MEDICINA NEI SECOLI ARTE E SCIENZA, 30/1 (2018) 167-210
Journal of History of Medicine

Articoli/*Articles*

EDUCATION AND DIASPORA THE PATH OF THREE NOBEL LAUREATE STUDENTS FROM THEIR ANATOMICAL TRAINING IN TURIN TO THE AMERICAN GENETIC-MOLECULAR MODEL (1930-1950)

ANDREA GRIGNOLIO
Unit and Museum of History of Medicine, Sapienza Università di Roma, I

A friend I hadn't seen for many years asked me in Lake Placid how to explain the miracle that Luria, Renato and I came from a practically unknown school like Turin. Luria told him that it is due to Giuseppe Levi and this - at least in part - is true.

R. Levi Montalcini, Cantico di una vita

SUMMARY

EDUCATION AND DIASPORA THE PATH OF THREE NOBEL LAUREATE STUDENTS FROM THEIR ANATOMICAL TRAINING IN TURIN TO THE AMERICAN GENETIC-MOLECULAR MODEL (1930-1950)

Three students who were subsequently awarded the Nobel Prize received part of their training in the Turin laboratory of the anatomist Giuseppe Levi (1872 - 1965): Salvador E. Luria for research on bacterial genetics (1969), Renato Dulbecco on oncogenic viruses (1975) and Rita Levi Montalcini for the discovery of the nerve growth factor (1986). It is a rare case in the history of science, especially considering the different paths that his three pupils took in the US after their common internship in Levi's laboratory which

Key words: Fascism - Jewish History - Salvador E. Luria - Rita Levi Montalcini - Renato Dulbecco

focused on the microanatomy of the nervous system. Trying to reconstruct the reasons for these professional successes, in their autobiographies, all three students recognized the great merits of their master's methodology (dedication and rigor in the job, the setting up and publication of the experiment, strictness and encouragement in the evaluations), while identifying the move to US labs as the decisive factor in their careers (research policy, meritocracy and substantial funding). In this contribution, I will attempt to trace the paths that made it possible for three students from an Italian school based on histology and microscopic anatomy according to the German tradition to become three Nobel laureates in various disciplines based on a molecular approach. Understanding how this 'metamorphosis' occurred means reconstructing how individual micro-histories, coming from a local scientific and methodological context -laboratory techniques, religious backgrounds, fortuitous choices, friendships and academic relations-, merged with macro-histories involving national politics, the Second World War, and institutional and disciplinary divisions.

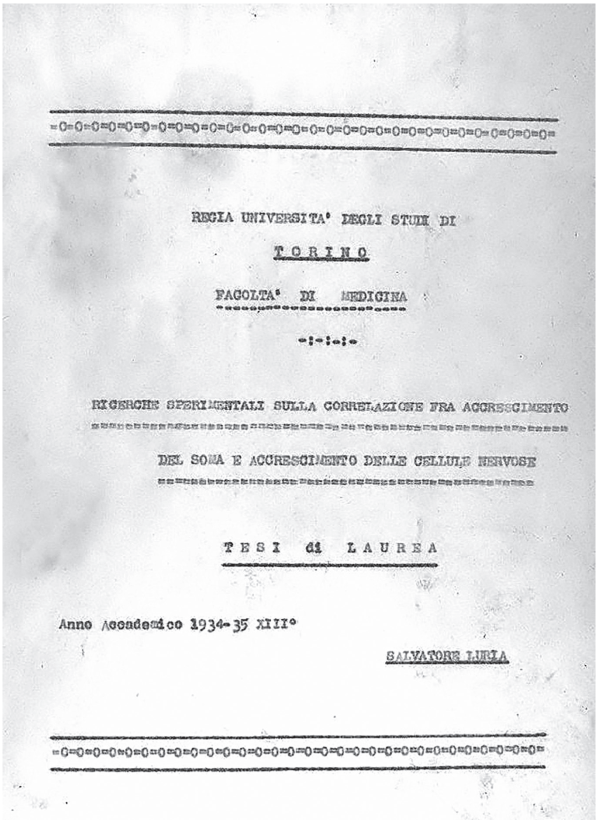
Introduction

When he met Salvatore Luria (1912-1991), a second-year medical student, Giuseppe Levi was a fifty-eight year-old Full Professor of Human Anatomy with a brilliant and accomplished career behind him. Of the fourteen areas of research shown on his curriculum, no fewer than thirteen had been tackled by Levi before the arrival of Luria in 1930 and of Renato Dulbecco and Rita Levi Montalcini in 1931[1]. As was his habit, Levi set up "a table in the room of the interns still wet behind the ears" for the three students so that they could practise on a precise task of histology chosen from an "exercise book of notes" which contained a list of the biological problems that he had tackled in his career[2]. From the time they entered the Institute to the years of post-graduate work, the three students were to practise on different aspects of the laboratory's research, ranging from histology to microanatomy and embryology, probing a structured but homogeneous field of biological interest which Levi had concentrated on the morphological-quantitative analysis of animal

tissues and cells (mainly nervous and muscular) in order to reveal their functional meaning and the behaviour in the various phases of growth, development and senescence.
The educational path of these students, as is known, was interrupted by their emigration to the United States: Luria left in 1938[3], Dulbecco and Montalcini in 1947. Almost ten years separate the two migrations, a period in which Luria, as we will see, played a decisive role. The three students, with some exceptions for Levi Montalcini, would decide to abandon histology and microscopic anatomy in favour of research in the genetic-molecular field. Luria will be the first to make this disciplinary and methodological change of discipline, outlining a professional path that would both inspire and ease the way for the other two students. It is therefore with Luria that we have to start to draw the parabola that led Levi's three students from education in Turin to the American 'diaspora'.

Luria's internship in Turin

In the first two years of his internship (1932-34) Luria started various studies on the structure and transformation of human striated muscle tissue in the phases of embryonic growth and senescence[4], in collaboration with Luigi Bucciante (1902 - 1994). Bucciante had worked as an assistant since 1931 at the Normal Human Anatomy Institute, and also had a grant from of the Rockefeller Foundation[5]. Although in the same years Bucciante[6] did research for the Rockefeller Foundation in Levi's Department on the effects of alpha rays on in vitro cells, it was not these experiments that initiated the young Luria to radiobiology. No trace remains of them in the articles or autobiography of the Nobel laureate. The reason is perhaps due to the fact that in the period 1932-34, this type of experiments on in vitro cells was still free of genetic ideas, thus not revealing a relationship with radio genetics, a discipline which Luria was to reach a few years later through medical radiology.



REGIA UNIVERSITA' DEGLI STUDI DI

TORINO

FACOLTA' DI MEDICINA

-:-:-:-

RICERCHE SPERIMENTALI SULLA CORRELAZIONE FRA ACCRESCIMENTO

DEL SOMA E ACCRESCIMENTO DELLE CELLULE NERVOSE

TESI di LAUREA

Anno Accademico 1934-35 XIII°

SALVATORE LURIA

Fig. 1. Luria S., Ricerche sperimentali sulla correlazione tra accrescimento del soma e accrescimento delle cellule nervose. A.A. 1934/35, Tesi di Laurea discussa il 17 luglio 1935, 48 pp. Archivio storico dell'Università di Torino, Fondo Tesi.

However, from the end of 1934, "acquiring considerable experience in the technique of histology"[7] Luria started to find his own experimental path, working individually on two lines of research: the first aimed at isolating in vivo the mitochondria in the sensitive and sympathetic neurons, thanks to their sensitivity to vital colours (electronegative)[8]; the second focused on the correlation between the growth of somatic and nervous cells, in which he showed that in mice in which the development had been artificially stopped, (by reducing feeding), the average size of the spinal ganglions also decreased[9]. Both, as mentioned, had been the object of previous studies by Levi[10]. In particular, Levi had seen a correlation between neurons and soma, which established that for homologous neurons of animals of a different somatic bulk (of the same or different species) the cellular size is greater in the largest ones and is proportional to the extent of the territory of innervation, had been one of the first professional successes that the scientific community recognized to the master, attributing the name of "Levi's law" to it. It was precisely on this subject that, after having carried out further research in general and neurological physiopathology[11], on 17th July 1935 Luria was to discuss his degree thesis *Experimental research on the correlation between growth of the soma and growth of the nerve cells*, which was recommended for publication and for which he was awarded the Lepetit Prize (Fig. 1)[12]. From then on, as we know to withdraw from his autobiography, Luria started to withdraw from histology, a subject in which in actual fact he only had a lukewarm interest even in the early years of university[13] but which he had continued to cultivate out of "stubbornness"[14] and for the esteem which he had for his teacher. Although not having a real passion for the subject, Luria, in the six years of internship (1930-1936), learned from Levi an important lesson of method which was to give him the knowledge necessary to "seriously set up an experiment and carry it through to its conclusion." Thus Luria, in tribute to Levi:

> *What I learned from Levi, and which I put to good use later on, was an attitude of strict professionalism, that is, I learned how to seriously set up an experiment and carry it through to its conclusion. I learned the importance of communicating the results: the master used to say that as soon as a set of data appeared significant, an account had to be published. When the manuscript was ready, Levi ruthlessly rewrote it from the beginning to the end. Another lesson that I learned […] was never to put my name*

> *on the publications of my students, unless I had made a direct and substantial contribution to their work. The personality of the master was such as to instil respect and make his teaching operative. His correctness, his abrupt ways, his distractions and his profession of anti-fascism made him an almost legendary figure in university circles*[15].

Being able to set up an experiment and publish the data immediately was the most important legacy of Levi for Luria as well as, clearly, the example of intellectual and moral rigour which all his students acknowledged. There is another tribute, which the students remained silent about, that has to be recognized: an extensive network of family and academic relations and contacts with international research centres that was to be of particular help for the students, in particular for Luria and Montalcini. When he moved to Rome to work with Fermi's group, Luria was welcomed and directed by Franco Rasetti, a close friend of the Levi family, who was to introduce him to radio genetics. However, to connect personal stories and academic and disciplinary paths capable of intercepting the interest of international philanthropic foundations, the story has to be reconstructed from the beginning, when Luria decided to leave Turin.

The Roman period: between physics and genetics

On the reasons for his abandoning histology, Luria's words are unequivocal: "I did not find histology particularly interesting. Some experiments I did were published in Italian and German journals [...] but my research did not focus on problems of fundamental importance", and shortly after he adds "histology was not for me. Nor did I find, during my medicine degree, further stimuli for my mind full of dreams about physics. But I was passionately maturing a plan."[16] In his "plan" Luria would choose a discipline that hovered between physics and biology, the then nascent biophysics, which began take shape in the year and a half between his degree and the post-graduate course. In this period the negative experiences that he had accumulated as a voluntary assistant at the surgical clinic of the University of Turin[17] and military service as a medical officer convinced Luria to abandon any clinical ambition.

The origin of Luria's passion for physics has to be sought in his high school years, in teenage discussions about Bohr, Heisenberg and Schrödinger with his classmate Ugo Fano (1912 - 2001). Born into a family permeated with science, Fano and his stories of theoretical physics were to embody in the mind of the young Luria a sort of idealization of academic life[18]. When he decided to leave Levi's laboratory in 1936, Luria consulted his young friend in search of professional advice, Fano had no doubts whatsoever: after having explained the atom and matter, physics would go on to explain biology. Fano's enthusiasm was due to the fact that he had recently joined the famous Roman group of physicists headed by Enrico Fermi, the so-called "boys of Via Panisperna", who in those very years were engaged in revealing the nature of nuclear reactions through ionizing radiations. This instrument, used by physicists mainly for theoretical purposes, started to attract biologists and doctors as well from 1927, when an article by the American biologist Hermann J. Miller (1890-1967) was published in the journal *Science:* for the first time radiations were used in the area of genetics to increase the rate of mutation of fruit flies (*Drosophila melanogaster*)[19] - the animal-model chosen by the American school of genetics headed by Thomas H. Morgan. This was the birth of radio genetics. Ten years later and in a technologically backward country, Luria, when he chose his postgraduate specialization at the University of Turin, chose animated medical radiology, not only through the reflected passion of Fano, also through the idea of studying this avant-garde research in further depth.

He decided to enrol in the post-graduate course of Medical Radiology at the University of Turin to then complete it at the University of Rome: there he could have devoted his spare time to studying physics, in close contact with Fermi's students. Having learned of the real intentions of the "plan" to move from Turin to Rome, Levi rejected his student's project and reacted with cries of disapproval, accusing Luria of ignoring, like most of the doctors of the time, the foundations of genetics[20]. The reasons which induced Fermi to consider the presence of Luria in his institute[21] as "reasonable" however, are more complex and have to be tackled because they throw light, once again, on the decisive role played by Levi. They start to reveal that close intertwining between micro and macro stories, between local events and wider institutional and disciplinary paths, which underlie the success of the Turin education of the three Nobel laureates.

Fermi, especially thanks to the education of some of his collaborators such as Franco Rasetti and Fano himself[22], was in close contact with the Copenhagen school of physics directed by Bohr, the great physicist who as well as intuiting the structure of the atom and founding quantum physics, was the first to formulate, at the *Light and Life* lecture in 1932, the idea of using the instruments and the methods of physics to interpret the laws of biology[23]. A whole generation of scientists destined to influence physics and the disciplines inspired by it, including biophysics, for several decades, was trained at the courses held by Bohr in Copenhagen in the 1930s. They included two young German physicists, Max Delbrück and Pascual Jordan and, although indirectly, two Austrian physicists, Lise Meitner and Erwin Schödinger, who played a key role in the relations between Fermi and Luria alongside Rasetti.

Famous for having explained together with Otto Hahn atomic fission at the end of the 1930s, Meitner, as director of the Kaiser Wilhelm Institut fur Chemie in Berlin, welcomed to her laboratory many young physicists interested in quantum physics. Thanks to funding from the Rockefeller Foundation, in 1931-32 Franco Rasetti and Max Delbrück, came to Meitner's laboratory. They were the two who inspired, as we will see, Luria's change of direction to biophysics and it was at the end of 1932 that Delbrück, having completed the experience with Meitner, decided to devote himself to biology following Bohr's lecture. Delbrück's project started as early as 1933, the year he organized a small discussion group on "the physical nature of the gene", made up of about ten scientists. The regular attendees of these meetings included Nikolai Timoféeff-Ressovsky (1890 - 1981), a Russian geneticist who in that period (1932 - 33) had in his laboratory, also at the Kaiser Wilhelm, Herman Muller himself, the father of radio genetics. During these informal discussions, Delbrück's attention fell on Timoféeff-Ressovsky (1890 - 1981), who had carried out pioneering research in the population genetics of drosophila and who in Berlin, as the director of the Department of Genetics of the Kaiser Wilhelm, was working with Muller on the most recent acquisitions of the mutagenic properties of X rays. Another figure who attracted Delbrück's attention was the German physicist Karl G. Zimmer (1911 - 1988), also at the Kaiser Wilhelm, whose work focused on the possibility of measuring the physical-chemical changes of molecules subjected to radiations. The result of those meetings was an article (which was to become known as the "Three-Man Paper" or "Green Pamphlet" because of the colour of the cover) published in 1935 entitled "On the nature of gene mutations and gene structure", in which the minimum energy to obtain a mutation was determined and - for the first time since the rediscovery of the laws of Mendel (1900) and since the introduction of the term "gene" by Wilhelm Johannsen (1909)- the dimension of the gene, understood as a molecule, was strictly calculated. A "quantum-mechanic model" of the gene emerged (or model of the "gene as molecule"), in which, like an atom, it had precise dimensions and seemed to possess various levels of energy. Although a few years later the contents of the article were partially proven wrong[24], Delbrück's theory of the gene had a lasting success from the middle of the 1940s. Written in technical language and published in an unknown journal, the article by Delbrück and his colleagues nevertheless had the merit of inspiring the first best-seller of scientific popularization in the 20th century: *What is life?* (1944), the result of a cycle of lectures held by the Nobel Prize winner for physics Erwin Schrödinger (1887 - 1961) during his exile in Ireland.

Whole generations of scientists, especially many of the physicists who laid the foundations of molecular biology were formed on the important intuitions in this book - imagine hereditary material as an aperiodic crystal which is essentially simple and repetitive (a crystal, precisely) the facets of which were capable of containing a great deal of information (the irregular, aperiodic alternation of the 4 bases of DNA); hypothesize that the complexity of the biological information could be delivered as in a Morse code by the linear sequence of two simple basic units (the "dash" and the "dot", where in DNA there are the 4 nitrogenous bases A, G, C, T). The gene model used by Schrödinger was the theoretical model of Delbrück called "hit-theory" or "target theory", which offered a simple and effective explanation[25]. These ideas were well known to Rasetti, as not only did he alternate with Delbrück in Meitner's laboratory in 1931 and 1932 but he also returned there in the winter of 1933-34, in the period that coincided with the publication of the "Three-Man Paper" by Delbrück. Rasetti was to remain in contact with Delbrück and in the following decade was to be an attentive reader of his articles on biophysics, linked to a passion for biology which, as is well known, was soon to appear - many years later, disappointed by the negative outcomes of the atomic bomb, Rasetti was to follow to some extent the footsteps of the German scientist, abandoning physics for biology and devoting himself to palaeontology and botany[26].

In the autumn of 1937, when Luria decided to study physics in Roma, it was Fano who spoke to Fermi and obtained his assent, but Fano could not introduce him into the "boys of Via Panisperna" because he was working in Heisenberg's laboratory in Leipzig[27]. Luria was thus initiated to physics by Edoardo Amaldi and above all by Rasetti, whose lessons of spectroscopy at Rome University he followed with great enthusiasm. It was in this period that Rasetti introduced Luria to the works of Delbrück which will mark his fate forever. There is also another explanation for the young physicist taking care of Luria: Rasetti had "practically grown up in the [Levi] family", a contact due to the long period spent in Florence by Giuseppe Levi, for his degree and post-graduate work and then, when the professor formed a close bond of friendship and a professional one with his fellow student and colleague pathologist, Gino Galeotti, the maternal aunt of Rasetti[28].

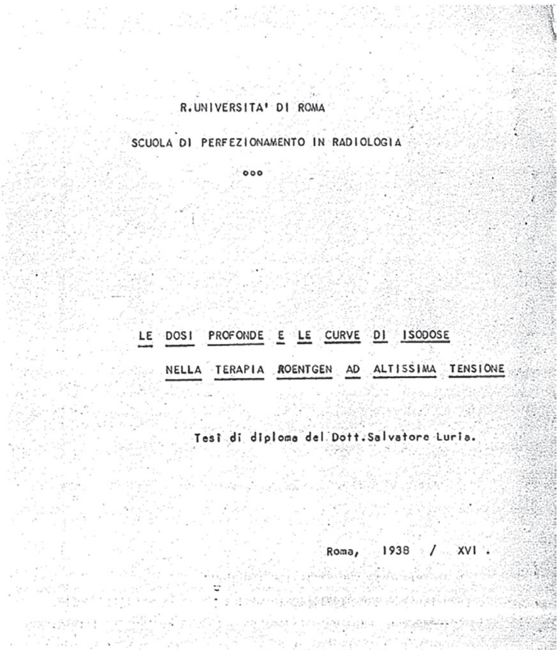
A further reason, independent of Rasetti and Levi, helped Luria's arrival in Rome. It was Fano, as Luria recalls, who obtained the assent of Fermi who deemed it "reasonable" to have in his laboratory a doctor interested in the physics of particles[29]. This "reasonableness", which was not obvious at all, has a story. Fermi, in all probability, made this heterodox decision because he was already aware of the recent and promising development of the physical analysis of genetic phenomena, which Luria was possibly the first to interpret. It was a field of study to which Fermi had been introduced during a seminar in Rome, some time earlier, held by the German physicist Pascual Jordan. It was Jordan, a controversial figure and close to Nazism[30], who induced Fano, on the suggestion of Fermi himself, to work on biophysics, as effectively took place in the first years of his American exile at Cold Spring Harbour in collaboration with Milislav Demerec[31] - from the summer of 1941, the two high school classmates from Turin, Luria and Fano, were the only two Italian exiles who took part in the development of the Carnegie Institute's Department of Genetics of Cold Spring Harbour, which in the following decade was to become the "Mecca of molecular biology."

Reading the articles by Delbrück and Muller on biophysics marked a juncture in Luria's career, who from that moment decided to give up medicine for good for biophysics and pure research. His enthusiasm for Delbrück's articles however, had no immediate experimental consequence: the poor genetic knowledge and great complexity of the drosophila - the fruit fly that both Delbrück and Muller used in their works as a model organism - convinced him to abandon a similar research project. The turning point came thanks to pure chance, due to the tram taking him to the university breaking down. During the long wait, Luria started to talk to a familiar face, Geo Rita (1911-1994), who was doing research in microbiology at Rome University, who told him of the existence of a possible new and simpler experimental model: bacteriophage viruses. With molecular dimensions similar to those hypothesized for the genes, with a very high reproductive rhythm and quantifiable by the naked eye thanks to the number of infectious stains that the groups of bacteria aggressed showed on the transparent Petri dishes, the bacteriophage immediately proved to be a much easier instrument than the drosophilae to test the biophysical theories of the gene put forward by Delbrück. In the following months, Luria started, in collaboration with Rita, an innovative research project to measure the minimum quantity of viral units necessary for the infection of a colony of shigella bacteria, which consisted of counting each infectious process of the bacteriophage viruses on the culture of bacteria identifiable by a clearly visible ring. It was the first case in which Luria adapted to the biophysical field a measurement used by the Roman school of physicists, the so-called "Fermi estimates", or an approximate but reliable calculation that the physicists used to calculate numerical estimates on the elementary particles and which Luria now used to measure the genes -assimilated, as Delbrück's theory suggested, with atoms.

The funding from the Rockefeller Foundation, the important professional relations due to the mediation of Levi, biophysics started by Delbrück in the direction of molecular biology: the contact between Luria and Rasetti already revealed some of the central elements that were able to create a virtuous relationship, at times casual, between those micro and macro stories which led to the success of the Turin school. As we will see, this relationship was confirmed and reinforced by Luria and by his companions in the years of exile.

The exile of Luria: the decade of reconnaissance

After a few weeks of work, the infamous fascist racial laws marked the interruption of the experiments, the results of which were therefore published in France[32], even though Luria was fortunately able to conclude his post-graduate course in radiology at the University of Rome (fig. 2)[33]. Like many other Jews who had received the gloomy news



R.UNIVERSITA' DI ROMA

SCUOLA DI PERFEZIONAMENTO IN RADIOLOGIA

ooo

LE DOSI PROFONDE E LE CURVE DI ISODOSE

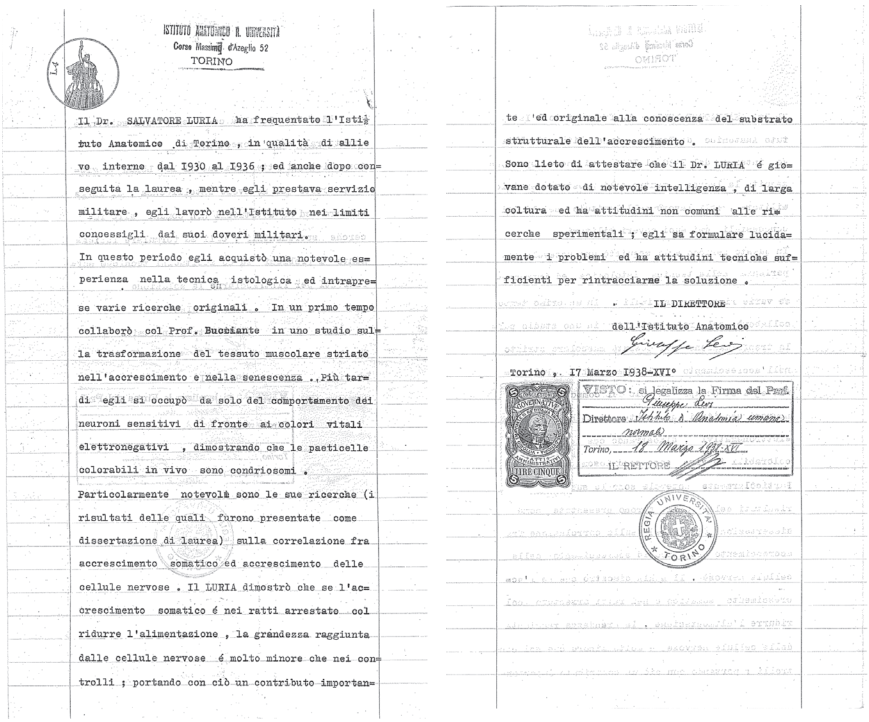
NELLA TERAPIA ROENTGEN AD ALTISSIMA TENSIONE

Tesi di diploma del Dott.Salvatore Luria.

Roma, 1938 / XVI .

Fig. 2. Tesi di diploma Scuola di Perfezionamento. S.E. Luria Papers, American Philosophical Society, Series IIb. Personal materials, Box 41, Università degli Studi di Roma 1938

of the "Kristallnacht" or "Night of broken glass", Luria left Rome for Paris where, thanks to his experiments on bacteriophage and a letter of introduction from Levi and Fermi (figs. 3 and 4), he was received with a scholarship at the Curie laboratory at the Institute of the Radio to continue working on the effects of radiations on the phage.
Together with Fernand Holweck (1890-1941), a physicist expert in radiobiology and the doctor and biologist Eugène Wollman (1883-1943), the author of pioneering articles on the importance of the phage for biological research, Luria jointly published two works on the quantity of radiation necessary for the inactivation of a single



ISTITUTO ANATOMICO R. UNIVERSITÀ
Corso Massimo d'Azeglio 52
TORINO

Il Dr. SALVATORE LURIA ha frequentato l'Istituto Anatomico di Torino , in qualità di allievo interno dal I930 al I936 ; ed anche dopo conseguita la laurea , mentre egli prestava servizio militare , egli lavorò nell'Istituto nei limiti concessigli dai suoi doveri militari.
In questo periodo egli acquistò una notevole esperienza nella tecnica istologica ed intraprese varie ricerche originali . In un primo tempo collaborò col Prof. Bucciante in uno studio sulla trasformazione del tessuto muscolare striato nell'accrescimento e nella senescenza .,Più tardi egli si occupò da solo del comportamento dei neuroni sensitivi di fronte ai colori vitali elettronegativi , dimostrando che le paeticelle colorabili in vivo sono condriosomi .
Particolarmente notevoli sono le sue ricerche (i risultati delle quali furono presentate come dissertazione di laurea) sulla correlazione fra accrescimento somatico ed accrescimento delle cellule nervose . Il LURIA dimostrò che se l'accrescimento somatico é nei ratti arrestato col ridurre l'alimentazione , la grandezza raggiunta dalle cellule nervose é molto minore che nei controlli ; portando con ciò un contributo importante 'ed originale alla conoscenza del substrato strutturale dell'accrescimento .
Sono lieto di attestare che il Dr. LURIA é giovane dotato di notevole intelligenza , di larga coltura ed ha attitudini non comuni alle ricerche sperimentali ; egli sa formulare lucidamente i problemi ed ha attitudini tecniche sufficienti per rintracciarne la soluzione .

IL DIRETTORE
dell'Istituto Anatomico
Giuseppe Levi

Torino , 17 Marzo 1938-XVI°

VISTO: si legalizza la Firma del Prof. Giuseppe Levi
Direttore Istituto di Anatomia umana normale
Torino, 18 Marzo 1938-XVI
IL RETTORE

CONCESSIONI GOVERNATIVE ATTI AMMINISTRATIVI LIRE CINQUE

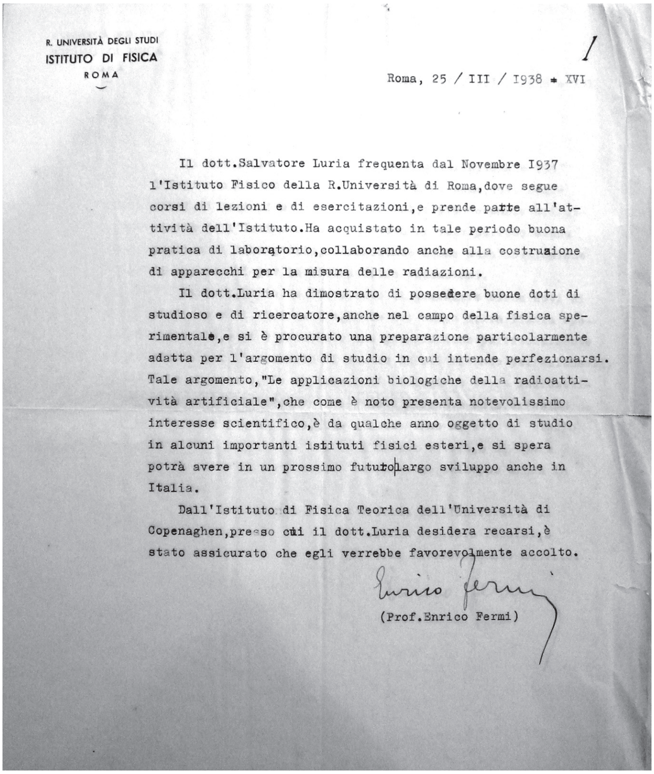
REGIA UNIVERSITA' TORINO

Fig. 3. Luria's letter of introduction from Giuseppe Levi (S.E. Luria Papers, American Philosophical Society, Series IIb. Personal materials, Box 41, Università degli Studi di Roma 1938).

phage. The fundamental idea that he worked out on his own in those months was that of calculating the number of viruses sensitive to the radiations using a statistical instrument to foresee sporadic events. In essence, Luria extended another intuition from physics to biophysics: Poisson distribution for rare independent phenomena[34]. As in the measurements of radioactive decadence, in which the probability of ‘success’ (particle decadence) is extremely low in the face of a very high number (about 10^{20}) of irradiated nuclei, Luria, in the heart of the gene-atom analogy, used Poisson distribution to foresee the quantity of inactivations (a few units) on a colony of about a billion viruses[35]. The originality of the importation was immediately recognized and some of these results were published in the famous scientific journal *Nature*[36].

In only four years since he had left the Turin laboratory, Luria was able to produce important results by originally integrating the lessons of two great teachers: from Giuseppe Levi he had learned how to correctly set up a biological experiment, as well as to write and publish a set of data as soon as they appeared significant -as shown by the numerous articles of microanatomy written during the Turin period, as well as the innovative importation of the experiments of bacterial and physical genetics of radiations (post-graduate thesis[37]) started in the Roman phase and subsequently developed and published in the two years he spent in France-; from Fermi he had learned a new language and method of reasoning, based on the statistical-probabilistic approach coming from nuclear physics - as shown by the Fermi estimates used to count the infectious plaques on the Petri dishes, and Poisson distribution for the lethal effects of ionizing radiations.

Forced into exile once again by the entrance into Paris of the Nazis, in September 1940 he arrived in New York where Fermi, then teaching at Columbia University, obtained a scholarship for him from the Rockefeller Foundation at the College of Physicians and Surgeons of New York. The Foundation positively accepted the authoritative opinion of Fermi (fig. 4), as Luria himself recalled[38], but in view of the constant and conspicuous funding paid out in the previous decade to finance Levi's laboratory during the difficult years of fascism[39], in awarding the grant it would not have been unaware, both for disciplinary continuity and the tradition of the 'school', of Luria's training at the Turin laboratory (fig. 3)- the same reasons that must have contributed to awarding the two Rockefeller scholarships which allowed Dulbecco and Levi Montalcini to emigrate to the United States in 1947[40].



R. UNIVERSITÀ DEGLI STUDI
ISTITUTO DI FISICA
ROMA

/

Roma, 25 / III / 1938 * XVI

Il dott.Salvatore Luria frequenta dal Novembre 1937 l'Istituto Fisico della R.Università di Roma,dove segue corsi di lezioni e di esercitazioni,e prende parte all'attività dell'Istituto.Ha acquistato in tale periodo buona pratica di laboratorio,collaborando anche alla costruzione di apparecchi per la misura delle radiazioni.

Il dott.Luria ha dimostrato di possedere buone doti di studioso e di ricercatore,anche nel campo della fisica sperimentale,e si è procurato una preparazione particolarmente adatta per l'argomento di studio in cui intende perfezionarsi. Tale argomento,"Le applicazioni biologiche della radioattività artificiale",che come è noto presenta notevolissimo interesse scientifico,è da qualche anno oggetto di studio in alcuni importanti istituti fisici esteri,e si spera potrà avere in un prossimo futuro largo sviluppo anche in Italia.

Dall'Istituto di Fisica Teorica dell'Università di Copenaghen,presso cui il dott.Luria desidera recarsi,è stato assicurato che egli verrebbe favorevolmente accolto.

Enrico Fermi

(Prof.Enrico Fermi)

Fig. 4. Luria's letter of introduction from Enrico Fermi (S.E. Luria Papers, American Philosophical Society, Series I. Correspondence 1938-1992, Fermi, Enrico, Box 12, 1938).

In December 1940, Luria met Max Delbrück with whom he immediately started working. Enthusiastic about their reciprocal interests, the two spent the Christmas vacation at grips with the first experiments on the infectious mechanisms of the phage. It was the start of a collaboration which continued almost without interruption for almost a decade and which in 1943 culminated in the formulation of the fluctuation test[41]: the most important discovery in their career[42], which proved, using a statistical model, that viral mutations were spontaneous and subject to selective dynamics, according to the Darwinian model then ignored by bacteriology. Although as early as his French period, Luria had used statistical instruments to measure the rate of mutation, it was only thanks to casually observing a slot machine at a university party that he guessed the common probabilistic mechanism[43].

It was the 1940s that marked the transformation and the international success of Luria. These were the years when he rekindled the relationship with Montalcini and Dulbecco helping them get into the USA. After two years at Columbia University (1940-42), Luria spent his professionally most significant years at Indiana University (1943-50), first as *assistant* and then as *associate professor* of bacteriology. After the fluctuation test, in 1946 he made the second important discovery of his career, identifying one of the first mechanisms of DNA repair by means of gene recombination[44]. The decade was also a rich period in personal and family terms. In this period he married (1945) the psychologist Zella Hurwitz -by whom in 1948 he had his only son, Daniel-, he became a US citizen (1947), he also cultivated his first political experiences, supporting the trade union movements and the election campaign of some progressive candidates and, in 1952, he made his third important discovery, revealing the existence of the restriction enzymes of DNA which was to lead to genetic engineering. The two key events which made Luria famous also took place in these years. In the first place, with Delbrück and Alfred Hershey

(1908-1997) he founded the so-called "phage group", a summer school at the Cold Spring Harbor Laboratory which, as mentioned, had the merit of laying the foundations of bacterial genetics and then inaugurating the development of molecular biology (a feat which contributed to the award of the Nobel Prize to the three founding fathers in 1969)[45]. The other important event took place in 1947, when his students on the course of bacteriology and virology included James D. Watson (1928 -), the first Indiana University student to do a doctoral thesis under the supervision of Luria. Just six years later, in 1953, Watson was to become a scientist of worldwide fame thanks to the discovery, in collaboration with Francis Crick and Maurice Wilkins, of the structure of the DNA, starting both for the teachers and for their students an exceptional trajectory of scientific fame and success, often crowned by the Nobel Prize[46].

It was in this propulsive phase of his personal and professional life, as mentioned, that Luria was able to help his former fellow students enter the USA, making a radical change in their lives but above all a disciplinary turning point towards molecularization in their respective lines of research. In the years of his American exile, Luria remained in contact by letter with his Turin family and also with Levi's laboratory through exchanges of letters with Rita Levi Montalcini who was aware of the studies on bacterial genetics that Luria was carrying out in the USA. In the summer of 1946 when Luria returned to Turin to see his family after the long period of the war and visit the elderly Levi who had recently been reinstated at the Institute[47], his visit was announced by the letters to Montalcini. In these letters, she prepared the ground both for the short but significant meeting between Luria and Dulbecco on the common ground of radio genetics, and for her own period of study at Victor Hamburger's laboratory in the USA[48]. It was these exchanges of letters with Luria, then an outstanding representative of US radio genetics, that convinced Montalcini to suggest to Dulbecco, once they met after the war, that she devote herself to physics to be able to use radiations as an instrument of investigation into genetics[49].

Diaspora and unification

In the summer of 1946, Dulbecco met Luria in Turin and the latter offered him a position at Indiana University. Dulbecco and Levi Montalcini boarded the same ship for the United States in the autumn of 1947. Both of them, as mentioned, started their American research thanks to a grant from the Rockefeller Foundation. From then on, their paths divided, Dulbecco towards the genetics of cancer and Levi Montalcini towards neuroscience. These two paths, although with differences, were to find common ground in the molecularization of biomedical knowledge, in which the United States in particular were leaders, as well as in the occasional recovery of the Turin tradition. Before the conclusions, let's look briefly at this intertwining to reveal the relations between education and diaspora, between local tradition and the historical and disciplinary events of international significance.

In 1930, at only sixteen, Dulbecco (1914 - 2012) entered the Faculty of Medicine of the University of Turin, the same year as Rita Levi Montalcini[50]. In the second year, he was also admitted as an intern in Levi's laboratory. The first task the master gave him, in which Levi Montalcini took part[51], consisted of examining the number of nerve cells in the backbone of mice to evaluate their possible fluctuation according to the litter, to then devote himself to the field of cellular regeneration and the in vitro cultivation of tissues, the area of research internationally most appreciated of Levi's laboratory, which was to return as partially useful to Dulbecco in the years of his American emigration[52]. Despite the initial enthusiasm and the publication of the first results[53], from the third year he decided to devote himself to Pathological Anatomy and left Levi's laboratory for Ferruccio Vanzetti's, and he devoted himself to physiopathology going from the electrophysiology of the heart to hepatic dysfunctions[54], dividing his clinical activity between the Cardiology Department of the Ospedale Mauriziano and the Ospedale delle Molinette. In 1936 he graduated with Vanzetti with a thesis on the degenerative effects of the liver caused by the obstructions of the bile ducts[55]. After two years of military service as a medical officer (1936-1938), Dulbecco continued his research at the Institute of Pathological Anatomy, which was interrupted by the outbreak of war: first of all he left for a brief experience on the French front (1940-1941) and then for the Russian campaign (1942-1943) taking part in the offensive on the Don. A dislocated shoulder and the relative leave gave him a period of reflection when he decided to desert the army until the liberation to offer his help sa a doctor to the partisans hidden in the Turin hills[56]. Having resumed his research, he started to work with his young colleague of the institute Giacomo Mottura (1906-1990) on neurogenic tumours, pulmonary pathologies and three-dimensional plastic reconstructions[57]. Towards the end of 1945, the great disappointment for the results of this research and once again meeting his former fellow student Rita Levi Montalcini represented a scientific and human turning point for the young scientist. In the next two years, Dulbecco, on the advice of Montalcini, overturned his research projects and started out on two new disciplinary paths: he returned as assistant (1946) to the Institute of Normal Anatomy of Levi, to work on the effects of ionizing radiations on chick embryos and enrolled in the faculty of Physics to study radioactive phenomena in further depth. With the new experiments, which represent the scientist's first step towards biophysics and genetics, casually pointing a needle of radon at the reproductive cells (larger and fuller of DNA compared to somatic cells) proved that the radioactive emission on the chick embryos was absorbed with greater intensity by the gonads, causing in the subsequent phases of development the correlated phenomenon of the absence of germ cells and the appearance of only the male sex[58]. However, despite the enthusiasm of the maestro for these first results, neither Levi nor his collaborators had the rudiments of genetics and biophysics necessary for Dulbecco to continue his experiments.

The relations with Italy and Levi ended with the encounter with Luria and the offer of a Rockefeller grant to study bacterial genetics at Indiana University. After two years of experiments in collaboration with Luria on the reactivation of the bacteriophage affected by radiation[59], in 1949 Dulbecco moved to the California Institute of Technology to work with Max Delbrück. It was here that he started the research that was to lead them being awarded the Nobel Prize. Stimulated by Delbrück to leave bacterial virology for animal virology, Dulbecco invented an innovative procedure to isolate and number the individual infectious processes of the virus in animal cells. The intuition came to him by readapting the "plaque technique" used to visualize the attacks of viruses on bacteria[60] and updating, in an important trip to American laboratories, the method of cellular cultures he had learned with Levi[61]. Contrary to expectations, Dulbecco found the Levi technique - borrowed from the suspension in drops of Harrison and particularly suitable for the culture of nerve tissues - almost unusable for his new purposes. More than growing nerve cells for a few days in order to observe their form and function, Dulbecco had to excogitate a system of cultures sensitive to viral infections, namely a system capable of developing the growth of infectible animal tissues but also, and above all, keeping in vitro cellular regeneration for several days to give the infectious process the time to take root on the host tissue. By perfecting this technique, Dulbecco was able to give animal virology a new quantitative approach, which in the years to come was to lead him to outlining the fundamental biological properties of the virus of poliomyelitis and to discover the infectious mechanisms of the first oncogenic viruses (Rous Sarcoma Virus, polyoma, SV40)[62]. He started by developing a method to isolate the virus of equine encephalitis[63], to then devote himself to isolate the pure lines of the poliomyelitis virus[64], which were to be used by Albert Sabin for the development of the anti-polio vaccine. From the mid-1950s, inspired by the collaboration of young virologists such as Howard Temin and Harry Rubin, Dulbecco devoted his attention to the oncogenic virus of the Rous sarcoma which was capable of developing tumours in chickens[65]. He sensed that the Rous sarcoma virus altered the genes of the host causing an uncontrolled proliferation and that these genes in the period of latency had to associate with the genes of the infected cell. To further study these innovative hypotheses, he used new oncogenic viruses based on DNA, such as the polyoma virus and the simian virus 40[66]. It was not until the end of the 1960s that he succeeded in showing, together with Joseph Sambrook, that the viral DNA was integrated into the cell genes, transmitted for some generations, until an alteration of the reproductive cycle responsible for the malignant transformation of the cell was caused[67]. Between 1972 and 1977 he moved to the Imperial Cancer Research Fund Laboratories in London to investigate in collaboration with Michael Stoker the development of cancer in human tissues, In 1975 he was awarded the Nobel Prize together with Temin and Baltimore for their "discoveries regarding the interaction between tumoral viruses and genetic material of the cell"[68]. A decade later, with an article in *Science* he launched the project for the sequencing of the entire human genome to understand the mechanisms of the onset of cancer[69].

The case of Rita Levi Montalcini is similar yet different. Of the three Nobel students, she was the only one to establish with Levi a long intellectual friendship, which started with her first work in 1932 and destined to last until the death of the professor, 33 years later[70]. She continued her research in neuroanatomy and collaborated directly with Levi, her "first and only assistant" on a series of studies conducted in the early 1940s and which she herself situated in the "prehistory" of the NGF (Nerve Growth Factor), the discover which made her famous and to which she devoted her life. Until 1947, the year of her American 'exile', Montalcini worked at the Institute of Anatomy of Turin and collaborated with the National Centre for studies on senescence of the CNR (Italian Research Council), created and directed by Levi. After the first work done together with Dulbecco as intern of the laboratory, Levi Montalcini approached several problems during her university years in contact with the maestro, including the study of tonofibrils in the hoof of the calf foetus, the development of the circumvolutions of the brain in human foetuses and the formation of the reticular collagen tissue of connective, muscular and epithelial tissues, which became the subject of her degree thesis (1936)[71]. With the rise to power of Hitler in Germany in 1933 the expulsion of Jews started and the Turin laboratory welcomed the scientist Hertha Meyer (1902-1990), well known for her innovative techniques on cellular cultures and above all for colouring the nerve tissue with silver salts, a local tradition acquired by the Turin laboratory which proved useful in the discovery of the NGF. The arrival in 1938 of the abomination of the racial laws forced Giuseppe Levi and Levi Montalcini to leave the University of Turin (see Appendice Fig. 4) and to carry on their research for long years in makeshift laboratories set up in their homes or abroad. In 1938, Levi moved to Belgium to continue his work on in vitro cultures, on the invitation of Professor Chèvremont, director of the Institute of Pathological Anatomy of the University of Liège. He stayed there from August 1939 to July 1941[72], even though the period of actual work - from March to December 1939 he was once again alongside Montalcini, who had also been forced into exile in Belgium, although in Brussels - was of only nine months, as in May 1940 the occupation of Belgium by the Nazi troops forced him into hiding. When he arrived in Turin, for a year, from the autumn of 1941 to the autumn of 1942, he worked with Montalcini in the makeshift laboratory his student had set up in her bedroom.

In the summer of 1940, Levi Montalcini read the article by Viktor Hamburger, that Levi had recommended to her a couple of years earlier, for the first time. This was the start of the journey that was to lead her to Stockholm. The article, focused on the nature of the mechanisms that govern the relationship between the development of nerve fibres and the tissues to be innervated[73], maintained that the peripheral territory had an active role in attracting the nerve fibres, i.e. that the growing nerve fibres 'sensed' the dimension and behaved as a consequence[74]. The hypothesis that in these years in hiding Levi and Levi Montalcini examined is, however, diametrically opposed: the peripheral territory seemed to release a diffusible factor that induced the growth of the nerve fibres. Hamburger had experimentally approached the problem of the relationship between the development of the extremities (wings and feet) and that of the corresponding vertebral nerve centres in the chick embryo, observing that the extirpation of the extremities, in embryos up to 72 hours of incubation, entailed the degeneration of the nerve tissue (sensory, but above all motor, spinal ganglions) and had attempted a qualitative explanation of the phenomenon. Levi and Levi Montalcini resumed the same experiment, but with different hypotheses and laboratory techniques. In the first place, they used a colouring technique -impregnation with silver nitrate, according to the Cajal-de Castro technique, re-elaborated by Herta Meyer- which, unlike the colouring with the Nissl method used by Hamburger, allowed clearly distinguishing the differentiated nerve cells from the undifferentiated ones and from the other cellular types present in the territory. They then concentrated their attention in particular on the (dorsal) sensory ganglions, better highlighted by the colouring and therefore more suitable for a quantitative evaluation of the cellular processes and, lastly, they made observations at different stages, instead of at only one, as the

German researcher had[75]. The difference of the conclusions of the article by the two Turin scientists made Hamburger, also after urging by Luria[76], offer Levi Montalcini a scholarship of a few months to check the correctness of one of the two hypotheses in his laboratory. With Levi Montalcini's departure for St Louis, the influence of Levi ended and the phase of biochemistry and then molecular of the discovery of the NGF started.

Turning upside-down the hypothesis of previous experiments which used the graft of a tumour and its capacity to induce proliferation to confirm the "peripheral" interpretation, in Hamburger's laboratory, Levi Montalcini showed rather that the tumour, although far and separated by a membrane, induced the growth of the nerve fibres towards it, proving that it had to release a diffusible humoural factor hitherto unknown, which was subsequently called *nerve growth promoting activity* and then *nerve growth factor*. Determined to subject to histological examination the diffusible nature of this factor, Levi Montalcini went back to using in vitro cellular cultures and morphological-quantitative analysis, two battle horses of the Turin laboratory which, with the due differences, were used both by Luria, who applied them to the plaque count technique on the phage - although hybridizing this technique with the "Fermi estimates" - and by Dulbecco, who applied the *Plaque Technique* to counting the viruses in the animal cells. Levi Montalcini, instead of evaluating the effect of the tumour on the embryo, a protocol which required 15-20 days of waiting, decided to use in vitro cultures of ganglions which, in 15-20 minutes not only showed a clear growth of nerve fibres towards the tumour, but made it possible to quantitatively evaluate the entity of the fibres, and therefore the content of NGF of a given source[77]. This solid hypothesis nevertheless needed a new experimental model to be validated, i.e. proof in biochemical-molecular terms. This was how the collaboration began in 1953 with the American biochemist Stanley Cohen (1922 -) who, in the first instance, wanted to establish whether the action of the growth factor was due to the protein or nucleic portion of the sarcoma, trying to exclude the nucleic component degrading it with cobra venom. Cohen, fortuitously, realized that the irradiation of the ganglions was centuplicated with respect to the use of the tumour, a sign that the venom was a new and valid source of NGF. The American biochemist, after having partially isolated the NGF from the cobra venom, discovered that the mouse salivary glands contained even greater amounts of NGF, becoming from then on the primary source of NGF[78]. In 1986 Levi Montalcini and Cohen were awarded the Nobel Prize "for the discovery of growth factors", a new class of extracellular messengers, the neurotrophins which have their progenitor in the NGF. The characterization of the NGF represented, in the words of the Nobel Prize winner Eric Kandel, "the start of the exploration of the nervous system at molecular level", reflecting "a new alliance between neuroembryology and modern biochemistry, in particular the biochemistry of proteins"[79].

Towards the end of the 1980s, the approach of molecular biology united the three students of Giuseppe Levi and their differing fields of biomedical knowledge. It was a path that had started in 1938 from the exile and disciplinary choices of Luria but which was also marked by affective motivations, linked to the formative years shared at Levi's laboratory, which appeared in difficult times; both immediately after the war, in the meeting of the 'trio' in Turin in 1946 and in the first years of the American exile of Dulbecco and Levi Montalcini, when the three students were to meet cyclically for advice and professional help in the Midwest. Levi himself in 1950 was to call on his students on his American trip and in 1957 Luria sent a manuscript entitled "Protoplasmotology" to Levi "with my best wishes and regards" which has next to the colophon the typed dedication "to Professor Levi on his 85th birthday, as a token of respect and affection"[80].

Conclusions

The story of the three Nobel Prize-winning students of Giuseppe Levi suggests different aspects of the relationship which links the success of a scientific discovery by a researcher with the years of education. The mentor naturally plays a central role, as recognized several times by students and by historiography[81], Levi succeeded in transmitting to his students how to keep disciplinary and moral rigour high and inseparably linked[82], how to set up an experiment correctly, how to write and boost scientific publications, how to alternate severity and encouragement in opinions on students, but he was also able to convey two techniques, rooted in the local tradition of the Turin laboratory, which were to be of use in the years of American exile: the technique of in vitro cellular cultures which Levi used with a morphological-quantitative approach[83] and the technique of Cajal - de Castro silver impregnation. In addition with respect to most of their U.S. colleagues, including the founding fathers of molecular biology, who came from a background in physics or biology, the three students had a medical background, therefore less rigorous but more organic in approaching biological problems, even though Luria and Dulbecco made up for this shortcoming by devoting their post-graduate years to studying physics[84]. On the other hand, the role of the network of relations with colleagues and institutions in an international context that Levi enjoyed has been neglected by students and historiography. His relations with Rasetti, Hamburger and the Rockefeller Foundation were central in this sense. The fact that Levi, Luria, Levi Montalcini and other members of the Turin laboratory belonged to the Jewish minority is also to be ascribed to this local dimension: in the difficult years of the restrictions of their rights inflicted by fascism, they had in common anti-fascism feelings and a courageous readiness for the human and work adventure capable of transforming constraints into professional opportunities[85].

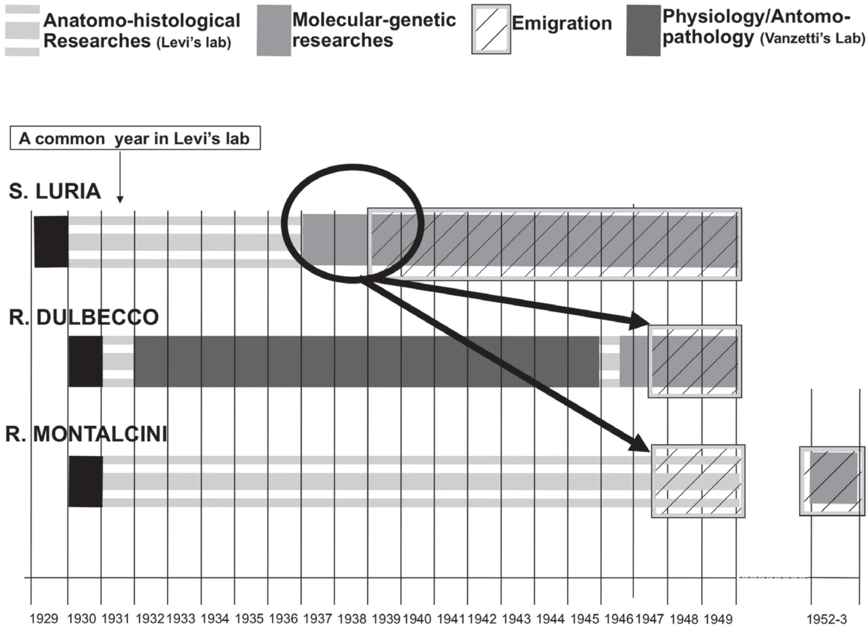


Fig. 5. The pivotal years: from education to diaspora.

If however these local stories succeed in going hand in hand with the major political, institutional and disciplinary events of those years, it is due to Salvatore Luria, the only scientist to have attended, representing a synthesis in some way, the two Italian ‘schools of Nobel Prizes: that of Levi in Turin and that of atomic physics founded by Fermi in Rome. Thanks to Levi and Fano, he came into contact with Rasetti who introduced him to radio genetics and the writings of Delbrück and after two years in Paris moved to the USA where in a few years, thanks to the foundation of the ‘phage school’ and the discovery of the structure of the DNA by his student Watson, he became one of the founding fathers of molecular biology. It was in the key decade from 1937-47 that Luria laid the foundations of molecular biology through bacterial genetics, inspired the choices of

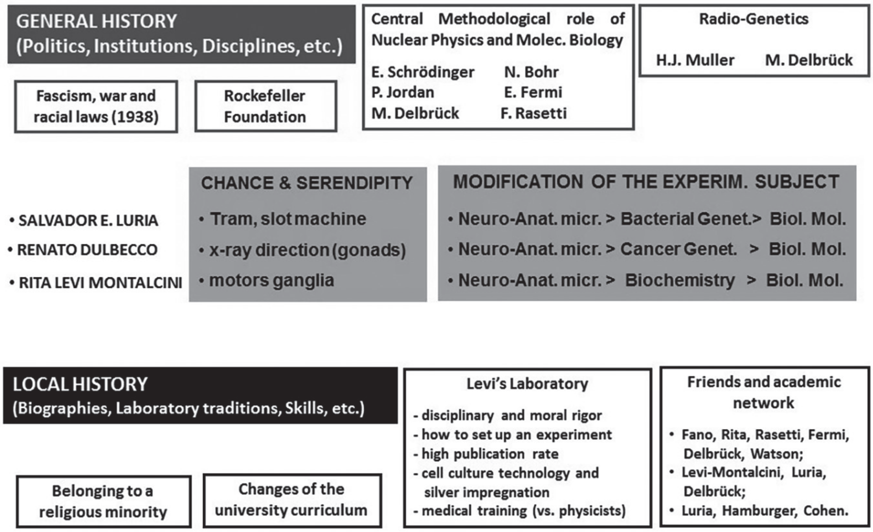


Fig. 6. Macro and micro history: biographic and institutional interconnections in the diaspora of the three Nobel students.

subjects of his former course companions who had stayed in Turin through correspondence with Levi Montalcini and made it easier for them to move to American laboratories (Fig. 5).

In the agreement between local history and general history, chance also inevitably played a central role, as shown by the various changes of course by the students who casually directed their research on to the correct rails, as well as the serendipity with which some of their key discoveries came about -Luria discovered the phage, the experimental object on which he built up his career, thanks to a chance encounter on a tram, just as he intuited the experiment which was to give him the Nobel Prize by observing a slot machine during an academic celebration; Dulbecco approached radio genetics by casually pointing the radium needle on the gonads of the chick instead of on other anatomical structures; while Levi Montalcini used a colouring technique which was to highlight some specific ganglions useful for the discovery of the NGF. A decisive role for the success of the three students was played by the molecularization of biomedical knowledge, even more than by chance. At different times and in different disciplines, the three Nobel laureate students of Levi were able to intuit the importance of the molecular explanation in their own disciplinary field, Luria and Dulbecco in the genetic one and Levi Montalcini in the neuroscientific one, tracing back their discoveries, whether bacterial genetics, oncological virology or neurotrophic factors, to the most productive and successful scientific paradigm of their time (Fig. 6).

BIBLIOGRAFIA E NOTE

1. Levi G, Curriculum Vitae. Historical archive of the University of Turin, Personal file, University of Turin (Archivio storico dell'Università di Torino, Fascicolo personale, Università di Torino), pp. 20.
2. Luria SE, Storia di geni e di me. Torino: Boringhieri; 1984. pp. 26-7; Levi Montalcini R, Elogio dell'imperfezione. Milano: Garzanti; 2000 (1987[1]). p. 78; the importance ofhaving, as eary as the second year of the course, "an experiment table" was also noted by Dulbecco, cf. Dulbecco R, Scienza, vita e avventura. Milano: Sperling & Kupfer; 1989. pp. 46-48; Cohen S, Interview with Renato Dulbecco. California Institute of Technology Oral History Project. Pasadena (Calif.): Caltech Archives; 2001. p. 10.
3. As will be better specified further on, Luria emigrated to France in 1938 to avoid the restrictions of the racial laws introduced by fascism and he did not reach the USA until September 1940.
4. Bucciante L, Luria S, Lo stroma dei muscoli volontari dell'uomo in rapporto all'età. Comunicazione alla IV riunione della Società Italiana di Anatomia. Monit Zool Suppl 1932; Idem, Lo stroma elastico dei muscoli volontari nelle varie età. Boll Soc Biol Sper 1932;7:535; Idem, Reperto di fibre muscolari a miofibrille attorte ed anulari nei muscoli oculari dell'uomo in rapporto all'età. Boll Soc Biol Sper 1933;8(3):1-3; Idem, Sulla struttura di alcuni muscoli volontari dell'uomo nelle varie età. Mon Zool Ital 1933;43:141-144;

Idem, Probabile significato delle fibre muscolari a fibrille attorte ed anulari nell'uomo. Arch Ital Anat Embr 1933;31(2):312-321; Idem, Trasformazioni nella struttura dei muscoli volontari dell'uomo nella senescenza. Arch Ital Anat Embr 1934;33:110-187.

5. Cf. in this book the contribution by G. Gemelli. See also Traniello F (a cura di), L'Università di Torino. Profilo storico e istituzionale. Torino: Pluriverso; 1993. p. 104; and Curriculum Vitae e Pubblicazioni Scientifiche di Luigi Bucciante, 4 pp., Archivio storico dell'Istituto di Anatomia Umana Normale.
6. Bucciante L, Foà A, Effetti dell'irradiazione con raggi alfa di emanazione di radio sopra cellule di varia natura coltivate "in vitro". Atti Soc. It. Anat. Monit. Zool. Ital. 1933;Suppl. vol 44:58-60.
7. Salvador Luria Papers (hereinafter SLP), American philosophical society, Series III, Works by Luria 1938-1997, Personal materials, Box 41: Giuseppe Levi, 17 March 1938, Università di Torino.
8. Luria S, Colorazione vitale dei condriosomi negli elementi dei gangli spinali con colori acidi. Seduta del 7 marzo 1935 - Sezione di Torino. Boll Soc Ital Biol Sper 1936; X: 281-283; Idem, Ricerche sulla colorazione vitale con colori acidi di gangli sensitivi e simpatici. Monit Zool Ital 1936;47 (3-4):83-91.
9. Luria S, Ricerche sperimentali sulla relazione fra accrescimento somatico e grandezza delle cellule nervose. Monit Zool Ital 1934;XLV:285-287; Idem, La grandezza delle cellule nervose in animali ad accrescimento artificialmente arrestato. Z Zell Mikrosk Anat 1935;22(5):724-34.
10. Research on the mitochondrion occupies one of the fourteen lines of research reported in the Curriculum Vitae di Giuseppe Levi, cf. infra Section III, Bio-bibliographical and document appendix. See, amongst the various works, Levi G, Sulla presunta partecipazione dei condriosomi alla differenziazione cellulare. Arch Ital Anat Embr 1911;X:168-195; ID., II comportamento dei condriosomi durante i più precoci periodi dello sviluppo dei mammiferi. Arch Zell 1915;13:471-524. The studies on the relations between the number and size of the cells in animals of different bulk date back to the first decade of the 20th century. Levi started with the comparison of the nerve cell of different species on invertebrates, discovering the existence of a 'fenestrated' apparatus in the neurons of the sensory ganglions and reached the so-called Levi's law, according to which the extent of the territory of innervation and the dimension of the neurons is proportional to the body size, as shown by the comparison of seventy specimens of fifty-six different species, cf. Levi G, I gangli cerebrospinali. Studi di istologia comparata e di istogenesi. Archivio italiano di anatomia e embriologia 1908;7:1-392.

11. As reported in "Verbale dell'esame di laurea in Medicina e chirurgia di Salvatore Luria" (Università degli Studi di Torino, Archivio storico), the subject approached for the first sub-thesis reached the conclusions according to which "The affection of gout is fundamentally characterized from the pathogenetic point of view, hence alteration in the exchange if uric acid" – where with the second sub-thesis Luria asserted that "With the alcoholization of the Gasserian ganglion in over 90% of cases lasting recovery is obtained."
12. Luria S, Ricerche sperimentali sulla correlazione tra accrescimento del soma e accrescimento delle cellule nervose. A.A. 1934/35, Tesi di Laurea discussa il 17 luglio 1935, 48 pp. [Degree thesis discussed on 17th July 1935, 48 pp]. Archivio storico dell'Università di Torino, Fondo Tesi (hereinafter ASUT). I wish to thank Paola Novaria, director of the Historical Archive for her help in following the retrieval and digitalization of Salvador E. Luria's degree thesis, now also available online http://www.omeka.unito.it/omeka/items/show/124 (updated to December 2017). Access to this, covered by copyright, was possible only thanks to the written consent of Luria's son (Dan) and wife (Zella Hurwitz), to whom I am deeply grateful. See also "Verbale dell'esame di laurea in Medicina e chirurgia di Salvatore Luria", Università degli Studi di Torino, Archivio storico and also VV. AA., Salvador E. Luria Biography. In: Nobel lectures including presentation speeches and laureates biographies: Physiology or Medicine, 1963-1970. Amsterdam, Elsevier, 1972, p. 437.
13. Luria SE, note 2, p. 26.
14. Luria SE, Prefazione all'edizione italiana. In Id., note 2; cf. also p. 178.
15. Ibid.
16. Luria SE, note 2, pp. 26-7.
17. Notification of the appointment by the Rector, on the proposal of the Director of the Clinic of General Surgery Ottorino Uffreduzzi, and request of Salvatore Luria for a certificate proving his qualification (February 7th, 1936); Luria, Salvatore, Documents, ASUT, note 12.
18. Belonging to a wealthy Jewish family, the son of a well-known lecturer in mathematics at the University of Turin (Gino Fano 1871 - 1952), Fano was also to be a victim of racial discrimination and forced to emigrate to the USA.
19. Müller H.J., Artificial transmutation of the gene. Science 66:84-87;1927.
20. On the ignorance of genetics in the years of Turin education cf. Luria SE, note 2, pp. 30, 74.
21. Ibid. p. 28.
22. In 1939 Fano emigrated to the USA with his wife, where he devoted himself for

a few years (1940-1944) to the study of radio biology, carrying out important experiments on drosophila with Milislav Demerec, director of the Cold Spring Harbor Laboratory, to then return to studies of atomic physics at the University of Chicago, where he was to occupy the chair that had been of his teacher Enrico Fermi. Cf. Luria SE, note 2, pp. 24-26, 74; and for the biographical accounts Clark CW, Ugo Fano (1912–2001). Nature 2001;410:164; Inokuti M, In Memoriam Ugo Fano 1912 - 2001. Radiat Res 2001;155:753-754. Another leading figure of the group of Via Panisperna who in the mid-1930s was to apply the methods and the instruments of physics to biology, in particular to the radio-tracing of lipids in the human metabolism, was Emilio Segrè; cf. Fermi L, Illustrious immigrants. The intellectual migration from Europe, 1930-41. Chicago - London: University of Chicago Press; 1968. pp. 315.

23. In his lecture Bohr (Light and Life. Nature 1933;131:421-423,457-459) suggested that while the principles of physics were sufficient to explain the world of matter, these became insufficient in front of organic matter. The world of living organisms, according to Bohr, therefore had to have some "fundamental traits" that were still hidden, that the new instruments of quantum physics were now able to reveal. Just as to penetrate the secrets of inorganic matter physics had to use "complementary" approaches with respect to the deterministic one - typical of classic physics - and have recourse to the indetermination theorized by quantum mechanics, in the same way to explain the obscure laws that govern organic matter, the traditional physical-chemical reductionism had to be integrated with an approach based on both disciplinary (physics and physiology) and theoretical (deterministic and finalistic explanation) complementarity). The influence of the physicists on nascent molecular biology was a subject on which both scientists and historians have practised. Cf.: Esanu V, La physique et la genèse de la biologie moleculaire. Virol. 1989;40(1):79-92; Perutz MF, Physics and the Riddle of Life. Nature 1987;326(9):555-558; Kay LE, Quanta of life: atomic physics and the reincarnation of phage. Hist. phil. life sci. 1992;14(1):1-21; Holliday R, Physics and the origins of molecular biology. J Genet 2006;85(2):93-7; Morange M, A history of molecular biology. Cambridge (Mass.): Harvard University Press; 2000,§ 7; Stent GS, That was the molecular biology that was. Science 1968;160(826):390-5; Fischer EP, Lipson C, Thinking about science: Max Delbrück and the origins of molecular biology. New York - London: Norton; 1988. pp. 78-102. On the specific influence of Bohr see: Stent GS, The Max Delbrück lecture. Light and life: Niels Bohr's legacy to contemporary biology. Genome 1989;31(1):11-5; Symonds N, Schrödinger and Delbrück: their status in biology. Trends

Biochem. Sci. 1988;13(6):232-4; Roll-Hansen N, The application of complementarity to biology: from Niels Bohr to Max Delbrück. Hist Stud Phys Biol Sci. 2000;30 Pt2:417-42; Mckaughan DJ, The influence of Niels Bohr on Max Delbrück: revisiting the hopes inspired by "light and life". Isis 2005;96(4):507-29; Domondon AT, Bringing physics to bear on the phenomenon of life: the divergent positions of Bohr, Delbrück, and Schrödinger. Stud Hist Philos Biol Biomed Sci. 2006;37(3):433-58.

24. In a few years, the results of this theory, known as the "target theory" or the "hit theory" were unreliable: biological molecules, as hypothesized by the quantum model, were not characterized by stable levels of energy, the dimensions of the gene were incorrect and, above all, the gene was no longer made up of proteins but of nucleic acids; cf. Zimmer KG, Delbrück M, Sloan PR, Fogel DB, Timofeev-Resovskii NV, Creating a physical biology: the Three-Man Paper and early molecular biology. Chicago: University of Chicago Press; 2011.
25. Once struck, the gene was excited and this caused a mutation: if the energy level reached was stable, the mutation was irreversible and was handed down to the offspring, if the energy level was unstable, it returned to its original energy state and the mutation disappeared in one of the next generations. Cf. Fleming D, Emigré Physicists and the Biological Revolution. In: Fleming D, Bailyn B (eds), The intellectual migration; Europe and America, 1930-1960. Cambridge (Mass.): Belknap Press of Harvard University Press; 1969. pp. 152-189; Delbrück M, A physicist's renewed look at biology: twenty years later. Science 1970;168(937):1312-1315; Holliday R, Physics and the origins of molecular biology. J. Genet. 2006;85(2):93-97; Domondon AT, Bringing physics to bear on the phenomenon of life: the divergent positions of Bohr, Delbrück, and Schrödinger. Stud Hist Philos Biol Biomed Sci 2006;37(3):433-458.
26. Del Gamba V, Il ragazzo di via Panisperna: l'avventurosa vita del fisico Franco Rasetti. Torino: Bollati Boringhieri; 2007.
27. Amaldi E, 20th century physics, essays and recollections: a selection of historical writings. In: Battimelli G, Paoloni G. (eds.), Edoardo Amaldi Foundation Series, Vol. III. River Edge (N.J.): World Scientific; 1998. p. 158.
28. Goodstein JR, Interview with Franco Rasetti. California Institute of Technology Oral History Project, Pasadena (Calif.): Caltech Archives; 2002. p. 38.
29. Cf. Luria SE, note 2, pp. 28, 74.
30. Beyler RH, The Scientific and Cultural Context of Pascual Jordan's Quantum Biology. Isis 1996;87(2):248-273; Wise MN, Pascual Jordan: Quantum

Mechanics, Psychology, and National Socialism. In: Renneberg M, Walker M (eds.), Science, technology, and national socialism. Cambridge - New York: Cambridge University Press; 1994. pp. 224-254; Gieser S, The innermost kernel depth psychology and quantum physics: Wolfgang Pauli's dialogue with C.G. Jung. Berlin - Heidelberg: Springer; 2005. pp. 92-102.
31. Cf. Inokuti M, Clark CW, note 22.
32. Luria SE, Sur l'unité lytique du bactériophage. Compt. Rend. Soc. Biol. 1939;130:904-7.
33. Cf. Luria S., Le dosi profonde e le curve di isodose nella terapia Roentgen ad altissima tensione. Tesi di Diploma della Scuola di perfezionamento in radiologia della Regia Università di Roma, 4 luglio 1938. SLP, note 7, Series III, Works by Luria, Box 43. It also has to be remembered that in those tragic months of 1938, the abomination of the racial laws prevented Luria from benefiting from a scholarship from the Italian government, which he had won just a few days before the restrictions, which would have allowed him to spend one year at the University of Berkeley to work on radiobiology (Luria SE, note 2, p. 31). See also Grignolio A, Geo Rita, in: Dizionario Biografico degli italiani. Roma: istituto dell'Enciclopedia Italiana Treccani; 2016. pp. 681-683.
34. Cf. Luria SE, note 2, p. 93.
35. Luria SE, Méthodes statistiques appliquées à l'étude du mode d'action des ultravirus. Ann Inst Pasteur 1940;64:415-438.
36. Luria SE, Action des radiations sur le Bacterium coli. Compt. Rend. Acad. Sci. 1939;209:604-606; Idem, Recherches sur le mode d'action des radiations sur les bacteriophages. Compt. Rend. Acad. Sci. 1940;210:639-42; Idem, Radiobiologie quantique. Paris méd. 1940;30(26):305-311; Idem, Effect of radiations on bacteriophage C16. Nature 1940;3685:935-36.
37. Luria SE, Le dosi profonde e le curve di isodose nella terapia Roentgen ad altissima tensione. Regia Università di Roma 1938. In: SLP, note 7, Box 43.
38. Luria S., note 2, pp. 24-26.
39. See the contribution by Giuliana Gemelli in this book.
40. Cf. the contribution by G. Gemelli in this book. Various clues reveal that coming from the school of Levi favoured the award of Rockefeller grants to the Nobel students. In the case of Luria, for example, this is suggested by the presence of the recommendation letter by Giuseppe Levi which, together with the one by Enrico Fermi, he took with him to New York. The six publications written together with Bucciante, a student of Levi as well as a fellow funded for a long time by the Rockefeller Foundation may also have played

a role in the curriculum. In the case of Levi Montalcini, alongside the many publications with the maestro, it has to be considered that the application for the Rockefeller grant came from Victor Hamburger himself, whose aim was to host in his laboratory the young student of Levi to compare his theories on embryonic neural development with those of the Turin school. Lastly, Dulbecco, who obtained the grant thanks to the interest as well as of Luria, of Paul A. Weiss, who had hosted in the two years 1938-39 in Chicago Rodolfo Amprino, Levi's favourite student, and of Max Delbrück.

41. Luria SE, Delbrück M, Mutations of bacteria from virus sensitivity to virus resistance. Genetics 1943;6:491-511.
42. In actual fact, contrary to the historical and popular tradition, Delbrück made only a final contribution to the fluctuation test, adjusting some wring calculations and proposing an elegant mathematical demonstration. Cf. Luria SE, Mutations of Bacteria and of Bacteriophage. In: Cairns J, Delbrück M, Stent GS, Watson JD (eds), Phage and the origins of molecular biology. New York: Cold Spring Harbor of Quantitative Biology; 1966. pp.174-5. Cf. also Letter from Max Delbruck to Salvador E. Luria on April 5, 1943. SLP, note 7, Series V. Research notes, 1941-1979, Bacterial Resistance 1943 Box 71 (http://profiles.nlm.nih.gov/ps/access/QLBBFT.pdf, uptodated to December 2017); Selya RE, Salvador Luria's unfinished experiment: the public life of a biologist in a cold war democracy. Ph.D. thesis in History of Science Department. Harvard University, Cambridge (Ma), USA, 2002, pp. 81 and ff. In the meantime, however, Delbrück had also succeeded, independently of Luria, in using Poisson distribution on phage, cf. Brock TD, The emergence of bacterial genetics. New York: Cold Spring Harbor of Quantitative Biology; 1990. pp. 119-28.
43. The role of chance and serendipity frequently wind through the autobiography of Luria, starting from the original title (A slot machine, a broken test tube: an autobiography) which recalls the two fortuitous events at the basis of the two most important discoveries in his career: the fluctuation test and the restriction enzymes (see Luria SE, A slot machine, a broken test tube: an autobiography. New York: Harper & Row; 1984). Specifically, reflecting on the statistical rules that govern slot machines, Luria intuited an analogy with the mechanisms of bacterial resistance to infections. The mutations which make the bacteria resistant and high wins are both rare events (Poisson) which can be calculated by measuring the statistical distribution of their variation (fluctuation) around a foreseeable constant average value. If the fluctuation of this value remains constant in different times, the Lamarckian

hypothesis will be valid, as the number of resistant bacteria will result from the number of viruses that induce it according to a proportional ratio; if, on the other hand the value increases with the passing of time (i.e. if on the increase of the generations passed the mutations are distributed in inhomogeneous groups), it will be the sign that the pre-existing bacterial families casually resistant have multiplied even more, according to the selective hypothesis, as effectively happened. Cf. Grignolio A, Salvador E. Luria. In: La cultura italiana - Il progresso scientifico. Roma: Istituto dell'Enciclopedia Italiana Treccani; 2013. pp. 736-741.

44. Luria SE, Reactivation of irradiated bacteriophage by transfer of self-reproducing units. Proc. Nat. Acad. Sci. USA 1947;9:253-64. Cf. Luria SE, note 2, pp. 109-110; Grignolio A, Luria, Salvador Edward, note 43.
45. Between 1944 and 1946 the trio wrote the so-called Phage Treaty in which research is concentrated on a limited number of phage and bacterial strains, in the attempt to standardize the experimental conditions and make comparable and reproducible the experiments of the different laboratories on the phage, cf. Hershey AD, Delbrück M, Doermann AH, Luria SE, Second revision: proposal on nomenclature, March 14 1946, in: SLP, note 7, Series III, Works by Luria 1938-1997.
46. The first, and perhaps main subject responsible for mythicizing the discovery of DNA were the founding fathers of molecular biology with direct accounts (this is the case of the famous book-interview of Judson HF, The eighth day of creation: makers of the revolution in biology. New York: Simon and Schuster; 1979) or self-celebratory books (Cairns J, Delbrück M, Stent GS, Watson JD, note 42). Among the founders, a decisive role was played by the two authors of the famous discovery: James Watson, who with "The double helix" (1968), an autobiographical story not free of immodest and triumphant declarations on the molecule that "revealed the secret of life", was to become the author of the first best-seller of scientific popularization, ending up by imposing an interpretative model which was to influence, although with a different force, science historians and the general public; and Francis Crick who a few years later, although in the attempt to rebalance with his own version provocations and evaluative errors of his ex-colleague, was to end up by corroborating the myth of the discovery of the DNA, diminishing not only biological disciplines and discoveries that made it possible but even stating the record of the discovery over the discoverers: "Instead of saying it was Watson and Crick who created the structure of DNA, I would rather emphasize how it was the structure of DNA that created Watson and Crick" (Crick F, What mad pursuit:

a personal view of scientific discovery. New York: Basic Books; 1988. p. 76). Cf. also Dulbecco R, note 2, pp. 302-305. The historiography of neuroscience has also started to consider the "molecularization" of the study of the nervous system as a historiographical watershed (Cf. Rose N, Abi-Rached J, The Birth of the Neuromolecular Gaze. Hist. Human Sciences 2010;1:1-26, part. pp. 7-10), a central element to balance the role of the Turin school and that of the American school in the discovery of the NGF by Montalcini.

47. cf. Levi Montalcini R, note 2, p. 145; Cohen S, note 2, pp. 14-15; Selya RE, note 42, p. 176.
48. Luria SE, note 2, p. 53.
49. Levi Montalcini R, note 2, pp. 94, 145. Dulbecco R, note 2, p. 133.
50. Some parts of the pieces reconstructing the scientific biographies of Luria, Dulbecco and Montalcini are taken from previous articles by the author on these topics, including: Grignolio A, De Sio F, Uno sconosciuto illustre: Giuseppe Levi tra scienza, antifascismo e premi Nobel. Med Sec. 2009;21(3):847-913; Grignolio A, Luria, Salvador Edward, see note 43; Grignolio A, Giuseppe Levi. In: La cultura italiana - Il progresso scientifico. Roma: Istituto dell'Enciclopedia Italiana Treccani; 2013. pp. 646-650; Grignolio A, Renato Dulbecco. In: Dizionario Biografico degli Italiani. Roma: Istituto dell'Enciclopedia Italiana Treccani; 2014.
51. Levi Montalcini R, note 2, p. 71.
52. Dulbecco R, note 2, p. 49; Witkowski JA, Alexis Carrel and the mysticism of tissue culture. Med Hist 1979;23(3):280-292.
53. Dulbecco R, Magri L, Ricerche sul numero dei neuroni sensitivi nei gangli dei metameri toracici dell'uomo. Monit Zool Ital 1933;44:126-131.
54. Dulbecco R, note 2, pp. 53-64. Dulbecco was to publish most of the publications on these topics in the years following his degree, during military service (1936-1938) and in the brief periods of leave (1939-1943), cf. Ibid., pp. 72, 83. See for example Dulbecco R, Palomba G, Osservazioni su di una curva di volume del cuore umano: al pletismodiagramma. Cuore Circ 1937;XXI(86):153; Dulbecco R, Cosiddetta atrofia giallo-acuta del fegato. Rev Clin Espan 1943; Idem, Nuove concezioni sulla patogenesi dell'ittero. Significato funzionale e classificazione. Minerva Med 1944;35.
55. Dispersed for many years, it is not possible to establish the exact title of Dulbecco's thesis, cf. Dulbecco R, Sulla alterazione del parenchima epatico nella stasi e nella infezione della bile. A.A. 1935/36, Tesi di Laurea discussa il 17 luglio 1936, Annuario della R. Università di Torino 1935-36, p. 253 [Academic Year 1935/36, Degree thesis discussed on 17th July 1936], ASUT, op.

cit. note 12; a different title is shown in the register of examination records, cf. Dulbecco R, Le alterazioni del parenchima epatico nella occlusione del coledoco. A.A. 1935/36, Tesi di Laurea discussa il 17 luglio 1936, Facoltà di Medicina e Chirurgia, Verbali Esami di Laurea, Aggregazione 1-775, p. 286, [Academic Year 1935/36, Degree thesis discussed on 17th July 1936, Faculty of Medicine and Surgery, Records of Final Degree examinations, Aggregation 1-775, p. 286], ASUT, note 12. For general indications, see Cohen S, note 2, p. 7; Dulbecco R, note 2, p. 65.

56. Cohen S, note 2, p. 9.
57. Mottura G, Dulbecco R, Sul neurinoma centrale. Arch Sci Med 1942;74(2):85-133. Dulbecco R, Ricerche sull'architettura dei bronchioli respiratori del polmone umano. Considerazioni sulla dinamica respiratoria e loro riflessi nella patologia. G Accad Med Torino 1945;7-12. Dulbecco R, Alcuni perfezionamenti tecnici al metodo delle ricostruzioni plastiche. Arch Sci Med 1945;79:180-183; Mottura G, Dulbecco R, Ricostruzione plastica di parenchima polmonare in casi di Pneumoconiosi siderotica. Rass Med Ind 1946;15:82-88; Mottura G, Dulbecco R, Architectural characteristics of various types of pneumoconiosis by means of plastic models. Bull Histol Appl 1947;24:11.
58. Dulbecco R, Sviluppo di gonadi in assenza di cellule sessuali negli embrioni di pollo. Sterilizzazione completa mediante esposizione a raggi [gamma] allo stadio di linea primitiva. Atti Accad Naz Lincei 1946;2:1211-13; Idem, Nuove ricerche sulla sterilizzazione di embrioni di pollo mediante irradiazione con raggi gamma. Costante determinazione del sesso femminile negli embrioni irradiati. Atti Accad Naz Lincei 1947;2:659-662; Idem, Azione dei raggi gamma del radio sullo sviluppo della gonade e sui caratteri somatici del sesso nell'embrione di pollo. Atti Accad Naz Lincei 1948;8(s.3,v.2,n.1):1-20; Idem, Développement de la gonade malgré la disparition totale des cellules sexuelles après irradiations par les rayons X. Schweiz Med Wochenschr 1948;78(17):412. Dulbecco's research on irradiated embryos, like that of Montalcini on embryonic development, were funded by the Research Centre on the Growth and Senescence of organisms and were carried out in the premises of the Institute of Normal Anatomy, cf. Testa C (a cura di), Inventario Archivio storico dell'Istituto di Anatomia Umana Normale. Torino: Università degli Studi di Torino; 2004, Fald. 34, Fasc. 264, v. 81.
59. Luria SE, Dulbecco R, Lethal mutations and inactivation of individual genetic determinants in bacteriophage. Genetics 1948;33(6):618-619; Idem, Genetic Recombinations Leading to Production of Active Bacteriophage from Ultraviolet Inactivated Bacteriophage Particles. Genetics 1949;34(2):93-125;

Dulbecco R, Reactivation of ultra-violet-inactivated bacteriophage by visible light. Nature 1949;163(4155):949.

60. Dulbecco R, The Plaque Technique and the Development of Quantitative Animal Virology. In: Cairns J, Delbrück M, Stent GS, Watson JD, note 42, pp. 287-291.
61. Dulbecco R, note 2, p. 173; Dulbecco R, The Plaque Technique and the Development of Quantitative Animal Virology. In: Cairns J, Delbrück M, Stent GS, Watson JD, note 42, pp. 287-291; Kevles DJ, Renato Dulbecco and the new animal virology: medicine, methods, and molecules. J Hist Biol 1993;26(3):429-30.
62. Ibid., Kevles DJ, p. 409-42.
63. Dulbecco R, Production of Plaques in Monolayer Tissue Cultures by Single Particles of an Animal Virus. Proc Nat. Acad. Sci. USA 1952;38(8):747-752.
64. Dulbecco R, Vogt M., Plaque Formation and Isolation of Pure Lines with Poliomyelitis Viruses. J. Exp. Med. 1954;99:167-182.
65. Dulbecco R, Interaction of viruses and animal cells; a study of facts and interpretations. Phys Rev.1955; 35(2):301-335.
66. Dulbecco R, Clonal derivation of viruses. Ann N.Y. Acad. Sci. 1957;68(2):245-249; Dulbecco R, Freeman G, Plaque production by the polyoma virus. Virology 1959;8(3):396-397; Dulbecco R, Induction of tumors in vitro with viruses. Nat. Canc. Inst. Mon. 1960;4:355-361; Dulbecco R, Vogt M, Significance of Continued Virus Production in Tissue Cultures Rendered Neoplastic by Polyoma Virus. Proc Nat. Acad. Sci. USA 1960;46(12):1617-1623; Ibid., Properties of cells transformed by polyoma virus. Cold Sp. H. Symp. Q. Biol. 1962;27:367-374; Ibid, Evidence for a Ring Structure of Polyoma Virus DNA. Proc Nat. Acad. Sci. USA 1963;50(2):236-243; Dulbecco R, Transformation of Cells in Vitro by DNA-Containing Viruses. J. Am. Med. Ass. 1964;190(8):721-726; Dulbecco R, Hatanaka M, Induction of DNA synthesis by SV40. Proc Nat. Acad. Sci. USA 1966;56 (2):736-740.
67. Dulbecco R, The state of the DNA of polyoma virus and SV40 in transformed cells. Cold Sp. H. Symp. Q. Biol. 1968;33:777-783; Dulbecco R, Sambrook J, Westphal H, Srinivasan PR, The integrated state of viral DNA in SV40-transformed cells. Proc Nat. Acad. Sci. USA 1968;60(4):1288-1295; Dulbecco R, Stoker MG, Conditions determining initiation of DNA synthesis in 3T3 cells. Proc Nat. Acad. Sci. USA 1970;66(1):204-210.
68. Dulbecco R, Nobel Lecture: From the Molecular Biology of Oncogenic DNA Viruses to Cancer, 1975. Nobelprize.org. Nobel Media AB 2013. http://www.nobelprize.org/nobel_prizes/medicine/laureates/1975/dulbecco-lecture.html

(updated to December 2017).
69. Dulbecco R, A turning point in cancer research: sequencing the human genome. Science 1986;231(4742):1055-1056.
70. Levi-Montalcini R, NGF: an uncharted route. In: Worden FG, Swazey JP, Adelman G (eds.), The Neurosciences: Paths of Discovery. Cambridge (MA): MIT Press; 1975. pp. 245-265.
71. Levi-Montalcini R, note 2, pp. 78-79, 82.
72. Gabrielli P, Col freddo nel cuore. Uomini e donne nell'emigrazione antifascista. Roma: Donzelli; 2004. pp. 157-158.
73. Hamburger V, The effects of wing bud extirpation on the development of the central nervous system in chick embryos. J. Exp. Zool. 1934;68:449–494.
74. Calissano P, Levi-Montalcini R, NGF. Dizionario Medico Treccani. Roma: Istituto dell'Enciclopedia Italiana Treccani; 2010.
75. Cf. Grignolio A, De Sio F, note 50. This description resumes the insightful observations of the part written by De Sio.
76. Calissano P, Rita Levi Montalcini, Renato Dulbecco, Salvador Luria: un trio formidabile. In: Cattaneo M (a cura di), Scienziati d'Italia. Centocinquant'anni di ricerca e innovazione. Torino: Codice Edizione; 2011. pp. 101-129.
77. Ibidem.
78. Cohen S, Levi Montalcini R, Hamburger V, A nerve growth-stimulating factor isolated from sarcomas 37 and 180. Proc. Nat. Acad. Sci. USA 1954;40:1014-1018; Cohen S, Levi Montalcini R, A nerve growth-stimulating factor isolated from snake venom. Proc. Nat. Acad. Sci. USA 1956;42:571-574; Cohen S, Purification of a nerve-growth promoting protein from the mouse salivary gland and its neuro-cytotoxic antiserum. Proc. Nat. Acad. Sci. USA 1960;46:302-311.
79. Kandel E, The Origins of Modern Neuroscience. Ann. Rev. Neuroscience 1982;5(1):299-303, in particular p. 302.
80. Inventory of the Archivio storico dell'Istituto di Anatomia Umana Normale, "Opuscoli e Memorie", vol. 201-208, extract from CV, cf. note 1.
81. Cf. note 2 for the autobiographical recognitions of the three students. For historiography see: Ribatti D, Tre compagni di studi. Gli anni torinesi di Renato Dulbecco, Rita Levi Montalcini e Salvador Luria. Riv. Sto. Med. 1993;III(2):43-53; Bentivoglio M, Vercelli A, Filogamo G, Giuseppe Levi: mentor of three Nobel laureates. J. Hist. Neurosci. 2006;15(4):358-68; Grignolio A, De Sio F, note 50; Calissano P, note 76, as well as the contribution of A. Piazza in this book.
82. The moral and civil inheritance of Levi's lesson on the three students would

deserve discussion on its own, which here cannot be outlined. In addition to the already quoted article on Levi and his great anti-fascist commitment (Grignolio A, De Sio F, note 50), see the biographical sections which deal with the political and social commitment of the scientists Luria and Dulbecco (Grignolio A, note 43; Grignolio A, note 50). As far as Levi Montalcini is concerned, the following are to be recalled: in the 1970s, her active support for the campaign for the regulation of abortion; in 1992, with her sister Paola, the establishment of the Fondazione Rita Levi-Montalcini with the aim of helping young African women, through awarding scholarships for the training of leaders in the scientific and social life of their countries; in 1999 her support of the campaign against hunger in the world with the appointment as ambassadress of the FAO; as well as the participation in many campaigns of social interest such as that against anti-personnel landmines, for the protection of the world's water resources or for the responsibility of scientists in relation to society, including her lucid support for agricultural biotechnologies, and in particular for the GMOs, for developing countries (a campaign also supported by Dulbecco). Cf. Tripodi G, La lezione di Rita Levi-Montalcini. Una vita tra scienza e solidarietà. Milano: Rizzoli; 2011. Strata P, Rita Levi Montalcini. In: Dizionario Biografico degli Italiani. Roma: Istituto della Enciclopedia Italiana; 2013; Bray M, Rita Levi Montalcini. Online encyclopaedias, Istituto della Enciclopedia Italiana. http://www.treccani.it/enciclopedia/rita-levi-montalcini (updated to December 2017).

83. In this regard, the comment of the colleague of Levi's years in Florence, Davide Carazzi, is particularly lucid: "Levi [...] even in his first observations on the cells cultivated in vitro seemed that he should not abandon the exquisitely morphological approach", cf. Carazzi D, Rivista Critica. Costituzione del protoplasma e strutture cellulari. Levi, Giuseppe. Rass. Sci. Biol. 1919;8:116-126. For a historical reconstruction of this technique, see Grignolio A, De Sio F, note 50.
84. For the historiographical discussion on the founding role played by the physics-mathematics approach to molecular biology, see notes 23, 24, 25 as well as the examination proposed in Grignolio A, De Sio F, nota 50, in particular n. 7.
85. Anti-fascism was obviously also professed by non-Jewish students, exemplary was the case of Amprino, cf. De Luna G, Anatomia della Resistenza. Giuseppe Levi e i documenti nascosti tra scheletri e reperti all'Università di Torino. La Stampa, 15/4/2008, p. 49. For an overview of Levi's anti-fascism see Grignolio A, De Sio F, note 50; Gabrielli P, note 72; as well as

the biographies of the three students: Luria S, note 2, p. 27; Dulbecco R, note 2, p. 47; Levi Montalcini, note 2, p. 69, 72.

Correspondence should be addressed to:

Andrea Grignolio, Dipartimento di Medicina Molecolare, Unità di Storia della Medicina e Bioetica, Sapienza Università di Roma, Viale dell'Università 34/A, 00185, Roma.

email: andrea.grignolio@uniroma1.it