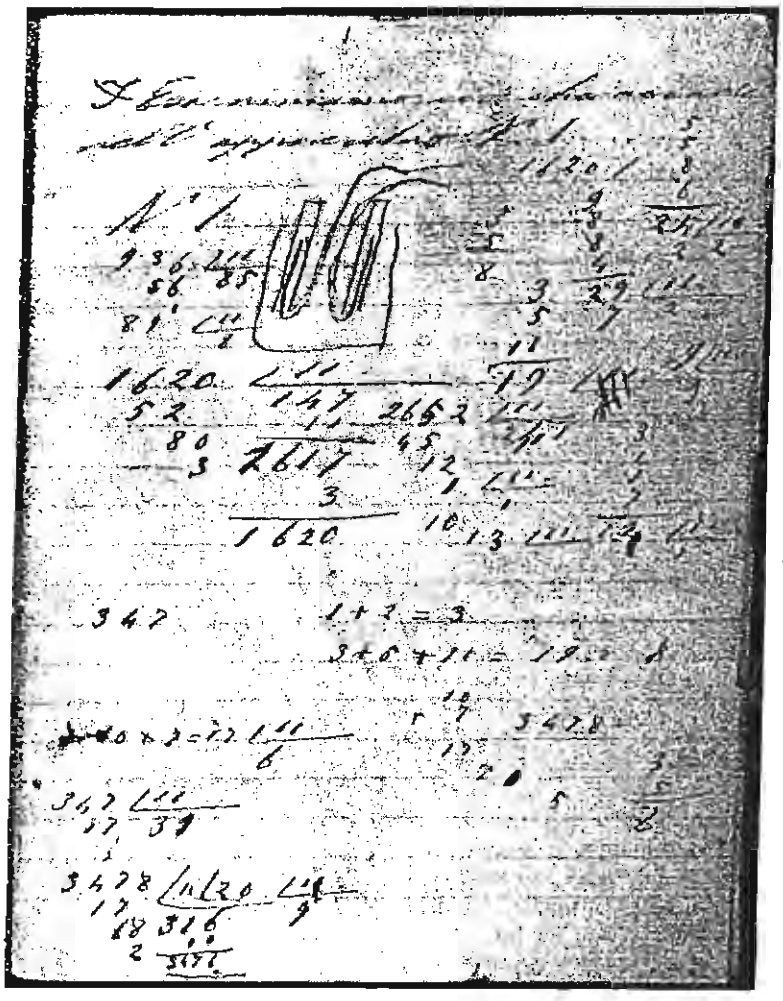
The recovery of new documentation on the electrical experiments carried out by Guglielmo Marconi when he was eighteen — just three years before his epoch-making invention of wireless telegraphy — spurred me on to reconstruct what actually happened in the laboratory set up in the attic of his father's house. I analyzed in detail certain pages in one of the notebooks recently recovered, the one with the blue

Guglielmo Marconi (1874, Bologna - 1937, Rome), from a photograph in the CEC Marconi Archives, Chelmsford, England.



Above and on p. 3 two pages from Marconi's Blue Notebook, dating from 1892, kept in the Accademia dei Lincei Archives, Rome.

in the years 1891-1893, not long before his first successful experiments in wireless telegraphy carried out near Bologna in 1895.
During that period, Marconi spent his winters in Tuscany, first in Florence and then in Leghorn where he took private mathematics lessons from professor Ciotto Bizzarrini and physics lessons from Vincenzo Rosa, a professor at the local high school. Rosa is the only person Marconi would later credit for having played an important role in his education.
From the draft of a letter Marconi mailed to his brother from Leghorn we learn that young Marconi in 1892 was «very busy studying», with a view to passing the exams and «obtaining his diploma at the Technical Institute or at the high school, as was the wish of Prof. Righi». The latter, Augusto Righi, taught physics at the University of Bologna, and was at the time doing successful research into electromagnetic phenomena in the field of Hertzian waves [4].
To get his diploma, Marconi asked for a tutor during the summer at his family home, 15 kilometres from Bologna. He then reported that his «special electrical studies» were going «very well, having achieved extremely satisfactory results, from both a theoretical and industrial standpoint». He was certain that the «latest machine» he had constructed deserved an «industrial patent» and was anxious to hear Righi's opinion on the matter.
This letter offers up precious information: young Marconi's commitment to his studies (though he never obtained his diploma); his relationship with Augusto Righi who counseled Marconi in his studies, experiments and attempts at inventions; the work regarding his experiments in electricity, somewhat distinct from his school studies. The reference in cover, in which Marconi recorded his summer 1892 experiments, as well as some loose sheets that were undoubtedly written a few months later.
The pages in the Blue Notebook are the typical pages of a laboratory notebook: in them young Guglielmo recorded data on his project for a new hydroelectric battery that he wanted to enter in a competition promoted by a technical journal called *L'Elettricità*.
It should be remembered that at the end of the last century many aspiring inventors were working towards designing new types of batteries and accumulators. Very often however the final results simply repeated the characteristics of batteries already patented. In the early 1890s the journal *L'Elettricità* launched a competition to try to improve the situation regarding «the much-felt lack of a praetical and economical source of electric power».
The announcement of the international competition «for a new electric battery», published for the first time on 20 Deeember 1891, stated it could be «hydroelectric or thermoelectric» and should satisfy certain characteristics such as not emitting toxic vapours, not requiring frequent maintenance, and performing better than existing batteries of similar size and weight.
It was then that young Marconi decided to try and design a new type of battery to enter in the competition. The pages bearing witness to such a project contain drawings, sketches and a whole series of data, mostly electrical measurements. Interpreting these data presents great difficulty on account of the abbreviations, messiness and gaps on the pages. At the same time it makes analysis of Marconi's notebooks particularly interesting since it helps recreate the atmosphere the young inventor carried his research out in (see figure on p. 4).
On one page of the Blue Notebook Marconi drew a voltameter, an apparatus commonly used to demonstrate the electrolysis of water, and noted down the data from the experiments he carried out with such an instrument. The results he obtained led Marconi to



the letter to the practical aspects and possible commercial value of his experiments is of great importance. In other parts of his notebooks Marconi writes of his intentions to file for a patent. This intention, which he pursued from the age of eighteen, and his desire to commercially exploit his inventions — three years before his wireless experiments — are of great significance in understanding Marconi's later work.

One of the notebooks recently recovered can be regarded as a laboratory notebook, and it refers very likely to the «machine» mentioned in the letter quoted above. Written in the summer of 1892, the notebook shows a young Marconi busy preparing for entry in the «International competition for a new electric battery», with a £2000 prize, promoted by the illustrated weekly magazine *L'Elettricità*.

The competition was publicised in many foreign scientific magazines as well. The announcement of the competition, which had appeared in *The Electrical World* of New York, was reported in the 20 March 1892 issue of *L'Elettricità*. The piece in the American journal stated the importance of «the real industrial point of view to which the competition refers» and the objective of «stimulating inventors to practical research on small sources of electricity». It was felt that small sources of electricity were urgently needed for «a wide range of applications».

A detailed analysis of the young Marconi's project (probably never carried through) is the subject of a research reported by Maurizio Bigazzi elsewhere in this newsletter.

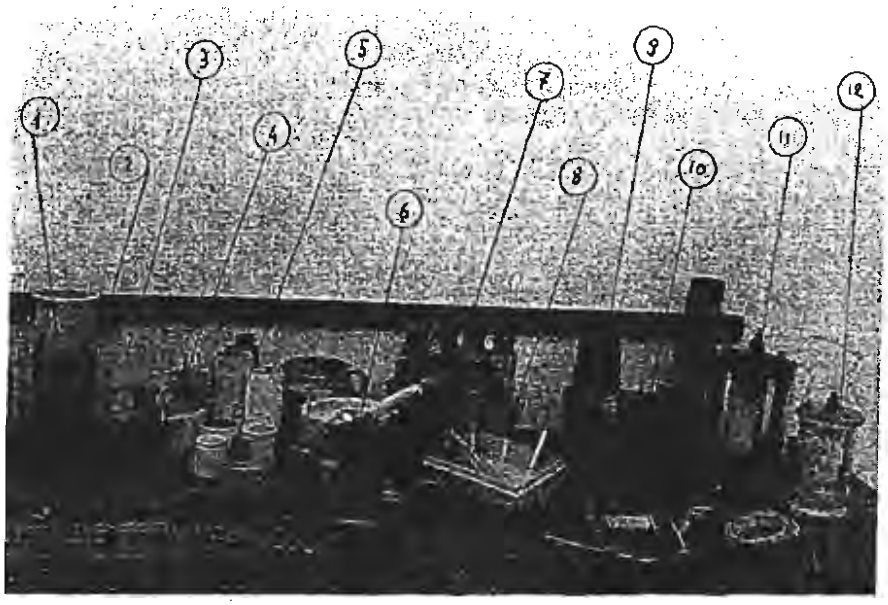
Thanks to the new documents which, it is worth stressing, represent the only laboratory notebooks in our possession regarding young Marconi's scientific activity, Maurizio Bigazzi was able to recreate the first ambitious experiments devised by young Marconi.

develop a new battery with three carbon electrodes, powered by an ordinary battery. The notebook records data on the electrical output of this apparatus, the performance of which Marconi noted down at set times. To this end he inserted, alternately, a small carbon-filament bulb and a copper-deposit voltameter and recorded the electrical values together with the densities of the electrolyte. Leafing through these pages one arrives at a point where the measurements end just as clear signs of burning appear (see figure on p.2).

In another notebook the entry regarding a «very interesting experiment» — curiously jotted down after an elementary mathematical problem — shows Marconi turning his attention to work on a thermoelectric battery. Marconi described the metals used (antimony, aluminium, zinc) and their quantities. He smelted these metals several times over in order to obtain an alloy with a high electronegative coefficient. A copper strip was fixed in the alloy so as to produce a thermoelectric couple and he measured the current intensity it produced at different temperatures.

This page is of particular interest for at least two reasons: it marks the beginning of his experiments on thermo–rather than hydro-electric batteries (based on the principle of the transformation of heat into electricity); furthermore, the terms Marconi uses to describe his experiments illustrate how familiar he had become in 1892-1893 with the electrical technologies of his time, and how quickly his manual skills were improving.

Some loose papers written in 1893 show that Marconi continued working on the thermoelectric battery for several months. The need for «special alloys» — more efficient, made of cobalt, nickel, etc. — led the young inventor to turn to companies specialized in the smelting and rolling of these metals which called for special treatment at high temperatures. The drafts of the letters he addressed to suppliers in different Italian cities, requesting materials prepared according to his precise instructions, illustrate his commitment to experimental work, his scientific readings and his ambitions as an innovator.



Maurizio Bigazzi's reconstruction of young Marconi's laboratory bench c. 1892.
1. Platinum-electrode voltameter.
2. Glass tap with rubber tube (for nitric acid producing apparatus).
3. Carbon filament lamp, 4 Volts 0.8 Ampères (used to test the new battery).
4. Nitrate of iron and hydrochloric acid (electrolyte for the battery).
5. Porous kaolin pots (for constructing batteries).
6. Copper-electrode voltameter (for measuring Ampères per second).
7. Materials for constructing batteries (putty, oil, pitch, etc.)
8. Baumé degree densimeter (for testing solutions).
9. Alcohol burner (for increasing depolarization).
10. Needle galvanometer (for measuring electromotive force).
11. The three-electrode battery devised by Guglielmo Marconi.
12. Zinc-carbon battery, known as «the exciter battery».

Maurizio Bigazzi has worked for years on the reconstruction of the instruments used by Marconi and others, following the evolution of Marconi's works from the first experiments in wireless telegraphy to the first transatlantic transmission in December 1901. The collection of these replicas, now kept at the Marconi Foundation, Bologna, is of particular importance for at least three reasons: in many cases the original instruments have been lost; the models are all *working* replicas; they were all realised, whenever possible, with material and parts from their own time. The recently recovered documents have provided Maurizio Bigazzi with a new opportunity for exploring the abilities and investigative style of young Marconi. Details regarding Marconi's project can be found in Bigazzi's article. Some remarks of general interest, however, are worth mentioning here.

Of particular significance in the new material is the interest young Marconi showed in the results of scientific research, concrete technological applications and the possible commercial exploitation of these latter.

Young Marconi's «daring», his ability to throw himself by dint of hard work and resolve into the scientific and technological community of his time also deserve mention.

The strategy Marconi adopted in the technological competition he was considering entering reveals important character traits that will crop up in later years. The interplay between scientific, technological and entrepreneurial interests is confirmed by the new documents as a crucial trait in the strategy innovation that would lead him to wireless telegraphy.

The minutes of the letters Marconi sent to scientific equipment manufacturers and electrical material suppliers in Florence, Leghorn Bologna and Milan in 1893, are also significant in this respect. These

Unfortunately the documentation regarding work on the thermoelectric battery is also incomplete. What is sure is that some time later young Marconi interrupted his experiments on batteries and started to work in the field of electromagnetic waves.

In this connection, an invoice sent to Marconi at his family house by the Società Elettrica Industriale in Milan, and dated 14 November 1893, is intriguing. It shows that the young experimenter bought on that date an «acid-free welding liquid». In those days the products commonly used for welding left an acid and hence electrically conductive residue. The ordering of the special, atypical welding substance may indicate that at the end of 1893 Marconi was carrying out delicate experiments with a new kind of equipment, using electromagnetic waves. In the welding of certain parts of the electromagnetic wave receiver an electric resistance left by the residue could in fact significantly affect the sensitivity of the apparatus. This document therefore may indicate a turning point in the work of young Marconi.

Marconi's early research on batteries and electricity (there is a good deal of indirect evidence of experiments carried out by Marconi in order to restage some of Benjamin Franklin's and Luigi Galvani's classical experiments as reported in popular publications) provide us with a valuable insight into the technical knowledge which Marconi made use of for his invention of 1895. The laboratory work he did in the years 1891-1893, we can now say, gave him a solid and mainly practical basis in electricity, chemistry and metallurgy.

His knowledge and understanding of metals in particular was important for developing one of the components of his later wireless telegraphy system: the coherer, an electromagnetic wave detector, already used by physicists such as Edouard Branly and Oliver Lodge.

It is well known that Marconi perfected this device achieving maximum sensitivity levels at the end of arduous work trying several combinations of metallic powders.

It is also known that further problems regarding interference caused by devices inserted in the receiving apparatus were resolved by Marconi by introducing

letters are striking for the details they contain of the different materials — confirmation of the young man's breadth of knowledge culled from his readings, the teachings of Rosa and his meetings with Righi.
Further evidence of his commitment to experimentation is to be found in the notes he made regarding the costs of materials: «copper wire, sulphuric acid, coke, tin», etc. If we add to these lists his father's accounts for books and material «for Guglielmo» it is clear that he could count on a sizeable amount of money for carrying out his research. The presence in the accounts for 1893 of various «objects ordered from Milan», probably bought from the Società Elettrica Industriale, bear witness to Marconi's seriousness and financial commitment. It is likely that his father, often described as «practical, businesslike, and somewhat tightfisted» [5] was slowly coming to recognize the ability of his son, shut up for hours on end in his laboratory in the attic of his father's villa doing strange experiments.
Marconi later declared that his reading widely during his formative years kept him abreast of research being done: «I was what I might say fairly well acquainted with the publications of that time dealing with scientific subjects including the works of Hertz, Branly and Righi» [6]. His subscription to *L'Elettricità* (evidence of which is contained in his father's accounts) points to one of the sources the young enthusiastic Guglielmo drew upon for his experiments and working methods.
As mentioned before, analysis of the material recently recovered is in progress and will keep scholars busy for some time. Nonetheless, the documents already shed new light on Marconi's research, culminating in the invention of wireless telegraphy. The new data demonstrate how Marconi — often described as a self-taught man lacking in scientific knowledge who succeeded in inventing wireless telegraphy almost by chance — was in fact, at barely twenty-years-old, well-informed on the latest advances in the field of electricity, was familiar with electrical technology, and kept industrial use and commercial exploitation firmly in mind as his main aim. Though no new evidence for the years 1894-1895 has as yet been found, it seems reasonable to assume that in conceiving wireless telegraphy Marconi was pursuing a strategy not too dissimilar from the one documented in the materials recently recovered. In spite of the gaps in the documents, the new material confirms that «it makes little sense to view the process of invention as typically dominated by chance, dependent for success on the lucky happenstance» [7], and that the inventive search is characterized by «projects and problems [...] pursued with persistence and ingenuity» [8] by a well-prepared mind.
We can only hope that new sources will surface soon to complement those recently recovered.

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NOTES

[1] The material was identified by Giovanni Paoloni and is now kept at the Accademia Nazionale dei Lincei, Rome.
[2] Giorgio Tabarroni, «Formazione e personalità di Marconi», in Giovanni di Benedetto (ed.), *Bibliografia marconiana*, Firenze, Giunti, 1974, pp. 3-12.
[3] Hugh G. J. Aitken, *Syntony and Spark: The Origins of Radio*, Princeton, Princeton University Press, 1985, p. 6.
[4] Righi gave a detailed account of his research which, following the work of Hertz, aimed at finally confirming the validity of Maxwell's theory in the volume *L'ottica delle oscillazioni elettriche* published in Bologna in 1897.
[5] Hugh G. J Aitken, *Syntony and Spark*, p. 163.
[6] Guglielmo Marconi, «Per il Premio Nobel», in *Scritti di Guglielmo Marconi*, Roma, Realc Accademia d'Italia, 1941, p. 165.
[7] David N. Perkins and Robert J. Weber, «Conclusion: Effable invention», in Robert J. Weber and David N. Perkins (eds.), *Inventive Minds: Creativity in Technology*, New York; Oxford, Oxford University Press, 1992, p. 321.
[8] *Ibidem*, p. 320.

Guglielmo Marconi at about fifteen (Mario Cassoli Collection, Marconi Foundation, Bologna).

electrochemical resistances (small voltameters) in his system. In both regards the documentation recently recovered adds to our understanding of Marconi's later achievements in wireless telegraphy. Further study of the new documents will, no doubt, make it possible to more completely recreate the laboratory young Marconi did all his hard work in.

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Guglielmo Marconi: a computerized bibliography

A computerized bibliography on Guglielmo Marconi was presented at the Conference «Science & Power», promoted by the European Science and Technology Forum and held in Florence at the Istituto e Museo di Storia della Scienza from 8-10 December 1994.
The new bibliography was produced on the occasion of the centenary of Marconi's first successful experiments in wireless telegraphy. As is well-known, in 1895 the twenty-one-year-old Guglielmo Marconi was experimenting on Hertzian waves in his family estate in Pontecchio, near Bologna. Later that year he successfully transmitted a wireless telegraphic signal to a receiver situated a mile and a half away, beyoud a hill. This episode has been regarded as the invention of the radio and a milestone in