

The Physical Tourist

Physical Science in Barcelona

Antoni Roca-Rosell and Xavier Roqué*

We provide a tour of Barcelona, Catalonia, Spain, following four routes through the city and one elsewhere in the city and beyond, focusing on sites of importance in physics. Route 1 covers the Old Town, its Gothic Quarter, *Plaça del Rei*, *Plaça de Sant Jaume*, and Jewish Quarter. Route 2 identifies sites on and close to *La Rambla*, the main promenade in the city. Route 3 goes from the medieval shipyards to the Board of Commerce to Citadel Park. Route 4 concentrates on the Extension (*Eixample*) and covers the restored University, the Industrial University, and the new campus of the University of Barcelona. Elsewhere in the city and beyond are the Fabra Observatory; the *Plaça de les Glòries* with its large steel sculpture depicting the meridian arc from Dunkirk to Barcelona; *Montjuïc*, the site of the National Art Museum of Catalonia; and the National Museum of Science and Technology in Terrassa.

Key words: Ferran Alsina i Parallada; Albert Billeter; Ildefons Cerdà i Sunyer; Tomàs Cerdà; Antoni Cibat i Arnautó; Josep Comas i Solà; Albert Einstein; Eduard Fontserè i Riba; Bernat de Granollachs; Rafael Guastavino; Abraham bar Hiyya; Pierre Méchain; Narcís Monturiol i Estarriol; George Orwell; Santiago Ramón y Cajal; Francesc Salvà i Campillo; Francesc Santponç i Roca; Francesc Subiràs; Esteve Terradas i Illa; Jesús M. Tharrats; Tables of Barcelona; University of Barcelona; Industrial University; Autonomous University of Barcelona; Royal Academy of Sciences and Arts of Barcelona; Royal Military Academy of Mathematics; Royal Academy of Medicine; Catalan Academy of Humanities and Sciences; Catalan Society of Physics; Catalan Society of the History of Science and Technology; Catalan Science Archive Service; Catalan National Library; Maritime Museum; Fabra Observatory; International Exhibition of 1888; Universal Exhibition of 1929; history of physics and astronomy.

Barcelona

The informed physical tourist will book a window seat on the right-hand side of the airplane since in approaching the airport, flying southwest along the coast of

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Catalonia, Spain, the layout of Barcelona becomes apparent: the Olympic Village and Harbor on a stretch of land that once housed many of the city's factories and iron works; the old harbor and medieval shipyards at the end of the maze of streets making up the Old Town (*Ciutat Vella*); *La Rambla*, the long tree-lined promenade going up from the sea to the core of the city; and above all of them the square-like grid of the Extension (*Eixample*) that Ildefons Cerdà i Sunyer designed in 1859 on rationalist and hygienic principles and is now the most distinctive element in the city's configuration.*

Each of these urban features holds clues for physics and technology. The city's factories and workshops provided a fertile, contested ground for mechanical invention and entrepreneurship. *La Rambla* was the original site of Barcelona's university and remains the site of the enlightened Royal Academy of Sciences and Arts. Cerdà's Extension (*Eixample*), its dimensions dictated by a mathematical formula, became the home of the modern University of Barcelona and the new engineering schools. Shipyards and academies, parks and clocks, all bear witness to the uses and meanings of the physical sciences for the political, economic, and cultural center of Catalonia since medieval times. From astronomy to nuclear engineering, physics has left many, if not always apparent traces in the city's landscape.

We propose four routes that will take the physical tourist through the most significant of these sites, while a fifth section describes sites elsewhere in the city and beyond. We have organized these routes geographically rather than chronologically or thematically, even though in many instances a certain chronological coherence might be discernible. We do not provide a history of physics in Barcelona—an altogether different enterprise.¹

Route 1: Gothic Quarter, *Plaça del Rei*, *Plaça de Sant Jaume*, Jewish Quarter

Our tour begins in the Old City (*Ciutat Vella*, figure 1). The area around the Cathedral, begun in the late 13th century with a cloister dating to the middle of the 15th century and a façade completed in the late 19th century, is the carefully preserved and freely reconstructed environment that made the study of astronomy and natural philosophy possible in the city: "Today, despite centuries of attrition and destruction, Barcelona's *Barri Gòtic* [Gothic Quarter] still contains the most concentrated array of thirteenth- to fifteenth-century buildings in Spain and, not discounting even Venice, the most complete in Europe."² Close to each other are the major sites of political power in the city and beyond, after the count-kings of Barcelona settled here in the 10th century, through the creation of the *Corts Catalanes* (a legislative council) in the 13th century and the military and commercial expansion around the Mediterranean, until the demise of Catalan institutions after

* The names of institutions and streets are mostly given in Catalan, which is the language proper to Catalonia and, together with Spanish, also its official language.

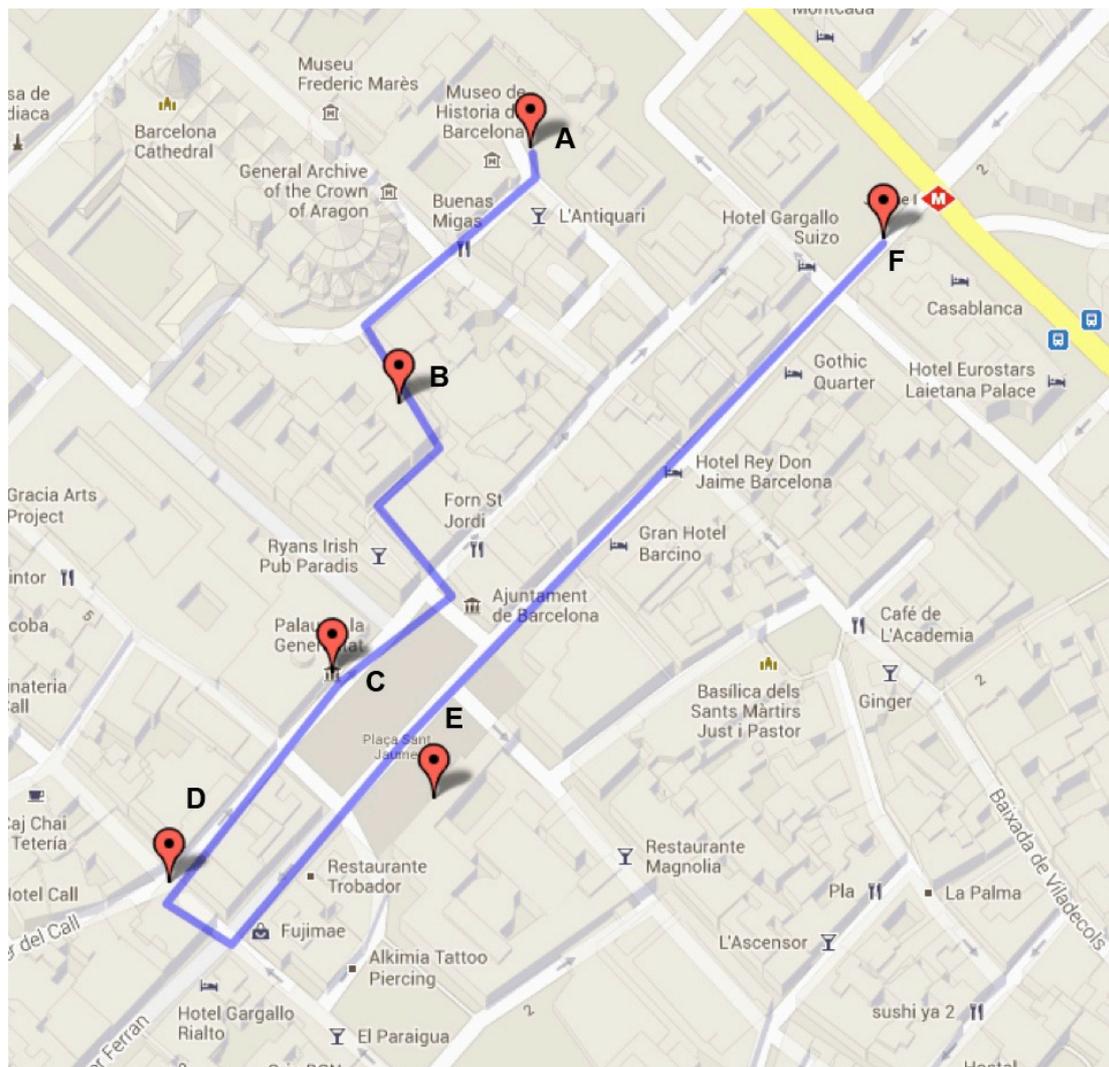


Fig. 1. Route 1 in the Old City begins at *Plaça del Rei* (King's Square, point A) and proceeds to the remnants of the Temple of Augustus (Catalan Alpine Club, *10 Paradís*, point B), the *Palau de la Generalitat* and the City Hall (*Plaça de Sant Jaume*, points C and E), the Jewish Quarter or *Call* (point D) and *Plaça de l'Àngel* (Angel Square, point F). Map data: 2013 Google, Institut Cartogràfic de Catalunya, based on BCN IGN Spain.

backing the losing Augsburg side in the War of the Spanish Succession at the beginning of the 18th century.

The medieval city was erected where Barcelona had begun its existence around the turn of the first millennium, as a Roman settlement by the name of *Barcino*, “quite a small town, constructed in the standard form of the *oppidum*, or ‘fortified camp’, thrown up by Roman legions on the march.”³ The highest point in the Roman camp is now marked by a plaque on the building of the Catalan Alpine Club (*Centre Excursionista de Catalunya*) at *10 Paradís*, tucked away behind the *Palau de la Generalitat*. The extant columns of the Temple of Augustus still sit in the courtyard of the building, restored early in the 20th century.

Our starting point is the *Plaça del Rei* (King's Square). The Catalan dynasty began with the counts of Barcelona in the late 10th century and was consolidated in 1137 through the marriage of Ramon Berenguer IV (1113-1162), Count of Barcelona, to the infant Petronila of Aragon (1136-1173), giving rise to the Crown of Aragon and Catalonia. The complex of buildings around the square comprises the former *Palau Reial Major* (Major Royal Palace), two of whose major features, the *Saló del Tinell* (Tinell Hall) and the *Capella de Santa Àgueda* (Chapel of Saint Àgueda), can be visited as part of the Museum of the History of Barcelona (*Museu d'Història de Barcelona*, MUHBA), which was built on remnants of the Roman city. Part of its structure, including mosaics and sections of the Roman walls, are visible in the basement. The MUHBA also displays the massive clock built in 1576 for the Cathedral, the mechanical device that marked the city's time for nearly three hundred years and which since 1985 is in the Chapel of Saint Àgueda. In 1865 it was replaced by a mechanical clock built by the Swiss Albert Billeter (1815–1895), who since 1850 had been making and selling astronomical clocks, electric telegraphs, and scientific instruments from his workshop in Gràcia, then an independent borough north of the city. According to its Latin inscription, the Cathedral clock was meant to be the first electrically regulated clock in the country (“*primum cum semi electrico regulatore in Hispania*”), but failed to live up to this expectation.

Opposite to the *Palau Reial Major* is the late Gothic-Renaissance Palace of the Viceroy (*Palau del Lloctinent*) at *2 Carrer dels Comtes*, which was built between 1549 and 1557. The building housed the Archive of the Crown of Aragon (*Arxiu de la Corona d'Aragó*), originally the Royal Archive of Barcelona. In 1994 its collections were moved to a modern purpose-built archive at *77 Almogàvers*. The archive is a uniquely complete source on medieval and Renaissance science and medicine. Wills, auction lists, and death inventories tell us about the production, ownership, and circulation of scientific and medical books in the Catalan court, where astronomy and astrology were esteemed in relation to medicine, agriculture, calendar-making, and natural philosophy.⁴

During the reigns of Jaume II (1267-1327) and in particular Pere III, the Cerimonious (1319-1387) from 1291–1327 and 1336–1387, respectively, astronomers were hired to compile astronomical tables bearing the latitude and longitude of the city. The best known of them are the *Tables of Barcelona* (*Taules de Barcelona*) of 1361–1381, begun by the King's astronomers and completed by Jacob ben Abi Abraham Isaac al-Corsuno (f. 1381), and the *Tables* (*Taules*) of 1361 compiled by Jacob ben David Bonjorn (b. 1333?).⁵ Extant manuscripts in Catalan, Hebrew, Latin, and Greek testify to cultural diversity and exchange, and to the importance of Jewish scholars fluent in Arabic.⁶ While both sets of astronomical tables were related to Jewish scholars, they stemmed from different astronomical traditions: al-Corsuno's *Tables of Barcelona* were of Indian origin, while Bonjorn's *Tables* were based on the work of Jewish mathematician and astronomer Levi ben Gershom (1288-1344), active in Orange in Provence in southeastern France. Another important member of

the Jewish community in Barcelona was the rabbi Abraham bar Hiyya (1070–1136 or 1145), known as Savasorda, a polymath interested in astronomy and natural philosophy who published a version of al-Battani's astronomical tables.⁷ The Jewish Quarter (*Call*) of Barcelona occupied the narrow streets around the *Palau de la Generalitat*; the major synagogue probably stood at *5 Marlet*, off *Carrer del Call*.

At the *Plaça Sant Jaume*, the *Palau de la Generalitat* and the City Council (*Casa de la Ciutat*) face each other. The *Palau de la Generalitat*, on the northwestern side of the square, became at the beginning of the 15th century the residence of the president of the *Generalitat*, the representative government of Catalonia, based on a written Bill of Rights (*Usatges*) that “acquired full form in the early twelfth century, nearly a hundred years before England had its Magna Carta.”⁸ The building has been copiously extended and refurbished (the Renaissance façade, for instance, dates from the late 16th century), and had several different uses until the definite restoration of the *Generalitat* following General Francisco Franco's death in 1975. In 1923 Albert Einstein (figure 2) gave three lectures on relativity in the Main Hall of the building during his visit to the city,⁹ because this was at the time the site of the Catalan Academy of Humanities and Sciences (Route 2) and the Provincial Council of Barcelona (*Diputació de Barcelona*).

Opposite to the *Palau de la Generalitat*, on the southeastern side of the square, is the City Council (*Casa de la Ciutat*). The Council of the One Hundred (*Consell de Cent*), a resilient elected body of representatives that governed the city for some 450 years, met in the *Saló de Cent*, a Gothic hall behind the Renaissance façade of the building (the original Gothic façade is to the left-hand side of the building at *Carrer de la Ciutat*). The *Saló de Cent*, like the stock exchange (*La Llotja*, Route 3), was designed by Pere Llobet in the 14th century at the height of Catalan medieval power. One of the members of the Council, Bernat de Granollachs (d. 1487?), the third Councilor of the city (in 1455–1458 and 1471–1474?) and a member of the faculty of the University of Barcelona, wrote a successful *Lunari*, the most widely diffused printed book on astronomy or related disciplines published in Spain before 1500. Granollachs's *Lunari* went through 90 editions until 1550, in Catalonia, Spain, France, and Italy, 42 of them in 1485–1500. According to historians José Chabás and one of the authors (AR-R), the

Lunari turned out to be a very popular book. In the various lists given by Sarton (1938) in his analysis of scientific incunabula, Granollachs's work is remarkably highly ranked. It is found, for instance, in 10th place among the best-sellers of scientific incunabula.¹⁰

Granollachs calculated his list of the syzygies (conjunctions and oppositions of Sun and Moon) from Bonjorn's *Tables*, referred to above.



Figure 2. Reception for Albert Einstein and his wife Elsa in the City Hall of Barcelona, February 27, 1923. Besides the Einsteins, we have only been able to identify, to Einstein's left, the interim mayor of the city, Enric Maynés; the president of the Royal Academy of Sciences and Arts, Eduard Alcobé; and the German consul in Barcelona, Ulrich von Hassell. *Credit:* Josep Brangulí, Arxiu Nacional de Catalunya (ANC1-42-N-9534).

Granollachs's *Lunari* was among the first incunabula in the city, where printers were active since 1473. These included Joan Gherlinch (f. 1489), Joan Rosembach (d. 1520), and above all Pere Posa (d. 1506), who printed Francesc de Santcliment's *Summa de la art de arismètica* of 1482, which was the first mercantile arithmetic printed in Spain, and likely the second one in Europe. Ramon Llull's *Arbor Scientiae* and his pseudo-Albertian treatise *Physica pauperum* of 1482 were among other works of natural-philosophical interest.¹¹ The Cathedral Quarter also was home to artisans and workers who contributed to the spread of the mechanical philosophy, including spectacle makers (*ullerers*), documented in the city since the end of the 14th century. By the end of the 16th century the Roget family (Joan and Pere) was making *ulleres de llarga vista*, deemed by some as among the earliest, independently invented refracting telescopes.¹² The Venetian Girolamo Sirturo (fl .1618), who appears to have examined the Rogets' lenses in 1609–1610, praised them as “the most exact built by anyone” in his early treatise, *Telescopium*.¹³ The Rogets' Barcelona workshop (one of the brothers ran another one in Girona, 80 kilometers north) was in the *Plaça del Blat*, now *Plaça de l'Àngel*, close to our starting point on this route.

Route 2: *Rambla dels Estudis* to *Biblioteca de Catalunya*

Our second route starts from *Plaça Catalunya*, a key transport node at the confluence of the Extension (*Eixample*) and the Old City, at the northwestern end of *La Rambla*, Barcelona's busy promenade (figure 3). Its upper section is known as *Rambla dels Estudis* after the University of Barcelona (*Estudi General de Barcelona*), established in 1450 by King Alfonso the Magnanimous (1396-1458) after repeated attempts since the end of the 13th century, which were successfully circumscribed by the *Consell de Cent*, who ran its own medical schools and bestowed its own titles. The *Estudi General de Barcelona* was the third such institution of higher learning in the Crown of Catalonia and Aragon, after those of Lleida (1301) and Girona (1446/1450). The first university building was erected in 1532, close to the *Portal de Santa Anna*. One of its prominent faculty members in the 16th century was Antic Roca (1530?–1584?), Professor of Language, Arts, Philosophy, and Arithmetic and author of an Aristotelian treatise and a remarkable arithmetical text of 1564.¹⁴ Along with the other Catalan universities, the University of Barcelona was closed in 1714 as a consequence of the War of the Spanish Succession. The new King Philip V of Bourbon (1683-1746) granted a university to Cervera, a small town some 80 kilometers west of Barcelona. When the University of Barcelona was restored more than a century later, it was located in different quarters until the building at *Plaça Universitat* (Route 4) was inaugurated in 1872.

At 115 *La Rambla* we find the Royal Academy of Sciences and Arts of Barcelona (*Reial Acadèmia de Ciències i Arts de Barcelona*, RACAB, figure 4), whose distinctive façade clock began marking Barcelona's official time in 1891. The Academy received its royal charter in 1767, but its groundwork had been laid in 1764 by the Experimental Physical and Mathematical Conference (*Conferència Físico-*

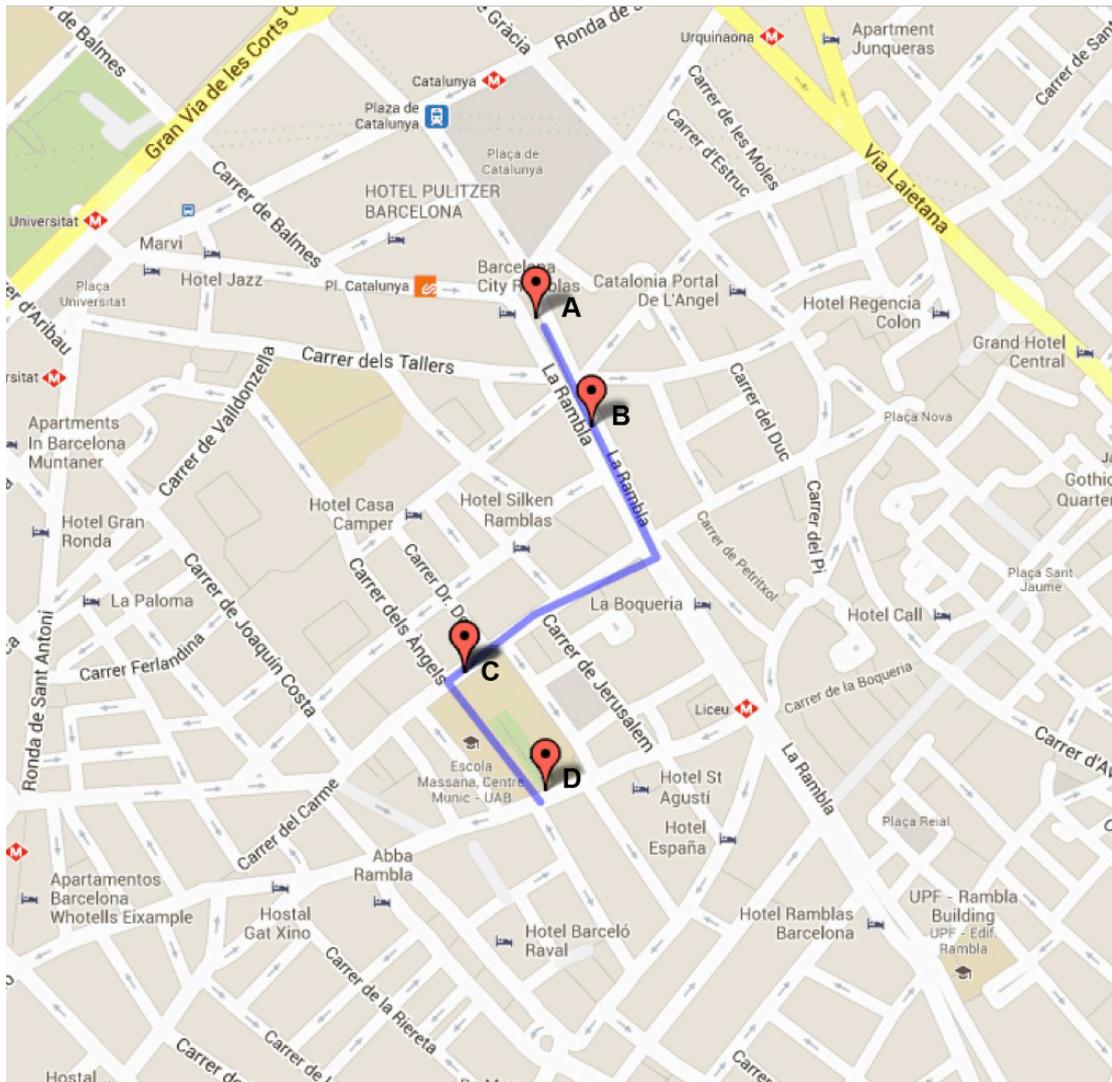


Fig. 3. Route 2 begins at *Plaça Catalunya* (point A) and proceeds to the Royal Academy of Sciences and Arts of Barcelona (*Reial Acadèmia de Ciències i Arts de Barcelona*, RACAB, 115 *La Rambla*, point B), the Catalan Academy of Humanities and Sciences (*Institut d'Estudis Catalans*, IEC, point C), and the Catalan National Library (*Biblioteca Nacional de Catalunya*, point D). Map data: 2013 Google, based on BCN IGN Spain.

Matemàtica Experimental) founded by a group of sixteen citizens, half of whom were physicians or apothecaries. In 1786 the Royal Academy received from King Charles III (1716-1788) a building belonging to the former Cordelles College (*Col·legi de Cordelles*), a Jesuit school for the nobility created in 1538. Mathematician and natural philosopher Tomàs Cerdà (1715–1791) taught at Cordelles, wrote a textbook on mathematics (figure 5), and managed to create a Public Chair of Mathematics associated with the college. His disciples were influential in the creation of the RACAB.

The Royal Academy building was thoroughly restored between 1883 and 1893, with the addition of twin astronomical and meteorological observatories. The theater

on the ground floor, the *Poliorama*, was inaugurated in 1912. The English novelist and journalist George Orwell (1903-1950) stood guard on the roof of the Royal



Fig. 4. The Royal Academy of Sciences and Arts of Barcelona at 115 *La Rambla*. *Credit:* Photograph by the authors.

Academy (which he took for a museum) in May 1937, when communist and anarchist factions fought each other on *La Rambla*:

[There] was a cinematograph, called the Poliorama, with a museum above it, and at the top, high above the general level of the roofs, a small observatory with twin domes....

They had already placed guards in the observatory. The next three days and nights I spent continuously on the roof of the Poliorama....

I used to sit on the roof marvelling at the folly of it all. From the little windows in the observatory you could see for miles around--vista after vista of tall slender buildings, glass domes, and fantastic curly roofs with brilliant

green and copper tiles; over to eastward the glittering pale blue sea--the first glimpse of the sea that I had had since coming to Spain.¹⁵

Today's visitor would see a similar view.

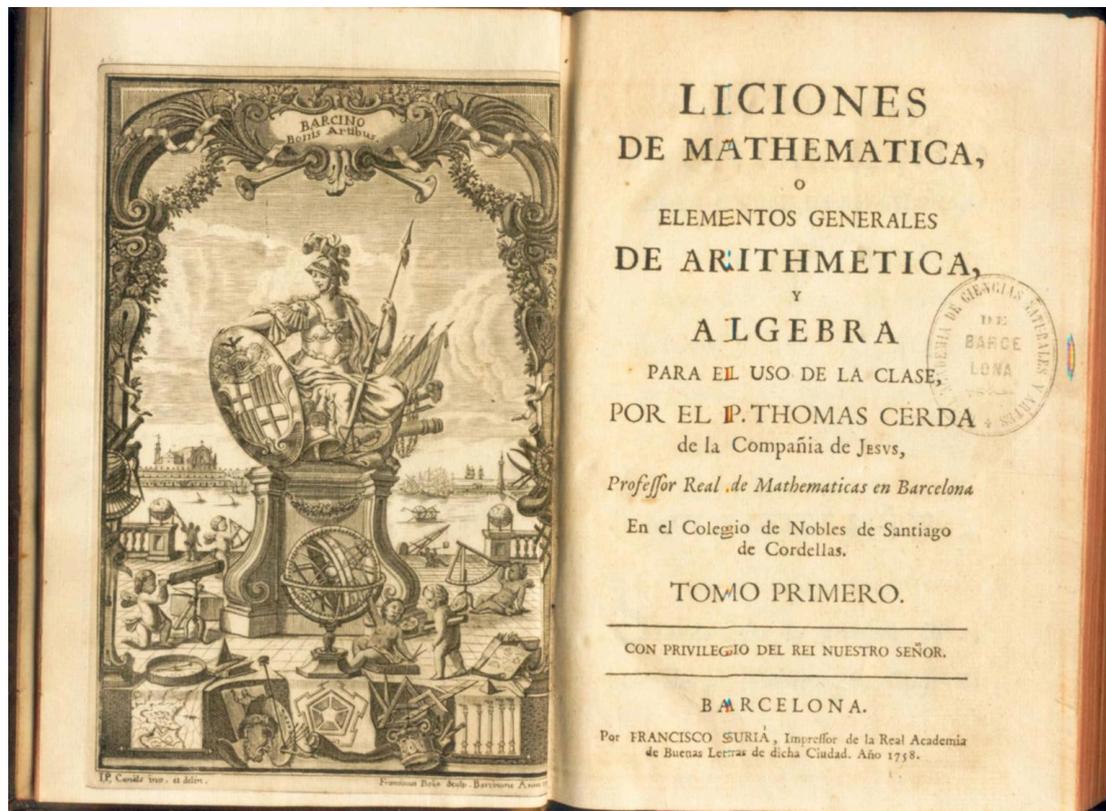


Fig. 6. Title page of Tomàs Cerdà's textbook, *Liciones de Mathematica* of 1758. *Credit:* Library of the Royal Academy of Sciences and Arts of Barcelona.

The RACAB stemmed from the enlightened intellectual and practical ambitions of the local nobility, bourgeoisie, professional classes, and artisans. In the absence of the university and a capital court, the Royal Academy controlled the introduction of experimental science and promoted a scientific culture linked to the industrial and commercial needs of the city.¹⁶ Newtonian and experimental physics became a symbol of modernity and regeneration in higher learning. In his inaugural discourse of the *Conferencia*, mathematician Francesc Subiràs (d. 1783), a disciple of Cerdà, blamed the sad state of the nation on the neglect of physics.

This peninsula alone, far from imitating the rest of Europe, looks as if it were in distant lands, where the news of true Physics have not yet reached....

And what is the cause of our delay, but the ignorance and the neglect of Physics, the source of the Arts and the Natural Sciences, which make all nations rich and happy.¹⁷

Half of the RACAB's departments were devoted to the physical sciences, including Statics, Hydrostatics, and Meteorology; Electricity, Magnetism and Other Attractions; Optics; and Pneumatics and Acoustics. After 1767 the RACAB was able to resume the mathematics course that Tomàs Cerdà had created, which included a number of subjects in physics deemed to belong to mathematics.

By 1800 the RACAB had 85 members, including the noted chemists Francesc Carbonell i Bravo (1758–1837) and Antoni Martí i Franquès (1750–1832) and the natural philosophers and experimental physicists Francesc Salvà i Campillo (1751–1828) and Francesc Santponç i Roca (1756–1821). Salvà was a keen engineer and inventor, best known for his work on electricity. In 1799 he demonstrated an electrical telegraph before the Spanish kings, and in 1804 he published a memoir describing a telegraphic device based on a Voltaic pile and a system of wires, each wire capable of encoding two signals through a change of polarity. The signal was detected through electrolysis in water—a similar device, more widely recognized, would be described five years later by the German physician Samuel Thomas von Sömmering (1755–1830).¹⁸ Santponç, who had collaborated with Salvà in the construction of a new machine for dressing hemp and flax, designed a steam engine for the calico printing factory of industrialist Jacint Ramon (f. 1804). Built in 1806 by skilled local artisans to Santponç's specifications, it was a double-acting steam engine based on the design of Agustín de Betancourt (1758–1824), as described in Gaspard de Prony's *Nouvelle Architecture Hydraulique* of 1790. This was the first double-acting steam engine installed in Spain, which was described by Santponç in his manuscript memoir, *Notes on a New Fire Pump*.¹⁹

Machines and instruments were conveniently seen by academics as byproducts of mathematical and experimental physics.

The construction of mills, lathes, looms, clocks, etc., optical glasses, astronomical and hydrostatic instruments, and all the other machines used by artisans, what are they but works regulated by the laws of mathematical and experimental physics?²⁰

Local artisans and instrument makers built up the Royal Academy's Cabinet of Machines and Instruments. In 1770 "artist academics" were admitted, beginning with Joan González i Figueres (1731–1807), elected in 1776, whose file bears witness to his inventiveness: Among other artifacts, he constructed delicate, detachable models of the eye, ear, and heart; solar and ocular microscopes; and electrical and pneumatic machines. Instrument makers sought to advance socially and professionally by becoming members of the Royal Academy, much as London's instrument makers sought to become members of the Royal Observatory, the Board of Longitude, or the Royal Society.²¹

In the last decades of the 19th century, the Royal Academy led attempts to unify time in the city. Since 1886 it had run a Time Service in conjunction with Josep Ricart i Giralt (1847–1930), a member of the Royal Academy who ran a chronometer shop for the time service of ships. In 1891 the RACAB created the Barcelona Official

Time Service (*Servei de l'Hora Oficial*), displayed by its façade clock. The young physicist Eduard Fontserè (1870–1970), later to become professor at the University of Barcelona and director of the Catalan Meteorological Service, was appointed to the observatories of the Royal Academy, the local time being determined by astronomical observations.

The RACAB holdings include the astronomical clock (Route 1) that the Swiss clockmaker Albert Billeter built for the Spanish Senate, in Madrid, from 1859 to 1869 (figure 6). The astronomical clock shows the Sun, Earth, and Moon, and their relative positions through the seasons; a calendar, including the time equation (which describes the discrepancy between the apparent and mean solar time), the time of sunrise and sunset, and the local time in twenty cities in the world. The clock was not delivered to Madrid and failed to sell at the International Exhibition in Barcelona in 1888 (Route 3). It was eventually acquired by the RACAB, where it is now exhibited, in perfect working order, along with other noted precision clocks and chronometers. Also exhibited is a special astrolabe of unknown provenance, a *Saphaea* (*azafea*) designed by the 11th-century astronomer Azarquiel (al-Zarqālī) from Toledo.²² Only four instruments of this kind are preserved in the world.

The RACAB also has been home to disciplinary scientific societies promoted by its members, such as the Spanish Society for the Protection of the Sciences (*Sociedad Española Protectora de las Ciencias*) from 1893 to 1902, which promoted the physical sciences and in 1896 first demonstrated X rays in the city, and the Astronomical Society of Barcelona (*Sociedad Astronómica de Barcelona*) from 1910 to 1921, which helped bridge expert and lay knowledge in astronomy.²³

Going down *La Rambla*, we turn right (southwest) at *Carrer del Carme* (a detour to the left through *carrer de la Portaferrissa* would take us to the birthplace and home of the physician and telegraphy pioneer Francesco Salvà i Campillo (1751–1828) at *11 Petritxol*). At *47 Carrer del Carme* a passage leads to a courtyard with a complex of buildings dating to the early 15th century, originally belonging to the Holy Cross Hospital (*Hospital de la Santa Creu*). Established in 1401 by the city's civil and ecclesiastical bodies, the hospital remained Barcelona's most important medical site until the early 20th century. With the building of the new *Hospital de la Santa Creu i Sant Pau*, a magnificent work by noted modernist architect Lluís Domènech i Montaner (1850–1923),* close to Antoni Gaudí's incomparable *Sagrada Família*, the old buildings were given new uses, some of which have played important roles in the physical sciences.

Thus, to the left as we enter the courtyard is the neoclassical building that housed the former Royal Military College of Surgery (*Col·legi de Cirurgia*), established 1761, and since 1929 has housed the Royal Academy of Medicine (*Reial Acadèmia de Medicina*), established in 1770. Its most distinctive feature is its anatomical

* Domènech i Montaner studied physics and mathematics at the University of Barcelona before embarking on his architectural career.

theater. After the restoration of the University of Barcelona in 1843 and until 1906 the building housed the Faculty of Medicine. Santiago Ramón y Cajal (1852–1934), who shared the Nobel Prize in Physiology or Medicine for 1906 with Camillo Golgi (1843–1926) for their work on the structure the nervous system, lectured here. In 1795 the College of Surgery created a chair of experimental ohysics, the first chair of physics in the city. The physician Antoni Cibat i Arnautó (1770–1812), a former student at the College who completed his training in London, occupied the chair of physics until its suppression in 1806, publishing his lectures as *Elementos de Física Experimental* in 1804. One of his disciples, Pere Vieta i Gibert (1780–1856), occupied the chair of physics at the new School of Experimental Physics (*Escola de Física Experimental*) created by the Board of Commerce in 1814 (Route 3).



Fig. 6. The astronomical clock in the Royal Academy of Sciences and Arts of Barcelona built by the Swiss clockmaker Albert Billeter. *Credit:* Royal Academy of Sciences and Arts of Barcelona.

The College of Surgery faces the former Convalescence House (*Casa de Convalescència*) of the *Hospital de la Santa Creu*, which is now the main site of the Catalan Academy of Humanities and Sciences (*Institut d'Estudis Catalans*, IEC). Built between 1629 and 1680 for the recovery of hospital patients, the Convalescence House has fine architectural features, such as the use of ceramic tiles throughout its rooms and in the main entrance (with murals devoted to Saint Paul), and the light, two-story courtyard with a central sculpture of Saint Paul. The IEC was created in 1907 by the Provincial Council of Barcelona (*Diputació de Barcelona*) as political Catalanism sought to promote higher education and research. Originally located in the *Palau de la Generalitat*, with the advent of the Republic in 1931 the IEC was granted the use of the Convalescence House and moved partially into the new quarters in 1932. After the Civil War, the building was seized by the new Francoist authority and the institution dismantled. Engaged in clandestine activities since 1942, the IEC was tolerated by the Franco regime until the late 1950s partly because it posed no threat nor was it deemed to have any academic or indeed political value.²⁴

Since 1911 the Science Section of the IEC promoted physics from its non-university environment.²⁵ Among its members and keenest promoters of physics in the city in the early decades of the 20th century was the physicist, mathematician, and engineer Esteve Terradas i Illa (1883–1950). His personal archive, which is deposited in the IEC, throws much light on the development of physics beyond the university, and on its connections to other sciences. Terradas was also active in civil engineering. In 1916 he supervised the Telephone Service of the Catalan regional government (*Mancomunitat*), which sought to extend the telephone network over the entire territory. In 1923–1926 he directed the extension of the underground train system from *Plaça Catalunya* to *La Bordeta* (at present integrated into Line 1), linking the center of Barcelona with *Montjuïc*, where the Universal Exhibition of 1929 was held. In the late 1920s Terradas also became director of the Spanish telephone company.²⁶

The IEC is home to the Catalan Society of Physics (*Societat Catalana de Física*), which today has 400 members. Established in 1986, the Society is the successor of the Catalan Society for the Physical, Chemical, and Mathematical Sciences (*Societat Catalana de Ciències Físiques, Químiques i Matemàtiques*), which was founded in 1932 by the physicist Eduard Fontserè i Riba (1870–1970), the chemist and pedagogue Josep Estalella i Graells (1879–1938), who eventually would direct the *Institut Escola* of the *Generalitat* (Route 3), and the chemical engineer Ramon Peypoch (1898–1984), who had founded and edited the journal *Ciència, revista catalana de ciència i tecnologia* from 1926 to 1933. The IEC is also home to the Catalan Society for the History of Science and Technology (*Societat Catalana d'Història de la Ciència i de la Tècnica*), which was established in 1991 and today is an active learned society with 300 members, a disproportionately large number. Beyond research in the history of physics, the Society and the IEC also support the Catalan Science Archive Service (*Servei d'Arxius de Ciència*, <http://www.sac.cat>),

which seeks to preserve, study, and make known the documentary heritage of science, technology, and medicine in Catalan-speaking territories.

As we leave the IEC, we enter through an arch on our right the courtyard of the former Hospital *de la Santa Creu*. In 1921 its building was acquired by the City Council and in 1931 it became the site of the Catalan Library (*Biblioteca de Catalunya*), which was created in 1907 as the library of the IEC. After the Civil War, as Catalan institutions were suppressed by Franco, it was renamed the Central Library (*Biblioteca Central*). In 1981, when Catalan political autonomy had partly devolved, it became the Catalan National Library (*Biblioteca Nacional de Catalunya*). The building was thoroughly restored in the 1990s; its main reading room now occupies the vaulted Gothic halls of the original hospital. The library is rich in medieval astronomical manuscripts, and holds most of the books produced in the workshop of the *incunabula* printer Pere Posa (Route 1). The library's holdings are also relevant for the historian of contemporary physics, as they include complete runs of several newspapers and journals, as well as the private library of Esteve Terradas and part of his personal archive. In the mid-1950s, in conjunction with the University of Barcelona and the city's industrial schools, the library created a dedicated section on Atomic and Nuclear Physics and acquired several thousand index cards from the U.S. Atomic Energy Commission. The resulting Library of Nuclear Physics (*Biblioteca de Física Nuclear*) was coordinated by Jesús M. Tharrats (1923–2001), Professor of Theoretical Physics at the University of Barcelona.²⁷

Route 3: From the Medieval Shipyards through the Board of Commerce to Citadel Park

At the southeastern end of *La Rambla* (figure 7) we find the old medieval shipyards (*Drassanes*), probably the largest and best preserved ones of its kind in the world. Recently restored, they are a magnificent example of Gothic civil architecture. The former shipyards house the Maritime Museum, which includes an actual-size replica of the flagship vessel of the Spanish navy at the Battle of Lepanto in 1571,* built here in 1568.

The rich archival holdings of the Maritime Museum include the papers of Narcís Monturiol i Estarriol (1819–1885), a pioneer of submarine navigation who defined himself as a “journalist, typesetter, printer, notebook maker, portraitist, a man of science, and inventor.”²⁸ A follower of the French utopian socialist Étienne Cabet (1788–1856), Monturiol supported the creation of Icaria, the utopian, technologically advanced, and socially just new city depicted in Cabet's *Voyage en Icarie* of 1840. Monturiol devised and constructed a number of increasingly sophisticated and ultimately ruinous submarine crafts, beginning in 1859 with *Ictineu I*, an actual-size

* At the Battle of Lepanto the fleet of the Holy League, a coalition of southern European maritime states, defeated the main fleet of the Ottoman Empire and prevented its further expansion on the European side of the Mediterranean.

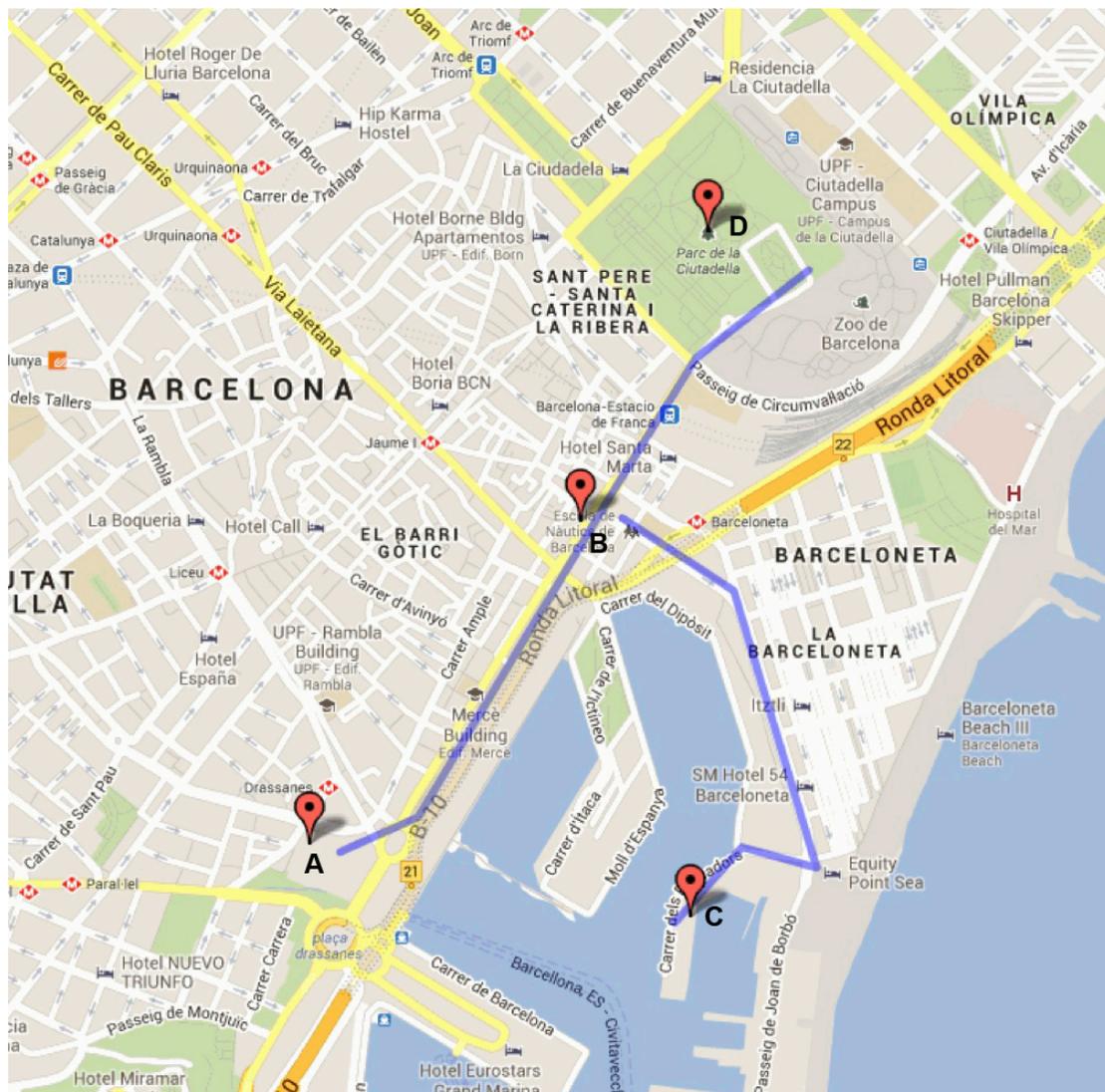


Fig. 7. Route 3 begins at the old medieval shipyards, currently the Maritime Museum (*Museu Marítim*, *Av. de les Drassanes s/n*, point A) and proceeds along *Passeig de Colom* to the site of the Board of Commerce of Barcelona (*Junta de Comerç*, *Pla de Palau*, point B), and the Citadel Parc (*Parc de la Ciutadella*, point D), with a detour to the former lighthouse at the Fisherman's Pier (*Moll de Pescadors*, point C). Map data: 2013 Google, based on BCN IGN Spain.

replica of which was built for the 1993 film *Monturiol, El senyor del mar*, directed by Francesc Bellmunt, and is erected outside of the Maritime Museum (figure 8). After Monturiol's project foundered in 1870—the same year in which Jules Verne (1828–1905) published his *20,000 Leagues Under the Sea*—Monturiol wrote his *Essay on the Art of Navigating Under Water* (*Ensayo sobre el arte de navegar por debajo del agua*), “an all-encompassing scientific treatise on underwater navigation, the first of its kind to lay out in detail the innovations and experiences achieved in the development and testing of a submarine.”²⁹ Monturiol failed to find a publisher, and his *Essay* appeared posthumously in 1891. He lectured on a wide variety of topics,



Fig. 8. The actual-size replica of Narcís Monturiol i Estarriol's submarine *Ictineu I* erected outside of the Maritime Museum. *Credit:* Gepardenforellenfischer, Creative Commons.

including cosmology, astronomy, and geology: “A General Idea of the Universe” (December 1874), “On Comets” (January 1875), “Igneous Meteors” (January 1875), and “Geosophy. Geological Part” (April 1875). His works reveal the influence of the Humboldtian view of science.

Walking along the seafront along *Passeig de Colom*, we come to *Pla de Palau*, the original site of the city's stock exchange (*La Llotja*). The neoclassical building there hides the original Gothic hall built by the 14th-century Catalan architect Pere Llobet, which since then represented the economic and social prowess of the city's mercantile class. The building is featured in one of the first daguerreotypes taken in Spain, in November 1839 by Ramon Alabern i Casas (*ca.* 1810–1868) and Pere Felip Monlau i Roca (1808–1878). The Royal Academy supported them both and now holds the camera they used. Since 1758, the stock exchange was the site of the Board of Commerce of Barcelona (*Junta de Comerç*), which promoted commerce and industry and became a prominent center for scientific and technical education. Beginning with the Nautical School (*Escola de Nàutica*) in 1769, the Board of Commerce set up schools and chairs that proved popular with the ambitious, socially rising commercial classes, even though students came from a broad social spectrum. The School of Experimental Physics (*Escola de Física Experimental*) was established in 1814. The Board's schools were integrated with the new Industrial School in 1851, the origin of today's School of Industrial Engineering.³⁰



Fig. 9. One of the towers of the Castle of Montjuïc, a key triangulation spot for Pierre Méchain's measurements in the city in 1792–1794. *Credit:* Photograph by the authors.

Not far from *Pla de Palau*, on the Fisherman's Pier (*Moll de Pescadors*) at the avenue *Joan de Borbó*, is a 1772 lighthouse, now sporting a clock that was at one of the triangulation points of the measurements of the French astronomer Pierre Méchain (1744–1804) in Barcelona between 1792 and 1794. Méchain left Paris late in June 1792 and arrived in Barcelona on July 10, where he set up quarters at *La Fontana d'Or*, a no-longer-extant hotel at the junction of *Avinyó* and *Ample*, close to *Pla de Palau*. He met Royal Academy members Antoni de Martí i Franquès (1750–1832), Francesc Santponç i Roca (1756–1821), and Francesc Salvà i Campillo (1751–1828). By the end of October 1792 he had measured his way north to the Pyrenees and back, and at the end of November he took a number of readings from the hills surrounding the city of Barcelona, with people reporting strange lights. Triangulation points included the roof of the hotel *La Fontana d'Or*, one of the towers of the Cathedral, the lighthouse, and a tower in the Citadel (to be discussed in next paragraph). Méchain then set up an observatory by the tower of the castle on *Montjuïc* (figure 9), south of the city (figure 10), constructing a wooden hut from which he made more than a thousand measurements of six stars over the next three months (more on *Montjuïc* below). As his work was nearing completion, war between Spain and France broke out, and Méchain got stuck; to complicate matters, he had a serious accident while visiting an hydraulic pumping station with Salvà.

Méchain left the city in May 1794, having been allowed to return just once to *Montjuïc* to check his data.³¹



Fig. 10. “Plan of the city and port of Barcelona”, with the Citadel to the right (northeast of the city) and *Montjuïc* to the left (south of the city). *Source:* Alexandre de Laborde, *Voyage pittoresque et historique de l'Espagne*. Tome premier. Premier partie (Paris: Pierre Didot l'Ainé, 1806), Planche IIB, between pages 4 and 5. The description on p. 4 reads: “Apart from the forth of *Montjuïc* to the south, Barcelona is defended by a Citadel at the northeastern extreme of the city. Built by King Philip V after reducing the Catalans to obeisance, it occupies a considerable extension and is well fortified, with difficult approaches”.

From *Pla de Palau*, a short walk along the *Avinguda del Marquès de l'Argentera* takes you to the *Parc de la Ciutadella* (Citadel Park). The Citadel (figure 10) was built over the remains of *La Ribera* Quarter by the chief engineer of Philip V's Army, Jorge Próspero de Verboom (1667–1744), in the wake of the War of the Spanish Succession. For a hundred and fifty years it remained a powerful symbol of the occupation of the city. The Royal Military Academy of Mathematics (*Real Academia Militar de Matemáticas*) was established at the Citadel in 1720, but soon moved to a refurbished building close to it. The remnants of one of its doors are visible at the *Plaça de l'Acadèmia (Tantarantana)*, while symbols of mathematical and civil engineering are visible on the doors at the *Carrer Comerç*. In 1803 the Royal Military Academy was moved to Aranjuez, south of Madrid, becoming the Academy of Engineers (*Academia de Ingenieros*).

In the 19th century, as the walls of Barcelona were demolished, the Citadel was also razed and a park built in its place. This was the main venue of the International Exhibition in 1888,³² the first of two such exhibitions held in the city, the second being in 1929, both contributing in their own ways to the redefinition of spaces for the production and consumption of knowledge in the city. The site of the Catalan Parliament is in the park, in a former ammunition dump refurbished in the 1880s as Museum and Royal Palace. Another Citadel building, the Palace of the Governor (*Palau del Governador*), became in the 1930s the site of the Republican *Institut-Escola*, which was founded and directed by the chemist and pedagogue Josep Estalella i Graells (Route 2), and is now a high school (*IES Verdaguer*).*

Route 4. The Extension (*Eixample*): From the Restored University to the Industrial University to the New University of Barcelona

The University of Barcelona, restored in 1837, did not get a building of its own until 1872 (figure 11). It lends its name to *Plaça Universitat*, a square close to *Plaça Catalunya* between the Old Town and the 19th-century Extension (*Eixample*). The university building appears as “a curious but dignified hybrid,” combining a Romanesque exterior with Mozarabic details in the interior decoration, both hinting at the Catalan past.³³ In 1857 a Physics Section was established within the Science Faculty. Around 1900 there were two chairs in physics, one for Advanced Physics (*Física Superior*), the other for General Physics (*Física General*), out of a total of thirteen chairs of physics at ten Spanish universities.³⁴ Chairs related to physics at the University of Barcelona included Cosmography and Rational Mechanics, which were mostly teaching chairs since the university was generally lacking in experimental facilities. Thus, in February 1896 X rays were first produced at the Royal Academy of Sciences and Arts of Barcelona, and then demonstrated at the University of Barcelona with a cathode-ray tube financed by Eduard Conde (1838–1914), owner of the department store *El Siglo*, located right by the RACAB.³⁵ It did not help to advance research that doctorates were, until 1954, awarded only by the Central University (*Universidad Central*) in Madrid. At any rate, physics was studied and practiced at the University of Barcelona until the 1960s, when a new campus was inaugurated at the *Avinguda Diagonal*, the major route running northwest into the city between the so-called Parallel and Meridian avenues (*Avinguda del Paral·lel* and *Avinguda Meridiana*); see the next section. A new building for the Sections of Physics and Chemistry of the Sciences Faculty was inaugurated in 1968, the same year that the second public university in Catalonia, the Free University of Barcelona (*Universitat Autònoma de Barcelona*), was established some twenty kilometers north of the city at Cerdanyola del Vallès.

* A plaque at the former Palace of the Governor commemorates the inauguration of the *Institut-Escola* on February 3, 1932.

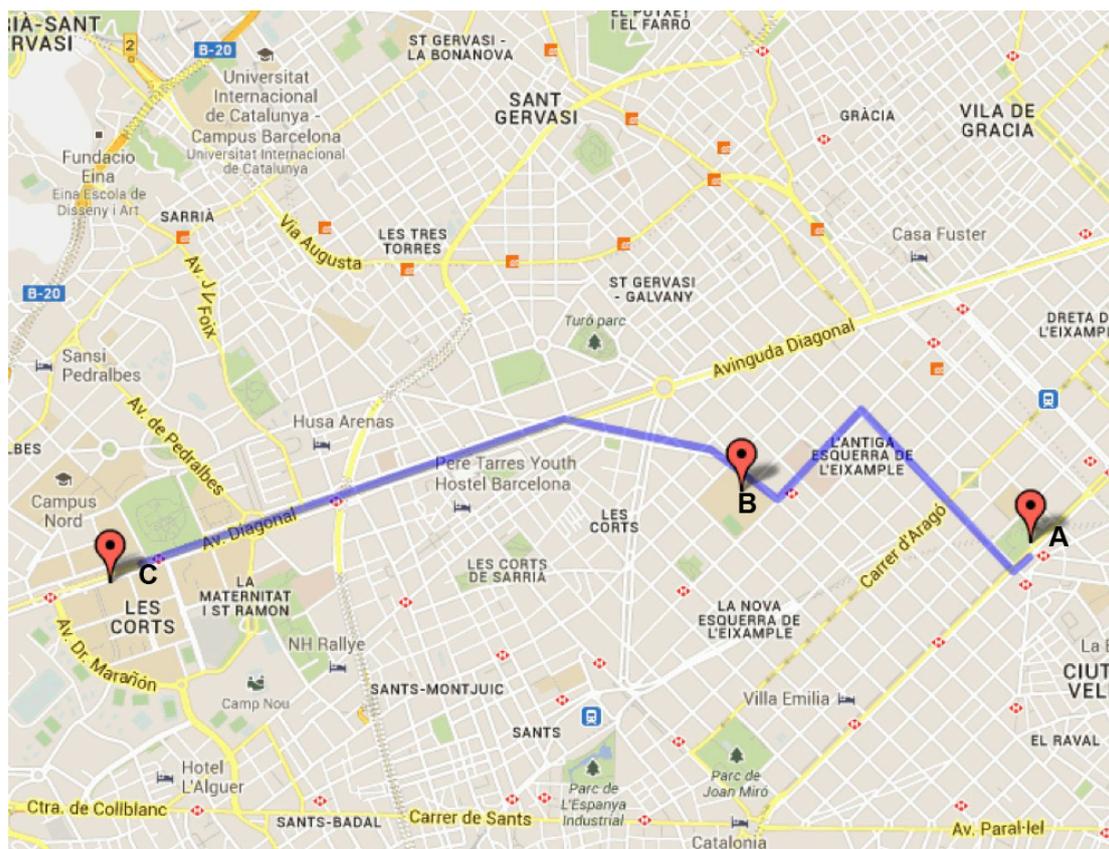


Fig. 11. Route 4 begins at the historic building of the University of Barcelona (*Plaça Universitat*, point A) and proceeds to the former Industrial School (*Escola Industrial*, 187 *Comte d'Urgell*, now part of the Technical University of Catalonia (*Universitat Politècnica de Catalunya*, point B), and the new university campus at *Avinguda Diagonal* (point C). Map data: 2013 Google, based on BCN IGN Spain.

One of the showpieces of the new campus at the *Avinguda Diagonal* was the experimental nuclear reactor Argos, inaugurated in 1962 while the new School of Industrial Engineering was still under construction. Although based on the design of the “Argonaut” (the Argonne Nuclear Assembly for University Training), Argos was built in Madrid at the *Junta de Energía Nuclear*, which was still divided on the issue of developing a nuclear industry of its own or getting the technology abroad. Argos remained operative for a couple of decades before it was dismantled.³⁶ Its installation took a central place in the training of nuclear engineers in which some professors in the Science Faculty played an important role.

The new campus of the University of Barcelona was erected on the northwestern edge of the Extension (*Eixample*, figure 12) designed in 1859 by the civil engineer Ildefons Cerdà i Sunyer (1815–1876). The Extension prompted Cerdà to develop a theory of urban planning, published in 1867, which is regarded as a founding contribution to the discipline. Cerdà envisioned the city as a grid of octagonal blocks (*mansanes* or *illes*), with secluded yet public inner gardens, whose cutoff vertexes (chamfers or *xamfrans*) would eventually ease the flow of heavy traffic (figure 12). He sought to justify the dimensions of grid and buildings mathematically:

$$x = \frac{pv - 2bd}{d} \pm \sqrt{\frac{pv}{d^2 f} (pvf - 4bdf - 4b^2 d)},$$

“where x is the side of the block, $2b$ is the width of the street, f is the depth of the building site, d is the height of the façade, v is the number of inhabitants per house, and p is the number of surface square meters per person.”³⁷ He took the values of the variables to be $2b = 20$ meters, $f = 20$ meters, $d = 20$ meters, $v = 43$, and $p = 40$, obtaining 113.3 meters for the distance between the blocks in the Extension.* Cerdà’s formula seems to be an empirical engineering formula, given with little justification. While his original intent was soon distorted by the construction of upper stories and the occupation of the inner gardens, the Extension nevertheless remains a magnificent example of urban planning.

In the first decades of the 20th century, supported by the Provincial Council (*Diputació de Barcelona*) and local businessmen, a new Industrial School or University (*Escola Industrial*) was installed in the former factory Can Batlló at *187 Comte d’Urgell*, which was built by a family of textile industrialists and patrons of modernist architecture. The Industrial University, which included Agriculture, Industrial Engineering, Mechanics, Chemistry, Construction, and Electrotecnics, employed many physicists. One of its driving forces was the physicist Esteve Terradas i Illa (1852–1950). At the entrance of the Industrial University is a plaque that commemorates Einstein’s visit in February 1923. Einstein spent a week in Barcelona lecturing on relativity at the Catalan Academy of Humanities and Sciences, and was shown the main institutions of the city, such as the RACAB (where he lectured on philosophical aspects of relativity) and the Industrial University. Einstein’s lectures had a clear impact on the then-small community of physicists in the city, and Einstein himself apparently was quite impressed by Catalan culture, especially by its language, architecture, and traditional music.³⁸

Elsewhere in the City and Beyond

The Fabra observatory (Observatori Fabra)

A visit to the Fabra Observatory at the Tibidabo hill affords a view of the city from the surrounding hills. Indeed, the Observatory owes its existence to the growth of the city and the extension of telegraphy and electric light, whose absence rendered the observatory at the RACAB useless before completion. In 1904 the new Fabra Observatory opened thanks to the donation of Camil Fabra i Fontanils (1833–1902), a textile industrialist and former major of the city. Its first director was Josep Comas i

* Inserting numbers, we obtain $x = 66 \pm 47.3 = 113.3$ meters, so when disregarding the meaningless negative root 113.3 meters, stated accurately, is the distance between two corresponding points in adjacent blocks.



Fig. 11. The Extension (*Eixample*) designed by Ildefons Cerdà i Sunyer in 1867, as seen from above *Plaça Universitat* looking northwest. The building at the bottom is the University of Barcelona (1872). The street on the left hand side is *Aribau* (number 3), the following to the right is *Enric Granados* (number 4), and the one on the right hand side is *Balmes*. The avenue number 2 refers to the data of proclamation of the Second Spanish Republic on April 14, 1931, and is now *Avinguda Diagonal*. Source: [Josep] Gaspar, *Barcelona desde el aire: Información completa en 29 fotos tomadas en avión* (Barcelona: Juventud, c. 1931), p. 21.

Solà (1868–1937), a leading Catalan astronomer who identified 11 new asteroids and discovered 2 comets, and was an active popularizer of science. The Observatory's 38-centimeter Mailhat refracting telescope allowed Comas to announce in 1908 the discovery of the atmosphere of Titan, the only fully developed atmosphere of a natural satellite in the Solar System.³⁹

Plaça de les Glòries and Avinguda Meridiana

A twenty-minute walk from Citadel Park along the *Avinguda Meridiana* takes you to the undistinguished *Plaça de les Glòries*, which Cerdà intended to be the new physical center of the city. Clutched in the center, almost inaccessible across the traffic lanes, is a 35-meter-long steel sculpture by François Scali and Alain Domingo showing the profile of the meridian arc from Dunkirk, France (N 51° 2' 9.20") to Barcelona (N 41° 21' 44.95") —a gift from Dunkirk on the occasion of the Barcelona Olympic Games in 1992.* The Meridian Avenue (*Avinguda Meridiana*) runs northward along the meridian arc 2° 13' 45".

Montjuïc

The mountain of *Montjuïc* dominates the southwestern end of the city. From the middle of the 16th century there has been a fortification on its top, becoming a castle with successive additions through the 18th century. As noted above, Pierre Méchain set up quarters there while measuring stars in early 1793. A plaque at the tower commemorates these measurements,[†] as does the installation "Metric Size of Nature" (*Talla mètrica de la natura*) by artist Valérie Bergeron, installed at the castle in 2000, which combines concrete, steel and plants and refers to the paradox of measuring natural things.

Montjuïc remained underdeveloped until the 20th century. Its present layout owes much to two international events, the International Exhibition of 1929 and the Olympic Games of 1992. The International Exhibition prompted the construction of the *Avinguda Maria Cristina*, off *Plaça Espanya*, at the end of the *Avinguda Paral·lel*. At the top of the avenue the National Palace (*Palau Nacional*) stands out. It is now the site of the National Art Museum of Catalonia (*Museu Nacional d'Art de Catalunya*, MNAC) with a magnificent collection of Romanesque art. Martín Arrúe

* The inscription, in Catalan, Spanish, and French reads in English: "On 20 June 1792 Jean Baptiste Délambre and Pierre Méchain started measuring the Paris meridian arc between Dunkerque and Barcelona. This operation, which took six years of trigonometric measurements, allowed them to calculate the circumference of the Earth and to establish the meter as the 1/10,000th part of a quarter of the terrestrial meridian."

† The plaque reads: "Des d'aquest emplaçament, el científic francès, / Pierre F. Méchain va efectuar el darrer / mesurament triangular que va donar lloc al / naixement del sistema mètric decimal. / Barcelona, 10 de desembre de 1999 / Del 1799 al 1999."

(d. 1976), a Spanish engineer who worked at the German firm Osram, coordinated the Light Exhibition in 1929.⁴⁰ Today, every weekend (every weekday in summer) the so-called Magic Fountain designed by the engineer Carles Buigas (1898–1979), which occupies a central place in the *Avinguda Maria Cristina*, continues to exhibit mobile water forms. The hydraulic and electric systems, which date to 1929, have been restored.

Paral·lel

Two avenues in the city were opened along parallel or meridian arcs. The *Avinguda Paral·lel* runs from the medieval shipyards (*Drassanes*) to the *Plaça d'Espanya* along parallel N 41° 22' 29". At the eastern end of the avenue three tall chimneys are all that remain of the first electrical power plant in the city, built by the Spanish Society of Electricity (*Sociedad Española de Electricidad*) in 1883. For more than a century, until the dismantlement of the last central plant in 1987, this was an industrial site on the outskirts of the Old City.

National Museum of Science and Technology (Museu Nacional de la Ciència i de la Tècnica)

Terrassa is an industrial town 30 kilometers northwest of Barcelona that thrived on the textile industry around the beginning of the 20th century. The National Museum of Science and Technology is located in a fine Art Nouveau industrial building, the Aymerich, Amat, and Jover mill. Its main architectural feature is its ceiling, a system of 161 vaults of light ceramic tiles, known as Catalan vaulting. Architect Rafael Guastavino (1842–1908) patented and deployed this vaulting system in the United States from the mid-1880s, where it can be seen in such places as the Boston Public Library and Grand Central Station in New York. The supporting cast-iron columns double as rainwater pipes. Of special interest is the *Mentora Alsina Cabinet*, the collection of physics demonstration instruments collected by the textile industrialist Ferran Alsina i Parallada (1861–1908), and recently donated to the museum.

Conclusions

The discipline of physics has grown significantly since the end of the Franco dictatorship in 1975, both in the number of practitioners and in the number of institutions. According to a report by the Catalan Academy, by the mid-1990s there were some 600 researchers in physics in Catalonia, most of them working in Barcelona and distributed among the University of Barcelona (250 researchers), the Autonomous University of Barcelona (*Universitat Autònoma de Barcelona*, 150 researchers), and the Technical University of Catalonia (*Universitat Politècnica de Catalunya*, 115 researchers). The universities in Girona, Tarragona, and Reus, doctoral students, and researchers at research institutes account for the rest.⁴¹ Indeed,

along with the growth of the University of Barcelona, the growth of physics in the Barcelona area has also been apparent in the creation of research centers in fields such as microelectronics, materials science and nanotechnology, photonics, and high-energy physics. Of particular significance has been the inauguration, close to the Autonomous University of Barcelona, of the ALBA Synchrotron Light Facility,⁴² the second largest scientific installation in Spain after the *Gran Telescopio Canarias*, the world's largest optical telescope that was inaugurated in 2009.

The relatively recent institutionalization of physical research in Barcelona has often been mistaken for a lack of tradition. Our tour, however, has revealed some of the ways in which the physical sciences have been understood, promoted, practised, and enjoyed in the city since medieval times. One important lesson we might draw from this story has to do with the sheer diversity of people and places involved: not just academic scientists, of which there have not been that many until very recently, but also spectacle makers, physicians, astronomers, military engineers, Jesuits, inventors, and entrepreneurs. And not just academic institutions, but academies, churches, castles, and parks. We hope that the physical tourist might feel as Einstein did after his visit to the city in 1923, when he deemed his stay in Barcelona to have been pleasant and stimulating in several ways.

Acknowledgments

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⁴ Lluís Cifuentes i Comamala, *La ciència en català a l'Edat Mitjana i el Renaixement* (Barcelona: Edicions de la Universitat de Barcelona, 2002).

⁵ José Chabás, "Astronomía andalusí en Cataluña: las Tablas de Barcelona," in Josep Casulleras and Julio Samsó, ed., *From Baghdad to Barcelona: Studies in the Islamic Exact Sciences in Honour of Prof. Juan Vernet* (Barcelona: Universitat de Barcelona, 1996), pp. 477–525; idem, "The Astronomical Tables of Jacob ben David Bonjorn," *Archive for History of Exact Sciences* **42** (1991), 279–314.

⁶ Josep Chabàs, “L’activitat astronòmica a l’època del rei Pere (segle XIV),” in Joan Vernet and Ramon Parés, ed., *La ciència en la història dels Països Catalans. I. Dels àrabs al Renaixement* (Barcelona and València: Institut d’Estudis Catalans and Universitat de València, 2004), pp. 483–514.

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¹⁰ José Chabàs and Antoni Roca, “Early Printing of Astronomy: The Lunari of Bernat de Granollachs,” *Centaurus* **40** (1998), 124–134, on 125.

¹¹ Vicent Salavert, “La impremta i la comunicació dels sabers i les tècniques,” in: Joan Vernet and Ramon Parés, ed., *La ciència en la història dels Països Catalans. II. Del naixement de la ciència moderna a la Il·lustració* (Barcelona and València: Institut d’Estudis Catalans and Universitat de València, 2007), pp. 83–100; Joana Escobedo, “Mercantile arithmetic and the incunable Catalan printing. Suma de la art de arismètica, by Francesc Santcliment (1482),” *Contributions to Science* **6** (2011), 59–73.

¹² Víctor Navarro and Vicent Salavert, “L’activitat científica i l’organització política,” in Vernet and Parés, ed., *La ciència en la història dels Països Catalans. II* (ref. 11), pp. 53–82, on p. 70; see also Nick Pelling, “Who Invented the Telescope?” *History Today* **58** (2008), 26–31, on 29–31, which is based on a communication by Josep Maria Simón de Guilleuma to the IX International Congress of the History of Science (1959).

¹³ Hieronymi Sirturi Mediolanensis [Girolamo Sirturo], *Telescopium: sive Ars perficiendi novum illud Galilaei visorium instrumentum ad sydera* (Francofurti [Frankfurt]: Pauli Iacobi, 1618), p. 26: “Nullibi haec ars exactior quam apud istos fratres Rogetos.” Intriguingly, this sentence is underlined in red in the exemplar available for download at the Sächsische Landesbibliothek–Staats– und Universitätsbibliothek Dresden as part of Europeana, the European digital library.

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²⁶ For an account of his life and work, see Antoni Roca-Rosell, “Professionalism and Technocracy: Esteve Terradas and Science Policy in the Early Years of the Franco Regime,” *Minerva* **43** (2005), 147–162.

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