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Laboratories, Microscopy, and the Making of Biology in Italy, 1861-1915

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Abstract

This article examines the emergence of biology as a scientific field in Italy between 1861 and 1915, focusing on the definition of its disciplinary boundaries, the development of laboratories and the spread of microscopy. Adopting a situated approach, it investigates how biological knowledge was organised within Italian universities by analysing how broader changes in research and teaching were shaped by local institutional and material conditions. It first considers Battista Grassi's 1911 account of the progress of biology in Italy, which sheds light on how medical and natural sciences came to be understood within a shared disciplinary framework. It then compares the development of botanical and zoological institutes at the Universities of Modena and Padua, tracing the reorganisation of existing spaces, the acquisition of scientific equipment, and the uneven expansion of facilities. The comparison highlights the decisive role of funding in shaping institutional trajectories, while showing that laboratories did not simply replace museums but emerged through the reconfiguration of established academic settings. Overall, the study argues that the most significant transformation occurred in scientific education, with the gradual consolidation of a practical model in which students' direct engagement with instruments and experimental procedures became central to their training. Laboratory development was thus driven primarily by the growing recognition of education as integral to the production and transmission of biological knowledge.

Introduction

To examine biological laboratories in post-unification Italy from today's perspective is to reflect not only on elements of continuity, such as scientific traditions and material developments, but also, and above all, on the differences between the past and the present. Carlo Ginzburg devoted an essay to the historiographical problem, already identified by Marc Bloch, of "the gap between the resilience of words and their shifting meaning" (Ginzburg 2012, pp. 97-98), focusing in particular on "the relationship between the observer's and the actor's categories" (p. 103). Drawing on Kenneth L. Pike's distinction between these "two levels of analysis […] labeled, respectively, as *etic* (from *phonetic*) and *emic* (from *phonemic*)", the Italian historian underscored the need to start "from *etic* questions aiming to get *emic* answers", while always maintaining "the tension between our questions and the answers we get from the evidence" (pp. 107-109). The starting point of this article is therefore this "difference between our words and theirs" (p. 109), which provides a basis for a critical reflection on the extensive literature on the formation of the biological field, the development of scientific laboratories and the rise of microscopic studies.

The emergence of biology as a scientific domain has been understood as the outcome of a centuries-long process involving a wide range of factors and actors, rather than as the result of a single event or the work of one founding figure (Barsanti 1995, pp. 88-89; Dröscher 2008, p. 36). Historiography nevertheless allows the reconstruction of three distinct stages through which the new field gradually took shape. First, the appearance of the term, albeit with different meanings, in the writings of various authors during the second half of the eighteenth century (Dröscher 2008, pp. 37-38; Kanz 2000;

McLaughlin 2002; Müller 1983). Second, its theoretical foundation as a general science of living beings, conventionally attributed jointly to Jean-Baptiste de Lamarck and Gottfried Reinhold Treviranus and dated to around 1802, resulting in the definition of a distinct branch of knowledge beyond the traditional tripartite division of the natural world and in the formulation of a unified programme for the study of phenomena and laws common to all forms of life (Barsanti 1997, pp. 357-366; Barsanti 2003, pp. 639-642; Dröscher 2008, pp. 38-40; Fantini 1988a, pp. 109-113; Klein 1954; Rey 1994). Third, its gradual institutionalisation from the final decades of the nineteenth century onwards, which became possible through the consolidation of a shared theoretical framework centred on cell theory, evolutionary theory, and theories of heredity, in a context of increasing specialisation across different areas of research that could thereby be brought together within a unitary perspective (Dröscher 2008, pp. 47-48; Kanz 2002; Kanz 2007; Kanz 2011).

The institutional establishment of biology, however, proceeded at very different rates and took different forms depending on the context. In England, the circle of scholars gathered around Thomas Henry Huxley played a decisive role in developing a new biological discipline grounded in the centrality of laboratory practice in training and in the conviction that the microscope constituted the privileged means of achieving accurate observation of nature, thus making mastery of associated techniques indispensable. During the 1870s and 1880s, biology acquired an increasingly prominent place through the establishment of dedicated chairs and the publication of specialised textbooks, while the term itself and the new pedagogical approach associated with it gained widespread currency, primarily through the education of trainee teachers (Desmond 2001, pp. 29-34; Gooday 1991, p. 334). The Italian case, by contrast, followed a different pattern. Within the post-unification system of higher education, the study of living organisms was distributed across a variety of educational institutions. Alongside the traditional Faculties of Medicine and Surgery, the Faculties of Physical, Mathematical and Natural Sciences offered programmes in Natural Sciences, primarily geared towards the training of secondary-school teachers, while professional schools in Pharmacy, Veterinary Medicine, and Agriculture provided additional pathways. Within this framework, biology did not emerge as an autonomous institutional field. Rather, between the late nineteenth and early twentieth centuries it came to be established as a common intellectual ground capable of encompassing both the natural and medical sciences together with their respective areas of application.

Significantly, this development coincided with the spread of new experimental approaches across the biological disciplines, including domains traditionally associated with observational and descriptive methodologies. Drawing on physiology's emphasis on experimentation and laboratory practice, a new generation of biologists came to see function replace form both as the objective of scientific investigation and as its principal explanatory framework, although this shift was not without its opponents (Fantini 1988b, pp. 99-101). In Italy, too, despite the absence of a specific institutional formulation, the fundamental change appears to have consisted in the systematic adoption of a new *modus operandi*, rooted in training centred on laboratory experience and mastery of microscopic techniques. The principle that future physicians and scientists should be educated not only through lectures but also, and above all, through practical exercises had already been enshrined in the first

university regulations to apply throughout the Peninsula, issued by the physicist Carlo Matteucci, then Minister of Public Instruction, in 1862 (Vezzani 2026, pp. 212-213, 344). In most cases, however, the laboratories and equipment needed to implement this principle were lacking (Simili 1998). Since the development of biology depended primarily on a transformation of the material conditions of teaching and research, the establishment of experimental spaces and the acquisition of scientific instruments are key to understanding both how this process unfolded and the chronology of its development.

The literature on scientific laboratories is characterised by the diversity of both the research questions posed and the methodological approaches employed. The present contribution rests on the premise that no single model can account for all times and places; rather, laboratories assumed distinctive configurations according to their geographical setting, historical period, disciplinary context and functions. Their study therefore calls for a situated approach, attentive to the specific socioeconomic conditions in which each facility operated (Galison 1999, p. 1; Gooday 2008, pp. 784-786; Kohler 2008, pp. 764-765). On this basis, the notion of a laboratory revolution – still used to describe the transformations that, in the second half of the nineteenth century, established the laboratory as the privileged site of research and training (van Berkel and Homburg 2025) – should be understood not as a uniform process, but as a plurality of trajectories to be reconstructed through the analysis of individual cases and their particular patterns of development. From this perspective, although the model of the German academic laboratory spread transnationally, its implementation remained far from universal. The ideal institution was conceived as a spacious, well-equipped and efficiently organised facility, where the work of large groups of students and researchers could be systematically coordinated. Most laboratories, however, remained housed in relatively small premises, not purpose-built for experimental work and equipped with only the instruments and personnel strictly necessary for their operation (Vanpaemel 2015; Vanpaemel 2025, pp. 319-320, 324).

A first line of inquiry therefore concerns the reorganisation of space, a subject of considerable interest to nineteenth-century scientists (Forgan 1989). Although laboratory practice has often been portrayed as a break with established ways of doing science, several scholars working on the English context have emphasised the enduring importance of museums throughout the nineteenth century as sites of both education and research, as well as their fundamental complementarity with emerging laboratories. In this respect, the transition that took place during the second half of the century has been characterised as gradual and multifaceted, involving a shift from an educational model based on museum collections and lectures to one centred on practical instruction and experimental work. This transition brought about a broader reconfiguration of the spaces devoted to the production and transmission of scientific knowledge, a process in which local factors played a decisive role (Desmond 2001, p. 14; Forgan 1994; Kraft and Alberti 2003). The parallel development of a discourse depicting laboratories as privileged sites for the study of nature was accompanied by the rhetorical construction of the scientific superiority of those who worked within them. The distinction between professionals and amateurs thus emerged as part of a redefinition of their respective roles within a scientific community that continued to depend on their collaboration, albeit recast within a hierarchical framework (Alberti 2001; Desmond 2001, pp. 14-15).

Drawing primarily on the United States, Robert E. Kohler has shown how this transformation led to the establishment of a conceptual polarity between fieldwork and laboratory investigation, giving rise to distinct spheres of activity that nevertheless remained characterised by frequent interaction and exchange (Kohler 2002a, pp. 189-194; Kohler 2002b, p. 3; Kohler 2012, p. 585). According to Kohler, the defining characteristic of laboratories lay in their *placelessness*: their apparent independence from the particularities of place lent the knowledge produced within them a claim to universal validity (Kohler 2002a, p. 191; Kohler 2002b, pp. 7-9; Kohler 2002c, pp. 473-474; Kohler 2008, pp. 766-767). This standardisation of experimental spaces, however, rested on a more fundamental premise: the scientific value of the laboratory depended on the assumption that the practices through which nature was investigated should be disciplined and standardised by adhering to precise procedures, so as to be controllable and repeatable. Put differently, the aim was to consolidate the conviction that, across different settings, it was possible to rely on a shared *modus operandi* which, notwithstanding differences in method, could serve as the foundation of scientific inquiry from the earliest stages of training (van Lunteren 2025, pp. 69-70, 73-74).

In biology, this process was reflected in the convention, established during the second half of the nineteenth century, that microscopic observation in the laboratory constituted the privileged means of analysing natural phenomena. Its growing prominence was fostered by continuous improvements in instrumentation, advances in fixation, microtomy and staining techniques for specimen preparation, and the spread of photomicrography (Bracegirdle 2003; Strasser 2004, pp. 753-755). At the same time, the diversification of microscopes to meet the needs of different users and working contexts extended their use across a range of educational and research settings. In this context, microscopes became central to scientific practice, serving as “the major experimental tribunal of expert opinion” (Gooday 1997, p. 421). The reliability of observations, however, depended not solely on the characteristics of the instrument, but also on the control of the material conditions under which they were conducted (p. 423). Microscopy therefore required the acquisition of specific skills and the mastery of specialised procedures, encompassing both technical proficiency in the use of scientific equipment and the ability to interpret the results obtained (Gooday 1991, p. 327).

More broadly, throughout the nineteenth century, the systematic use of scientific instruments in teaching played a decisive role in the transmission of knowledge and in the formation of the experimenter’s *savoir-faire*. Education in the sciences was not confined to theoretical learning but also required students to participate in practical activities and to engage in the sustained exercise they entailed (Brenni 1998, p. 427; Brenni 2012, pp. 191-195). Practical instruction took the form both of demonstration experiments, intended to illustrate the theories presented in lectures, and of experimental work carried out directly by students (Heering and Wittje 2012, p. 152). Over the course of the century, however, the pedagogical function of experimentation underwent a profound transformation. Whereas in the early nineteenth century experiments served primarily as demonstrations for students to observe, the following decades witnessed the spread within universities of spaces specifically designed for training in experimental practice (Morus 2023, p. 221; van Berkel and Homburg 2025, pp. 23-24). At the heart of this transformation was the development of the teaching-research laboratory, whose establishment marked

a turning point in science education (van Berkel and Homburg 2025, pp. 17-20). A substantial body of scholarship has identified Justus von Liebig as a key figure in understanding this transition, highlighting the decisive impact of his innovative approach to the training of chemists on the broader renewal of scientific instruction (Brock 1997; Brock 2003; Farrar 1979; Good 1936; Holmes 1989; Morrell 1972; Rocke 2003; Rocke 2021).

Appointed extraordinary professor of chemistry at the small University of Giessen in 1824 and promoted to a full professorship the following year, Liebig set about establishing a laboratory designed to integrate teaching and research. In his courses, lectures were confined to fundamental concepts, while practical work occupied a central place. Organised in successive stages, the programme guided students from the most elementary operations to the conduct of independent investigations, the results of which could be published in journals such as the *Annalen der Pharmacie*, founded by Liebig in 1832 and renamed *Annalen der Chemie und Pharmacie* in 1840. Beyond the systematic incorporation of experimental practice into student training and the intertwining of teaching and research, the Giessen system was distinguished by its capacity to coordinate the work of large numbers of investigators in the solution of problems that exceeded the capabilities of any single individual (Farrar 1979, pp. 221-224; Holmes 1989, pp. 131-132).

This model spread to other universities through networks of collaborators, pupils, and emulators. Its expansion followed a twofold trajectory, both geographical and disciplinary: on the one hand, this system of scientific organisation took root in other German cities and, more gradually, in other European countries; on the other, from the mid-nineteenth century onwards, it extended beyond chemistry to other disciplines (Farrar 1979, pp. 224-228; Rocke 2021, pp. 54-64). Liebig was not, however, the sole architect of this transformation, but rather the most prominent representative of a broader movement that helped shape and consolidate a laboratory culture without a single point of origin (Rocke 2021, pp. 47-54). The mythologisation of his figure went hand in hand with the actual dissemination of the Giessen system, helping to establish it as a paradigm. The Italian case, however, calls for specific consideration. The slower and more fragile process of industrialisation, together with the characteristics of the university system – marked by often poorly equipped experimental facilities, the more gradual introduction of practical instruction, and the predominance of general courses oriented towards the training of secondary-school teachers – contributed to shaping distinctive patterns and timelines of reception. Rather than presupposing a straightforward process of diffusion, it is therefore necessary to examine how the model was translated and adapted to local conditions.

Against this background, the article examines three closely interrelated aspects, each addressed in a separate section. It first explores the definition and boundaries of biology in Italy at the beginning of the twentieth century, focusing in particular on a volume published by Battista Grassi in 1911. This discussion is situated within a broader context in which the ideal of pure science acquired increasing prominence in the conceptual horizon of European and North American scientists. Several studies have traced the spread, during the second half of the nineteenth century, of this paradigm, grounded in the notion of science for its own sake, namely the claim to the autonomy of research from immediate

productive demands and to the priority of scientific discovery over practical application. At the same time, scholars have highlighted its ambivalent relationship with the emerging category of applied science within the broader debate concerning the relations between science, technology, and the economy (Bud 2012; Carnino 2015, pp. 126-129; Gooday 2012; Lucier 2012; Schatzberg 2012). The second and third sections, by contrast, take the development of zoology and botany at the Universities of Modena and Padua as case studies in order to examine both the gradual formation of experimental spaces in the wider reorganisation of scientific environments and the transformation of the pedagogical practices associated with them. The aim is to show, on the one hand, how the development of biological laboratories followed different trajectories and timelines according to specific material conditions and, on the other, how the most significant change lay in the progressive systematisation of a new model of practical instruction.

Defining Biology: Concepts and Boundaries in 1911

In 1911, Battista Grassi, Professor of Comparative Anatomy at the University of Rome and among the most prominent biologists of his generation, published *I progressi della biologia e delle sue applicazioni pratiche conseguiti in Italia nell'ultimo cinquantennio* (*The Progress of Biology and Its Practical Applications Achieved in Italy over the Last Fifty Years*). This contribution formed part of *Cinquanta anni di storia italiana* (*Fifty Years of Italian History*), a three-volume collection published under the auspices of the Accademia dei Lincei to mark the fiftieth anniversary of Italian unification. The project aimed to provide a comprehensive account of the socioeconomic transformations and scientific advances that had taken place over the preceding five decades. Far from being an isolated undertaking, Grassi's work was part of a broader proliferation of conferences and commemorative events that offered an important opportunity to reflect on what had been achieved and what remained to be done in the sciences. Particularly significant among these initiatives was the fifth meeting of the Società Italiana per il Progresso delle Scienze, held in Rome in October 1911, during which leading scholars from a wide range of disciplines were invited to review developments in their respective domains before the Italian scientific community and to outline future prospects (Reina et al. 1912, p. VI). While these conferences generally followed divisions that closely mirrored the academic organisation of science – maintaining, for example, separate reports on botany (Mattirolo 1912) and zoology (Camerano 1912) – Grassi adopted a considerably more ambitious approach.

By conceiving biology as a unified field of knowledge, the volume sought to provide an overarching perspective on a broad array of disciplines that, within the Italian system of higher education, were distributed across different faculties and schools (Grassi 1911). Even a cursory examination of the work reveals the remarkable breadth of the domain encompassed by Grassi. Alongside botany, zoology, and comparative anatomy, all taught within the Faculties of Physical, Mathematical and Natural Sciences and discussed in relation to fields more closely associated with the Higher Schools of Agriculture, he included a variety of subjects belonging to the Faculty of Medicine and Surgery, covering both experimental and clinical areas of study. The picture was completed by pharmacology and veterinary medicine, the defining disciplines of their respective university schools. Beyond these branches of

“theoretical and practical biology”, an entire section prepared by his assistant Anna Foà was dedicated to practical applications. While firmly upholding the principle that science ought to be pursued for its own sake, regardless of any immediate practical utility it might yield, this section highlighted the close relationship between biological knowledge, productive activities, and the extensive network of technical and vocational schools in which such knowledge was most intensively cultivated (p. 285).

At the beginning of the twentieth century, the concept of biology thus functioned as a common framework for a range of disciplines scattered across the Italian academic structure. A first, albeit tentative, form of institutional recognition had been achieved through the regulations of the Società Italiana per il Progresso delle Scienze. Following the classification established at the Society’s second meeting, held in Florence in October 1908 (Reina et al. 1909, p. VII), a class of Biological Sciences was created alongside those of Physical and Mathematical Sciences and Moral Sciences. In June 1909, in preparation for the subsequent meeting in Padua, the four sections composing this class were formally defined: Zoology, Anatomy and Anthropology; Botany and Applications; Physiology; and Pathology (Reina et al. 1910, p. XXXI). By exploiting the possibility of combining or subdividing these sections, subsequent meetings witnessed considerable variation in the organisation of biological activities, covering an exceptionally broad area that largely corresponded to the scheme proposed by Grassi.

However, his volume sought not merely to define the boundaries and internal divisions of biology, but also to identify the fundamental processes that had transformed the many disciplines it encompassed over the preceding half-century. These different fields converged around two closely interconnected elements, which he regarded as indispensable for understanding both the recent past and the contemporary state of biological studies. Starting from the premise that scientific production derived almost entirely from the universities (Grassi 1911, p. 72), he focused on the spaces and practices that had played a decisive role in this development. First, by describing the University of Pavia as “the sun of Italian biology during the last fifty years”, he attributed its pre-eminence to the development of histological research and microscopic technique (p. 54). More generally, emphasising the fundamental contribution of microscopy to the advancement of knowledge (p. 55), Grassi declared: “The new temple of the Italian biological sciences has been built with histological stones” (p. 65).

Closely connected with this first point was a second line of reflection, introduced through a comparison between the state of biological studies before 1860 and that of his own time. Whereas lectures had once been purely theoretical, courses were then almost everywhere illustrated by demonstrations; whereas “institutes in which young people could train in scientific research under the guidance of their teachers” had previously been exceptional, most chairs then possessed laboratories equipped with scientific instruments, libraries, and assistant, technical, and service staff (p. 73). The same transformation had taken place in research itself. Fifty years earlier, those engaged in experimental studies in Italy had been “a rare exception”; gradually, however, their numbers increased until approaches based on experimentation spread across every sector of biological inquiry, leading to the establishment of numerous laboratories. In summary, Grassi concluded: “That laboratory life which in 1860 was unknown in Italy is nowadays customary in our universities, hospitals”, and elsewhere (pp. 375-376).

Grassi's assessment of the progress of Italian biology was therefore broadly positive. Its development appeared all the more remarkable when measured against the scarcity of resources available to scientists and the considerable difficulties involved in securing even these limited means (p. 74). Such deficiencies became even more evident in comparison with other countries: "In Italy, scarcity in everything, indeed genuine poverty; in Germany and Austria, the greatest possible convenience for study […] Abroad, science is queen; with us, she is a servant" (p. 75). Italian institutes thus continued to suffer from a pronounced backwardness and remained clearly inferior to their northern European counterparts in terms of equipment and facilities. This inadequacy appeared particularly serious given that, since the 1870s, it had become possible to acquire a sound biological training only through "long years of study and practice in laboratories organised along modern lines". The analysis therefore culminated in an explicit criticism of the Italian political class, which had proved incapable of recognising that practical applications could arise only from substantial and systematic investment in scientific laboratories and, more broadly, in pure science itself (p. 380). Despite the remarkable advances that had been achieved, "the work of our biologists would evidently have been far more important had it received from the Government and from public opinion the support that it deserved" (p. 381).

As a Senator of the Kingdom of Italy, Grassi was particularly concerned with finding solutions to these problems. In his view, the path had already been indicated by Germany, the country that had contributed more than any other to the development of biology and that possessed the most advanced scientific infrastructure of the time (pp. 381-382). His programme aimed to secure "a better and stronger technical organisation of scientific studies" through a series of targeted measures directed at the various actors operating within the biological sciences and designed to intervene across education, research, and the dissemination of scientific knowledge (p. 389). These included introducing a new pedagogy centred on observation in schools, encouraging the active involvement of amateurs and collectors, improving the training of natural history teachers in secondary education, substantially strengthening laboratory provision, and increasing the number of researchers by redefining and diversifying career opportunities in a field still overwhelmingly centred on the university teaching profession. Finally, at the level of public opinion, scientific culture needed to be elevated above literary culture, affirming both the essential role of scientists in society and the primacy of science over other forms of human activity (pp. 389-398).

Many of the issues addressed by Grassi were neither specific to biology nor confined to the Italian context. Rather, they formed part of a debate that had already acquired a transnational dimension several decades earlier. The centrality of laboratories to the transformation of nineteenth-century science and the denunciation of their persistent material shortcomings had become established *topoi* of contemporary scientific discourse.

A scathing critique of the Italian university system, described as "a mere factory of intellectual pauperism", had already been advanced in 1889 by Tullio Martello, Professor of Political Economy at the University of Bologna (Martello 1889, p. 105). In his inaugural lecture for the academic year, entitled *La decadenza dell'università italiana* (*The Decline of the Italian University*) and clearly intended to provoke wide discussion, among the many accusations he levelled against the State was the charge that it left

“laboratories and cabinets in a miserable condition, so that Italian professors – deprived of the best and, too often, even of mediocre scientific instruments, today extremely powerful means of research and teaching – find themselves as if disarmed before their rivals at other European universities”, despite their “miracles of activity and study” (p. 57).

In 1868, seeking increased funding for his institute from the French Minister of Public Instruction, the chemist and biologist Louis Pasteur adopted a similar strategy through his brief but influential pamphlet *Le budget de la science* (*The Budget of Science*), in which he publicly denounced the deplorable condition of experimental facilities, arguing that such deficiencies prevented France from attaining scientific pre-eminence (Pasteur 1871, p. 13). Convinced that “laboratories and discoveries are correlative terms”, he maintained that such institutions had to be multiplied and adequately equipped with personnel, financial resources, and apparatus, since they constituted the “temples of the future, of wealth, and of well-being” (Pasteur 1868, pp. 3-4).

Equally significant was the anonymous article *The Laboratory in Modern Science*, published in the American journal *Science* in 1884. Built around the claim that experimental institutes constituted “the most remarkable and influential creation of science in our time” (Anon. 1884, p. 173), the text contrasted two images of scientific activity and its setting, one belonging to the past and the other to the present: “The material circumstances under which scientific discovery is prosecuted have been completely revolutionized during the last forty years […] Forty years ago there were very few, more properly no laboratories which we of to-day would consider even tolerable. Now every university of importance and high repute, the world over, has large suites of rooms for each department of science, and often numerous great buildings within whose walls thousands and thousands of students are daily brought face to face with the facts and laws of nature” (p. 172). The anonymous author encapsulated the argument in a striking formula: “To teach science, have a laboratory; to learn a science, go to a laboratory” (p. 174).

Taken together, these testimonies from different national and institutional contexts do more than highlight certain common themes. The persistent need for resources to address material deficiencies and the different temporal frameworks through which the spread of laboratories was represented also reveal important differences. Chronologically, the introduction of experimental practices into biology and other sciences during the second half of the nineteenth century was by no means a simultaneous process; rather, it unfolded at different rates across institutions and disciplines. At the same time, the growing centrality of the laboratory was associated in all these texts with an irreversible transformation of scientific work, affecting both the material circumstances of research and the very ways in which knowledge was produced and transmitted. Such a transformation, however, depended upon concrete conditions, including space, personnel, instruments, and financial resources. It is precisely this last factor that assumes particular significance in the Italian case. For a country that, in the immediate aftermath of unification in 1861, was still almost entirely devoid of experimental establishments, the availability of resources proved decisive in determining the particular forms assumed by biological laboratories at different universities. Against this background, the analysis focuses on two specific

academic settings, the Universities of Modena and Padua, examining the biological disciplines taught within their Faculties of Science. The next two sections explore the different configurations assumed by the experimental spaces devoted to botany and zoology, together with the practices that developed within them.

A Laboratory from Scratch? Experimental Spaces for Botany and Zoology

In the decades following Italian unification, the Faculties of Physical, Mathematical and Natural Sciences were confronted with the need to build, renovate, and equip lecture rooms and laboratories to provide students with specialised training grounded in both theoretical knowledge and practical skills. Within a system in which the ordinary annual grants provided by the Ministry of Public Instruction for the upkeep of scientific facilities remained consistently inadequate (Simili 1998), the development of such spaces relied primarily on two complementary factors. On the one hand, the expansion and improvement of scientific equipment was one of the main reasons behind the creation of university consortia, institutions that gradually emerged to support individual universities by bringing together municipalities, provinces, and other local entities in their recurrent financing (Vezzani 2026, pp. 162-164). On the other hand, the preferred means of constructing *ex novo* experimental institutes was through the negotiation of extraordinary agreements with the Ministry, which made it possible to mobilise substantial one-off financial resources, generally shared between the state and local authorities.

The ability to draw upon these funding channels, together with the strategies adopted to strengthen the material infrastructure of the faculties, gave rise to a variety of institutional configurations, characterised by differing numbers of assistants and technicians, unequal provision of space and equipment, and different rates in the creation and progressive specialisation of laboratories. The cases of Modena and Padua are particularly revealing, as they represent opposite poles within this process. In the Emilian city, the management of the limited resources provided by the Ministry and by the university consortium, established in 1877 on an exclusively municipal and provincial basis, imposed a strategy of gradual development that left little room for large-scale planning. Funds were allocated case by case to address the most pressing needs, allowing only partial renovation of facilities and the purchase of instruments strictly necessary for teaching and research, without bringing about any substantial qualitative leap in the scientific institutes. This situation fostered a persistent perception of inadequacy, accompanied by the conviction that local structures remained markedly inferior to those of other universities (pp. 254-258). In Padua, by contrast, the considerable resources mobilised at both local and national levels enabled the Faculty of Physical, Mathematical and Natural Sciences to benefit from renovated and extensively equipped premises designed around specific teaching and research requirements. Spaces devoted to practical and experimental work were progressively differentiated in line with the growing specialisation of scientific disciplines, producing an increasingly articulated institutional landscape. The first decades of the twentieth century constituted a particularly significant phase in the university's history, marked by the conclusion, in 1904 and 1913, of two major agreements for the improvement of facilities and by the establishment, in 1904, of a consortium that united all the provinces of the Veneto region in support of the university. These initiatives made it possible to provide almost every discipline

with purpose-built, state-of-the-art premises and to consolidate the position of the University of Padua as a centre of national and international prominence (pp. 262-270).

The picture outlined thus far must, however, be interpreted in light of a further consideration: biological laboratories did not emerge as entirely new institutions but developed within pre-existing environments, such as botanical gardens and zoological cabinets, which generally came to be known as “institutes” as their experimental component expanded. As parts of the same establishment, the museum section housing the collections, the library, and the spaces devoted to microscopy were conceived as interdependent, both in the training of students and in research activities. The laboratory was therefore not understood as a self-contained space distinct from other rooms; rather, it consisted of a range of environments differentiated according to the activities carried out within them and the individuals who used them.

This dynamic is clearly illustrated by the development of the Institute of Zoology, Comparative Anatomy and Physiology in Modena (pp. 307-308). Antonio Carruccio, who worked in the city between 1872 and 1883, played a leading role in the first systematic reorganisation of the collections of the Museum of Natural History and in their redistribution, in 1877, into separate geo-mineralogical and zoological cabinets, while also laying the foundations of the institute’s laboratory activities. To this end, he purchased a microscope and additional equipment for histological studies, supplementing the Nachet microscope already in use, and arranged a small room in which practical demonstrations could be combined with theoretical instruction and preparations made to illustrate the systems and organs of different animals. By the end of his tenure in Modena, in addition to the seven rooms devoted to zoological specimens and anatomical and microscopic preparations, he had secured dedicated accommodation for the director and the assistant, premises for taxidermy work and the attendant, as well as a space devoted to teaching, although the overall level of equipment remained limited (Carruccio 1872, pp. 5-16; Picaglia 1893, pp. 18-34, 64).

His successors continued along similar lines: they expanded the collections and library, reorganised the lecture room, acquired microscopes, microtomes, and other scientific instruments, and repeatedly modified the internal arrangement of the environments. Although the often cursory nature of the surviving descriptions makes it difficult to reconstruct the precise organisation and function of individual spaces, it was above all the museum section that grew in extent, reflecting the rapid accumulation of zoological specimens. It comprised twelve rooms in 1887 (Della Valle 1887, p. 28), sixteen by 1900 (Università di Modena 1900, p. 180), and even more after 1907, following the transfer of the chemistry laboratory from the university building (Cesari 1915, p. 20). On the laboratory side, by contrast, once dedicated premises had been secured for the director, assistant, taxidermist, carpenter-attendant, and student practical classes, attention appears to have focused less on enlarging the available space than on improving the conditions for research and teaching through the steady acquisition of scientific equipment. Special care was taken to ensure the availability of microscopes suited to the different tasks performed within the institute (Della Valle 1887, p. 28; Picaglia 1893, pp. 35-48, 64; Università di Modena 1900, p. 180).

A similar process of gradual expansion of both museum and laboratory can be observed in Padua, promoted above all by Giovanni Canestrini, professor of Zoology, Comparative Anatomy and Physiology from 1869 to 1899. An even more significant development, however, occurred when this logic of incremental growth within existing facilities was superseded. Thanks to the agreements concluded with the Ministry in 1904 and 1913, it became possible to construct a new zoological institute, completed in 1915 but inaugurated only after the end of the First World War (Vezzani 2026, pp. 314-315). In 1910 the holder of the chair, Davide Carazzi, published a short pamphlet outlining the plans for the new building in an effort to secure additional funding for its construction. The text provides valuable evidence of the ideal model to which a zoological establishment was expected to conform at the beginning of the twentieth century, while also revealing the new balance that was meant to govern the relationship between museum and laboratory. The expenditure was justified not only by the prospect of further advances in research but also by the substantial practical benefits that "the purely scientific study of biology" was expected to generate, especially in combating plant and animal diseases (Carazzi 1910, p. 11). Underlying this vision was the conviction that, over the preceding decades, the museum had gradually receded into the background, while the laboratory and library had acquired an increasing share of space and resources. The new institute was therefore to be conceived primarily around its experimental dimension (pp. 11-13).

According to Carazzi's plans, the building was to comprise a large lecture theatre, a smaller room for students' practical classes, a dissection room, quarters for the taxidermist-preparator and the illustrator, accommodation for the library and the anatomical and teaching collections, together with two large halls and a smaller room for the museum holdings. Laboratories were assigned to the professor, assistant, deputy assistant, and resident students, while provision was made for the eventual separation of zoology and comparative anatomy into distinct chairs, a carpentry workshop for the attendant, and a basement laboratory for experimental zoology, adjoining areas intended for the incubation and rearing of organisms for research purposes (pp. 13-16). Carazzi also set out precise figures for the allocation of floor space. In 1900, the institute's 857 m² were divided between 617 m² occupied by the museum and 240 m² devoted to laboratories. The new building, by contrast, was designed to cover 1,120 m², including a large lecture theatre of 99 m², a museum section of 560 m², and a laboratory section of 461 m² (pp. 4-5, 19-20). At the beginning of the twentieth century, the collections were intended to occupy the entire top floor of the building, while laboratories were placed at its centre. The arrangement reflected a broader conviction that the future of both research and education lay in experimental work.

A marked change in teaching and research practices was also evident in botany. When Pierandrea Saccardo became professor at Padua in 1877, it was customary to provide "brief and theoretical teaching" and to pursue "systematic studies of phanerogams", while "there was a small room with an old English microscope for the most elementary investigations, and no room whatsoever designed for laboratory work" (Università di Padova 1900, p. 46). In 1880 he therefore promptly converted a greenhouse into a laboratory facility, assigning one large room to assistants and resident students and another to practical exercises, while also purchasing the instruments required for microscopical studies (Béguinot 1916, pp. 12-13; Saccardo 1895, p. 4; Università di Padova 1900, pp. 46-47). In the 1915-1916

academic year, the first of Augusto Béguinot's professorship, three recently refurbished rooms were still in use: a small laboratory adjoining the director's office, one for assistants and resident students, and another for external students. The spatial organisation of the institute had therefore remained largely unchanged, whereas its equipment had become substantial and kept pace with contemporary teaching and research requirements (Béguinot 1916, pp. 24-25).

In Modena, the transformation of the botanical garden into a fully fledged botanical institute was due primarily to Antonio Mori, who held the chair between 1883 and 1901. In 1892, a modest subsidy from the Ministry made it possible to erect a new building which, in addition to expanding the collections and creating a lecture room specifically dedicated to botany, responded to the growing demand for experimental facilities for teaching and research by providing "a room for practical exercises, laboratory premises and study rooms" (Cesari 1915, p. 58). From 1902 onwards, Giovanni Battista De Toni continued the work begun by his predecessor, drawing on ministerial grants and the continuous support of the university consortium. Particular attention was devoted to repairing extensive damage to the greenhouses and buildings, introducing gas lighting, and equipping "the laboratory with various apparatus and means for physiological experiments intended for teaching" (De Toni 1906, pp. 10-12). The situation nevertheless remained critical. In 1915, the former rector Giuseppe Cesari openly criticised the Ministry's policies: "Since for several years, owing to the denial of government subsidies, nothing could be done to carry out the necessary repairs, the buildings of the Botanical Garden are now in such a condition as to jeopardise even the preservation of the material housed within them" (Cesari 1915, p. 58).

Beyond the differences arising from the unequal levels of funding that the botanical institutes of Modena and Padua were able to attract, the professors who directed them shared similar priorities. All devoted considerable effort both to expanding and enriching libraries and collections – through improvements to greenhouses and the growth of botanical garden and herbarium holdings – and to strengthening the scientific equipment required for microscopical investigations and the training they required (Vezzani 2026, pp. 309-311, 316). This plurality of interests was also reflected in the organisation of space. Rooms specifically designated as laboratories remained relatively small and, above all, the distinction between them and other areas continued to be blurred. The resulting institutional configuration was one in which the different functions remained closely integrated.

The Laboratory as a New Educational Paradigm

In the history of the natural sciences, the second half of the nineteenth century was marked by the gradual expansion of spaces devoted to experimental work. The growing need for premises capable of accommodating the activities of professors and assistants, as well as students' lengthy practical exercises, made it necessary to continually renegotiate the relationship between the two principal components of these establishments: the laboratory and the museum. The closing decades of the nineteenth century are particularly significant in the Italian context because, despite the considerable expansion and enrichment of both sections, the hierarchy between scientific collections and

experimental spaces gradually shifted, signalling a broader transformation in scientific work. In educational terms, students' training, which combined lectures with practical sessions, increasingly focused on the acquisition of skills associated with laboratory equipment, while the instructional role of collections was substantially reduced (Vezzani 2026, pp. 344-348).

It is no coincidence that all those who held chairs in Modena and Padua actively promoted the development of laboratory facilities, transforming establishments centred almost exclusively on collections into institutes with a clear experimental orientation. Antonio Carruccio provides an emblematic illustration of the two poles of this gradual transition. When he arrived in Modena in 1871, the Sardinian zoologist found "not even a trace of an anatomical laboratory, nor even the most indispensable instruments usually required for such purposes" and was therefore obliged to create the institute's first experimental environment himself (Carruccio 1872, pp. 14-16). At the same time, his efforts were directed towards ensuring that the collections were arranged according to a "scientific order fully respected in their distribution", thereby reaffirming the traditional function of the cabinet as a teaching space through the orderly display of specimens designed to reflect the natural order (p. 7).

The case of botany in Modena is even more revealing. In 1862, Ettore Celi, holder of the chair, published a *Guida al parterre-scuola dell'orto botanico della R. Università di Modena* (*Guide to the Teaching Parterre of the Royal University of Modena Botanical Garden*), in which he presented a new arrangement of plant species according to De Candolle's taxonomic method (Celi 1862; De Toni 1906, p. 7; Vezzani 2023, pp. 315-316). Reissued in 1871 within the second edition of his *Lezioni elementari di Botanica* (*Elementary Lessons in Botany*), the work took the form of a systematic catalogue of the specimens cultivated in the flowerbeds and central basin, recently remodelled "for the convenience of the students of this School" (Celi 1871, p. 479). The initiative embodied a specific educational project: transforming the botanical garden into a living classification system capable of guiding students towards a practical understanding of plant characteristics through a spatial organisation designed specifically for that purpose, placing direct observation in constant dialogue with theoretical instruction.

At the beginning of the new century, by contrast, the image selected in 1902 to commemorate Antonio Mori, one of the leading figures of the Faculty of Science in Modena, was that of the accomplished experimentalist. In the university calendar, his colleague Dante Pantanelli dwelt at length on Mori's "laboratory life", quoting a memorial written by his pupil Enrico Pantanelli and presented before the Società botanica italiana (Pantanelli D 1902, p. 379). Convinced that "scientific institutes" were "destined to provide scholars with the means to advance the glorious progress of the mother of civilisation", the younger Pantanelli portrayed Mori as an exemplary director, praising above all his role in establishing experimental facilities and his constant commitment to teaching. "He never missed a practical exercise and, seated among the students at their benches, offered explanations to all, encouraging everyone with his words and often with his own hands". He regarded the most devoted ones almost as sons, assisting them continuously in their work and becoming, through his advice, a "valuable auxiliary in the original investigations carried out in his laboratory"; a place that "he wished to remain open to anyone who might need it". "With rare generosity he allowed all who frequented it to make use of books and equipment as

they pleased, so long as the Institute's limited financial resources permitted". A constant source of frustration for Mori was "the scarcity of resources, made increasingly burdensome by the growing needs of advancing science; a constraint that prevented him from introducing those improvements and modifications that corresponded to his ideals", including a laboratory specifically dedicated to physiology which he had begun to establish. Equally indicative of the Tuscan botanist's educational approach was his commitment to continual verification and discussion: "He was particularly fond of repeating, for his own instruction and conviction, new observations and experiments conducted by others or by his students, and often shared the results with us, giving rise to discussions in which we younger men became accustomed to observing and judging with the same sense of precision" (Pantanelli E 1902, pp. 59-62; Vezzani 2023, pp. 318-319). Mori therefore did more than create a laboratory (De Toni 1906, pp. 8-10). He embodied a new pedagogical paradigm, transforming the institute into a vibrant environment of learning in which scientific knowledge was produced and continually reassessed through collaborative and dialogical practice.

A similar representation of the botanist as an eminent experimental scientist and the driving force behind laboratory life was proposed in 1925 by Achille Forti in his commemoration of Giovanni Battista De Toni, Mori's successor in Modena. "Precise and persuasive both in speech and in writing, he possessed a special ability to render accessible notions that students do not easily acquire. A skilled and reliable experimenter, he always maintained that the direct demonstration of a phenomenon or a fact was preferable to any verbal description." Accordingly, his "clear and orderly lecture [...] was followed by a series of demonstrations using the microscope or whatever other means were suggested by technique", accompanied by frequent commentary and answers to students' questions (Forti 1925, pp. 143-144).

In Padua, the implications of this transformation were explored at length by Davide Carazzi and Augusto Béguinot. In the pamphlet discussed above, written to secure additional funding for the new Institute of Zoology and Comparative Anatomy, the Veronese zoologist argued that the functions of such an establishment had changed radically from those of the recent past. "At that time the aim of teaching was simply historical. A professor needed only a lecture room and a collection of stuffed animals or specimens preserved in spirit in order to deliver a purely descriptive course. In a second phase, beginning in the Napoleonic era but becoming dominant only in the second half of the nineteenth century, the teaching of zoology", within the broader "renewal of human thought towards positive research", ceased to rely solely upon "the historical method" and became "demonstrative and observational". Thanks to "the refinement of that precious instrument of investigation, the microscope", laboratory facilities gradually emerged alongside "the collections crystallised within display cases and jars". "While the museum receded into the background (which certainly does not mean that collections are useless), the space and resources devoted to the laboratory and specialised library continued to expand, so as to meet the changed requirements of higher education and scientific research". Over the preceding two decades, zoology and comparative anatomy had acquired an increasingly experimental character, making larger facilities and more extensive equipment fundamental for introducing students to practical investigation, particularly in its applied forms (Carazzi 1910, pp. 11-13).

After succeeding Pierandrea Saccardo as professor of botany in 1915, Augusto Béguinot regularly reported on the state of the institute and the principal initiatives undertaken under his direction. In 1916, he stressed that the section of the botanical garden known as the “school” should continue to fulfil its role of “completing on site the knowledge imparted from the chair regarding the principal natural families”, while the areas devoted to medicinal and industrial plants, together with the experimental section founded by Béguinot himself and devoted chiefly to genetic research, were to be further expanded (Béguinot 1916, pp. 15-17). A botanical institute, however, was not simply a garden or a museum, “but also an active centre for investigating the intimate structures and functions of plants inaccessible to direct observation”. This required adequate provision for its two principal laboratories and a stronger experimental orientation in teaching. Such developments, however, were not intended to displace the garden’s original foundations. Rather, “the substantial patrimony of books and plants, both living and dried”, was to serve as “the old trunk onto which new branches must be grafted”, allowing the institution to flourish in both traditional and emerging fields, provided that increased government funding could sustain the effort (pp. 19-20). The importance Béguinot attached to laboratory work emerged again four years later when, in commemorating Saccardo, he summarised half a century of botanical research in a single observation: “To the botanist of fifty years ago, the field of cryptogamic studies must certainly have appeared as ground still scarcely cultivated and rich in discoveries, and the microscope as an instrument from which all possible advantages had not yet been extracted” (Béguinot 1920, p. 6).

Microscopy played a central role in the broader transformation of natural sciences cabinets into increasingly laboratory-oriented institutions, profoundly affecting research while also reshaping teaching methods. Carazzi himself published a *Manuale di tecnica microscopica* (*Manual of Microscopic Technique*) in 1899, seeking to provide guidance in a domain that was “almost entirely empirical and still very far from becoming [...] a science” (Carazzi 1899, p. V). It should nevertheless be emphasised that, despite the substantial evolution of subject matter, the overall organisation of botanical and zoological courses in Italian universities remained broadly the same, continuing to revolve around morphology and taxonomy, histology, and physiology. What changed fundamentally was the balance among these components. Alongside description and classification, the study of the structure and functioning of organisms gained increasing importance until it came to occupy a central position. It is no coincidence that, as experimental practices increasingly came to be shared across the natural and medical sciences, the concept of biology emerged as a common intellectual framework capable of encompassing them all (Vezzani 2026, p. 348).

Conclusion

The emergence of biology as a disciplinary field, the development of laboratories and the spread of microscopical practices were closely intertwined processes that, during the second half of the nineteenth century, helped redefine the production and transmission of biological knowledge. The analysis of scientific environments nevertheless shows that this transformation did not necessarily entail the replacement of pre-existing structures and functions. Museums continued to play a central role, serving as veritable morphological encyclopaedias whose collections were constantly enriched and

whose displays were frequently rearranged, not least in response to changing principles of classification. The multiplicity of teaching and research responsibilities assigned to biological institutes, combined with the scarcity of new buildings, instead encouraged the continuous reorganisation and reconfiguration of existing spaces, giving rise to what might be described as an architecture of reuse.

It was, however, in educational practices that the most significant transformation took place, unfolding along two complementary lines: the systematic integration of experimental work into *curricula* and the direct involvement of students in the use of scientific instruments. Technical mastery over apparatuses thus became an essential component of the educational process. The construction, expansion, and renovation of biological institutes during the second half of the nineteenth century should therefore be understood primarily as the consolidation of a new pedagogical paradigm centred on practical experience. Gradually, thanks to funding from the government and university consortia, spaces were structured to meet different instructional needs, with areas devoted to the replication of experiments presented in lectures, laboratories dedicated to practical exercises, and rooms reserved for the semi-autonomous work of advanced students.

Within this framework, the educational function of the scientific institutes constituted a fundamental element in both their legitimation and their expansion. Their capacity to train new generations of specialists and introduce them to original investigation constituted a central argument in public addresses and funding requests submitted to the Ministry of Public Instruction. The German laboratory model, presented as the emblem of an organisation capable of integrating teaching and research while linking the production of scientific knowledge to its potential applications, helped underpin these claims and build consensus for the strengthening of experimental facilities. The dissemination of this image did not, however, entail its uniform reproduction. Material conditions profoundly shaped the possibilities for reorganising Italian institutes. Although the emergence of a laboratory culture contributed to their renewal, the ability to provide a continuous progression from practical exercises to experimental inquiry and to coordinate the work of large groups of investigators depended closely on the resources available within individual faculties.

Carlo Ginzburg often described microhistory as a form of history observed through a microscope (Ginzburg 2012, pp. 114–115). The history of biology offers an opportunity to reverse this metaphor. A microhistorical approach to the development of microscopical studies across different Italian sites of knowledge production would make it possible to assess more precisely both broader patterns and local specificities (Jackson 2016, p. 304). Observing the microscope itself through the lens of microhistory may, in turn, help restore scientific education to a central place in the history of science and technology (Wittje 2023).

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