Aristocratic Culture and the Pursuit of Science: *The De Broglies in Modern France*

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ABSTRACT

Louis de Broglie received the Nobel Prize in Physics in 1929 following experimental confirmation of his theory of the wave properties of the electron. De Broglie was an anomaly among twentieth-century physicists: he was a prince by birth who would become the seventh duc de Broglie. What did it mean to be an aristocrat in an age of science? This essay explores aristocratic culture in France in the early twentieth century and examines the family life, education, scientific practices, and social values of Louis de Broglie, his brother Maurice, who was a distinguished experimental physicist, and their sister Pauline, who became a well-known novelist and literary scholar after her scientific interests were discouraged.

DE BROGLIE IS A FAMILIAR NAME in the history of quantum physics, identified with the original theory of the wave nature of the electron and with the equation

$$\lambda = h/mv,$$

in which the wavelength λ is associated with Planck's quantum of action constant h and the electron's momentum mv. As with some other revolutionary heroes, including Max Planck, there is an irony in the commonplace association of Louis de Broglie's name with the 1920s revolution in physics, since he struggled against its outcome and resisted what by the late 1920s had come to be called the Copenhagen interpretation of quantum mechanics.

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Louis de Broglie, in the 1920s. Studio Piaz. (Courtesy of Archives de l'Académie des Sciences, Paris.)

Still, de Broglie taught the Copenhagen theory at the Sorbonne during the 1930s and 1940s, discussing its philosophical implications and difficulties in enormously popular lectures and books.[1] Then, in the early 1950s, he formally revived his rejected "double solution" of 1927, which associates a real "pilot wave" with a material point in the wave, following up the independent reintroduction of a similar approach by David Bohm, then a physicist at Princeton.[2]

The modern program for quantum mechanics was mapped out at the fifth Solvay Council in Physics, in 1927. This program included the Schrödinger wave equation, Heisenberg's uncertainty principle, and Bohr's theory of the complementarity of wave and particle. The Copenhagen interpretation rejected physical realism in favor of mathematical formalism and empirical data.

In lectures as early as 1928, Werner Heisenberg claimed the fundamental principles of quantum mechanics for the "Kopenhagener Geist der Quantentheorie . . . which has directed the entire development of modern atomic physics." He characterized de Broglie's electron waves and Maxwell's electromagnetic waves as "classical" conceptions, by way of contrast with Schrödinger's "discovery" of the correct equation for matter waves. Paradoxically, just as the thirty-seven-year-old Louis de Broglie was embarking for Stockholm to receive the 1929 Nobel Prize in Physics, his role in the history of modern physics was being marginalized through the "missionary spirit" of the Copenhagen circle.[3]

From 1928 to 1962 Louis de Broglie exercised substantial intellectual and administrative influence within France as a faculty member at the Sorbonne. He was perpetual secretary of the French Academy of Sciences from 1942 to 1976. Many younger French physicists came to feel that theoretical physics and chemistry languished in France in the 1930s and 1940s largely owing to de Broglie's influence. After World War II, a rival curriculum to de Broglie's Sorbonne physics was created within the French Atomic Energy Commission, where Yves Rocard taught up-to-date quantum mechanics.[4]

[1] See Louis de Broglie, *An Introduction to the Study of Wave Mechanics,* trans. H. T. Flint (London: Methuen, 1930), p. 7. His other titles include *Ondes et corpuscles* (Paris: Hermann, 1930), *L'electron magnétique* (Paris: Hermann, 1934), *Une nouvelle conception de la lumière* (Paris: Hermann, 1934), *Nouvelles recherches sur la lumière* (Paris: Hermann, 1936), *Matière et lumière* (Paris: Albin-Michel, 1938), *La mécanique ondulatoire des systèmes de corpuscles* (Paris: Gauthier-Villars, 1939), *Théorie générale des particules à spin* (Paris: Gauthier-Villars, 1943), and *Optique ondulatoire et corpusculaire* (Paris: Hermann, 1950).

[2] On Bohm and de Broglie see James T. Cushing, *Quantum Mechanics: Historical Contingency and the Copenhagen Hegemony* (Chicago: Univ. Chicago Press, 1994); and Peter R. Holland, *The Quantum Theory of Motion: An Account of the de Broglie–Bohm Causal Interpretation of Quantum Mechanics* (Cambridge: Cambridge Univ. Press, 1993). In his original theory of 1923–1924 de Broglie proposed a real physical wave existing in three-dimensional space. His theory of 1927 attempted to deal with objections to that approach. Bohm proposed a wave existing in $3n$-dimensional abstract configuration space, consistent with Erwin Schrödinger's wave mechanics (where n is the number of particles in the system). See Cushing, *Quantum Mechanics,* p. 149. Antony Valentini argues that de Broglie in fact proposed in 1927 a complete pilot-wave dynamics for a many-body system with a wavefunction in configuration space, not just a one-body theory with a wavefunction in three-dimensional space. See Antony Valentini, "Pilot-Wave Theory of Fields, Gravitation, and Cosmology," in *Bohmian Mechanics and Quantum Theory: An Appraisal,* ed. Cushing, Arthur Fine, and Sheldon Goldstein (Dordrecht: Kluwer, 1996). De Broglie's paper in question is "Nouvelle dynamique des quanta," in *Electrons et photons* (Paris: Gauthier-Villars, 1928), pp. 105–132.

[3] Werner Heisenberg, *The Physical Principles of the Quantum Theory,* trans. Carl Eckart and Frank C. Hoyt (Chicago: Univ. Chicago Press, 1930), pp. x, 47, 157–158. The chapters of this book are a set of lectures given at the University of Chicago in the spring of 1929. Arthur H. Compton introduced the book with mention of "Professor Heisenberg's leading place in the development of the new quantum mechanics" and his uncertainty principle, which "has become a household phrase throughout our universities" (p. vii). On the marginalization of de Broglie see John L. Heilbron, "The Earliest Missionaries of the Copenhagen Spirit," in *Science in Reflection,* ed. Edna Ullmann-Margalit (Dordrecht: Kluwer, 1988), pp. 201–233, on p. 219.

[4] For this information, I am grateful to Dominique Pestre. See Dominique Pestre, *Physique et physiciens,*

For almost forty years Louis de Broglie was the most recent French Nobel laureate in physics. Jean Perrin had received the award in 1926, three years before de Broglie, and Albert Kastler was so honored in 1966. A succession of commemorations celebrated de Broglie's life and career, but, oddly, only one substantial volume of biography has appeared, written by his protégé Georges Lochak, who characterized de Broglie as a man marginalized in the French physics community during the course of his lifetime. Paul Germain, who was perpetual secretary of the Academy of Sciences at the time of de Broglie's death, similarly depicted him as an outsider: "It seems that he never really fit into the scientific community."[5]

While the particle "de" preceding a name is by no means an infallible guide to class and family, in this case it provides a reliable clue about Louis de Broglie's peculiar status in a French university network dominated since the mid-nineteenth century by a meritocracy of scientists from families in the middle class and professions with republican sympathies. Louis de Broglie was not born into a commercial, professional, bureaucratic, or academic family, as were 112 of the 113 scientists appointed to the Paris Faculty of Sciences between 1901 and 1939. He was the one member of the Sciences Faculty from social origins designated "grand propriétaire noble."[6]

Alone in the Paris faculty as an aristocrat, Louis de Broglie was unusual; but he was not the only aristocrat in the broader scientific community. In the early 1920s the name of his elder brother, the experimental nuclear physicist Maurice de Broglie, was better known in France and abroad than that of Louis de Broglie. As Bruce Wheaton, among others, has noted, it was Maurice who provided the inspiration and opportunity for Louis's scientific originality to unfold.[7] Thus, for the historian, the de Broglies are a notable case not only for studying connections between aristocratic values and modern scientific culture, but also for analyzing links between family history and scientific creativity.

The linking of nobility and science seems anachronistic for the twentieth century, yet recent historical work has suggested how seventeenth- and eighteenth-century aristocratic codes of honor and civility were transformed into modern systems of scientific and pro-

1918–1940 (Paris: Editions des Archives Contemporaines, 1984). See also Anatole Abragam, *Time Reversal: An Autobiography* (Oxford: Clarendon, 1989), pp. 48–62; and Micheline Charpentier-Morize, "Perrin, père de l'atome et détracteur de la chimie moderne," *Recherche,* 1997, no. 295, pp. 94–99, on p. 98.

[5] Georges Lochak, *Louis de Broglie, un prince de la science* (Paris: Flammarion, 1992), e.g., pp. 9, 246; and Paul Germain, "Louis de Broglie ou la passion de la 'vraie' physique," *La Vie des Sciences,* 1987, *4:*569–593, on p. 581. (Here and elsewhere, translations are my own unless otherwise indicated.) Bruce Wheaton noted the importance of constructing a detailed biographical study of Maurice de Broglie, as well as Louis de Broglie, with the aid of papers that still may be held in private collections. See Bruce R. Wheaton, "The Laboratory of Maurice de Broglie and the Empirical Foundations of Matter-Waves," in *La découverte des ondes de matière: Colloque organisé à l'occasion du centenaire de la naissance de Louis de Broglie 16–17 juin 1992* (Paris: Technique et Documentation-Lavoisier, 1994), pp. 25–39, on p. 31.

[6] Christophe Charle and Eva Telkes, *Les professeurs de la Faculté des Sciences de Paris: Dictionnaire biographique (1901–1939)* (Paris: Editions du CNRS, 1989), p. 9. Craig Zwerling, John Weiss, and others have argued that the social status of French scientists declined during the course of the nineteenth century and that the social origins of scientists shifted from the upper to the lower bourgeoisie. Further, it has been argued that a modern division between scientists and *notables* persisted in France, with laboratory- and university-trained, often left-wing scientists constituting one bloc within the universities, while graduates of the *grandes écoles,* mainly right-center engineers and technocrats, constitute another group in industry and government. See Craig Zwerling, "The Emergence of the Ecole Normale Supérieure as a Centre of Scientific Education in the Nineteenth Century," in *The Organization of Science and Technology in France, 1808–1914,* ed. Robert Fox and George Weisz (Cambridge: Cambridge Univ. Press, 1981), pp. 31–60, on p. 31; John H. Weiss, *The Making of Technological Man: The Origins of French Engineering Education* (Cambridge, Mass.: MIT Press, 1982), pp. 73–75; and Pierre Papon, *Le pouvoir et la science en France* (Paris: Centurion, 1978).

[7] See Wheaton, "Laboratory of Maurice de Broglie" (cit. n. 5).

fessional ethics. Some wealthy and titled members of the scientific community, who set up laboratories at country estates as well as in academic centers, have been subjects of biography, particularly in the English context, among them Lord Kelvin, the third baron Rayleigh, and Lord Cherwell.[8] However, none of these figures had titles rooted in the rank of *noblesse d'épée,* which dates from military service in the early modern period, as did the de Broglies.

The study of aristocracy is rooted in family relations and family traditions, and family has been of some interest for historians of science. There are a number of notable scientific families that have crossed generations (the Darwins, the Huxleys, the Herschels, the Saussures come to mind). Some scientific families extend three or four successive generations in the very same field. Four generations of the Becquerel family held the chair of physics at the Museum of Natural History in Paris. Three generations of the Perrin family and the Curie family have worked in physics, and, of course, the Curies are one of the collaborative couples that have been studied by historians focusing especially on women and gender in science.[9]

In the unusual case of the de Broglies, we ask, What did it mean to be an aristocrat in the modern scientific period? What customs, values, and goals characterized the French aristocracy of the early twentieth century? What were the circumstances, especially of family and education, under which the de Broglie brothers came to choose scientific work? What were their roles in the scientific community, and what connections might there be between their social status and their scientific reputations?

THE DE BROGLIES AS NOBILITY

Louis de Broglie (1892–1987) was the youngest of five children born to Victor, the fifth duc de Broglie (1846–1906). The eldest was Albertine (1872–1946), who married the marquis Pierre de Luppé. Albertine left home well before Louis was born. The eldest son

[8] For the early modern period see Steven Shapin, *A Social History of Truth: Civility and Science in Seventeenth-Century England* (Chicago: Univ. Chicago Press, 1994). For the modern period see Robert A. Nye, *Masculinity and Male Codes of Honor in Modern France* (Oxford: Oxford Univ. Press, 1993); and Nye, "Medicine and Science as Masculine Fields of Honor," *Osiris,* 2nd Ser., 1997, *12:*60–79. For pertinent biographies see Crosbie Smith and M. Norton Wise, *Energy and Empire: A Biographical Study of Lord Kelvin* (Cambridge: Cambridge Univ. Press, 1989); Robert John Strutt, *John William Strutt: Third Baron Rayleigh* (Madison: Univ. Wisconsin Press, 1968); Roy Forbes Harrod, *The Prof: A Personal Memoir of Lord Cherwell* (London: Macmillan, 1959); and Frederick W. F. S. Birkenhead, *The Prof and the Prime Minister: The Official Life of Professor F. A. Lindemann* (Boston: Houghton-Mifflin, 1962).

[9] Four generations of Becquerels held the chair of physics at the Museum of Natural History in Paris: Antoine Becquerel (1788–1878), Alexandre Edmond Becquerel (1820–1891), Henri Becquerel (1852–1908), and Jean Becquerel (1878–1953). Jean Perrin (1870–1942), Francis Perrin (1901–1992), and Niels Perrin are another eminent French scientific family; as are Marie S. Curie (1867–1934) and Pierre Curie (1859–1906), Irène Joliot-Curie (1897–1956) and Frédéric Joliot-Curie (1900–1958), and Hélène Langevin-Joliot (born 1927). On the Perrins and Joliot-Curies see Francis Perrin, "Distinguished Nuclear Pioneers—1972: Frédéric and Irène Joliot-Curie," *Journal of Nuclear Medicine,* 1972, *13:*405; and Bernadette Bensaude-Vincent, "Star Scientists in a Nobelist Family," in *Creative Couples in the Sciences,* ed. Helena M. Pycior, Nancy G. Slack, and Pnina G. Abir-Am (New Brunswick, N.J.: Rutgers Univ. Press, 1996), pp. 57–71. For collections treating collaborative couples see *ibid.;* and Abir-Am and Dorinda Outram, eds., *Uneasy Careers and Intimate Lives: Women in Science, 1789–1979* (New Brunswick, N.J.: Rutgers Univ. Press, 1987). Probably the most thoroughly argued examination of the relationship between family dynamics and scientific creativity is Frank J. Sulloway's work on birth order. Sulloway's sample of 3,890 scientists in selected scientific debates includes 105 individuals who were siblings of one another, although Sulloway nowhere mentions the de Broglies. See Frank J. Sulloway, *Born to Rebel: Birth Order, Family Dynamics, and Creative Lives* (New York: Pantheon, 1996), pp. 50, 389. Sulloway brings into his argument matters of gender and class as well as birth order, but he warns that his generalization about birth order is least well supported for the aristocracy (pp. 49–50).

was Maurice (1875–1960), who became the sixth duc upon the death of their father in 1906. Philippe (1881–1890) died in childhood. Pauline (1888–1972) was Louis's closest childhood companion.

In 1900 there were some five thousand noble families in France, representing a precipitous decline in numbers from some twenty-five thousand in 1789.[10] All the de Broglie children were princes and princesses, the hereditary title of prince (a title of the Holy Roman Empire) having been conferred upon their great-great-grandfather Victor François de Broglie (1718–1814) by the Austrian emperor. Victor François was already a duc, a hereditary French title conferred on his father François Marie Broglie (1671–1745) by Louis XV in 1742. By that time the Broglie family had been in France for about a hundred years, its members distinguishing themselves in military service and changing the name from the Italian Broglia to Broglie (pronounced as in "oeil") in the second French generation.[11]

On their father's side, the de Broglie children numbered marshals, princes, and dukes among their ancestors, as well as clergymen, cabinet ministers, ambassadors, and members of the Académie Française. The third duc married Albertine de Staël, the daughter of the novelist Mme. de Staël and her lover, the novelist and political writer Benjamin Constant (1767–1830).

On their mother's side was their grandfather comte Louis d'Armaillé, a collector of *objets d'art* and a close friend of the French Rothschilds and the Englishman Sir Richard Wallace. Their maternal grandmother, born Célestine de Ségur, in whose residence they grew up, was the daughter of one of Napoleon's generals and the sister-in-law of the comtesse Elisabeth Greffulhe (1860–1952), a model for the duchesse de Guermantes in Marcel Proust's masterpiece *Remembrance of Things Past* (*A la recherche du temps perdu*).[12]

Contrast the family backgrounds of leaders in the French scientific establishment in the early twentieth century. Jean Perrin's paternal grandparents were peasants and his father an army officer who came up through the ranks. Marie Sklodowska Curie's parents were school teachers and administrators. Pierre Curie and his brother Jacques, also a physicist, were children and grandchildren of medical doctors and inventors. Paul Langevin's grandfather was a locksmith, his father an army veteran, and his mother a great-niece of the psychiatrist Philippe Pinel.[13]

Like most of the French aristocracy, the de Broglies divided their time between the countryside and Paris, where they resided in their grandmother's *hôtel particulier* in the

[10] See Monique de Saint-Martin, *L'espace de la noblesse* (Paris: Editions Métailié, 1993), p. 13. The Association de la Noblesse Française was established in 1932 to authenticate nobility (p. 75). By 1969 there were 2,797 designated families, branching out to some 12,500–40,000 persons. Many more families use particles for their names (p. 13).

[11] The Broglia were a younger branch of the Gribaldi family of Piedmont, dating to the twelfth century. François Marie Broglia (1611–1656) was named marshal posthumously; Victor Maurice de Broglie (1647–1724) was the second French marshal. See Anatole Abragam, "Louis Victor Pierre Raymond de Broglie, 1892–1987," *Biographical Memoirs of Fellows of the Royal Society,* 1988, *34:*22–41, on pp. 23–25; Dominique de Broglie, *Les Broglie: Leur histoire* (Paris: Editions du Palais Royal, 1972); Jean de Varende, *Les Broglie* (Paris: Fasouelle, 1950); and unidentified article in Dossier Louis de Broglie, Archives, Académie des Sciences, Paris.

[12] The comte Henri Greffulhe (1844–1932), who was fabulously rich from family money in Belgian banks, served as Proust's model for the unfaithful and jealous duc de Guermantes. See Eric Mension-Rigau, *Aristocrates et grands bourgeois: Education, traditions, valeurs* (Paris: Plon, 1993), p. 432 n 1.

[13] See Mary Jo Nye, *Molecular Reality: A Perspective on the Scientific Work of Jean Perrin* (London: Macdonald, 1972); Susan Quinn, *Marie Curie: A Life* (New York: Simon & Schuster, 1995); and Bernadette Bensaude-Vincent, *Paul Langevin: Science et vigilance* (Paris: Bélin, 1987).

Figure 1. *The entrance at 48, rue La Boëtie, in the eighth arrondissement of Paris, the site of the family* hôtel *purchased by Célestine Ségur's father in 1822 and sold by the de Broglies in 1902. It is now an office building for the Fondation Nationale du Crédit Agricole.*

fashionable eighth arrondissement, not far from the Arc de Triomphe and Champs d'Elysées. (See Figure 1.) At the time of Pauline's marriage in 1910, when she, but not Louis, left the house, there were some forty servants.[14]

Within the French aristocracy, the oldest, most Catholic, and most royalist families had the greatest prestige: the Mortemort, La Rochefoucauld, Choiseul, Harcourt. Some of the older and monarchist noble families were suspicious of the de Broglies, remembering that the third duc de Broglie, the husband of Albertine de Staël, had consorted with the "doc-

[14] Comtesse Jean de Pange [Pauline de Broglie], *Comment j'ai vu 1900* (Paris: Grasset, 1962), [Vol. 1], p. 23. This autobiographical work eventually ran to four volumes, the last of which appeared the year after Pauline's death: *Comment j'ai vu 1900,* Vol. 2: *Confidences d'une jeune fille* (Paris: Grasset, 1965); Vol. 3: *Derniers bals avant l'orage* (Paris: Grasset, 1968); Vol. 4: *1900 s' éloigne* (Paris: Grasset, 1973). Hereafter this work will be cited as **Comtesse de Pange,** ***Comment j'ai vu 1900,*** with the appropriate volume number.

trinaires," a political party that had attempted to steer a middle path between royalism and liberalism in the 1830s.[15]

Some thought, too, that the de Broglies, in their alliance with the Armaillé and Greffulhe clans, were too intimate with the wealthy and Jewish Rothschilds, as well as with Englishmen like Wallace. The Greffulhe, who were Protestant, often fell under suspicion. The de Broglies' links to these families, their Orléanist sympathies, and their relatively recent French roots all contributed to a less prestigious niche in the French noble hierarchy. Indeed, the young de Broglies' grandmother Ségur frequently voiced liberal and even anticlerical views, which were regarded with considerable suspicion by their father, a member of the Chamber of Deputies representing one of their country estates.[16]

Family routines included the parents' visits to England during hunting season and family sojourns at the villa at Dieppe, the château at Saint-Amadour in Anjou, or the older and larger property in a village called Broglie (pronounced brog-lee), about 150 kilometers from Paris in Normandy in the Eure. The Normandy château dated to the first duc de Broglie. In the early 1900s, its library of more than forty thousand volumes was said to be the second largest private library in France and included all the books that had belonged to Mme. de Staël.[17]

Because of the habits of travel among aristocrats, it was customary to employ an *institutrice* or *précepteur* so that the children's education would not be interrupted as the family moved from one residence to another. The presence of English personnel in good French families, especially in Paris, was common from the end of the eighteenth to the middle of the twentieth century, and the de Broglies employed English nannies as well as tutors who were clergymen.[18]

For the de Broglies, as for other older families, the family châteaus and residences were, as they remain, sites of immensely important archives and possessions: maps, acts of sale, testaments, autobiographical texts, letters, books, coats of arms, paintings, and portraits. Furnishings, silverware, serving pieces, all in use, were objects literally linking present and past. Selling the family property was a kind of treason—treason not just to the family tradition, but to the *patrie* of France itself. As one aristocrat, a man born in 1925, said: "When a property is sold, it is a page of history which disappears, a library which burns."[19] The de Broglies sold the large Paris hôtel in 1902, moving to a smaller residence nearby, in order to keep the château in Broglie.

And what were aristocrats to do? At the core of aristocratic values was the conception of service, rooted in religious, military, and diplomatic service to the state. Service "careers" in diplomacy and banking, and in government administration at the highest levels, were acceptable, but work in "professions" like law, medicine, and education was denigrated as nothing more than a "job." Most important in choosing an activity was its identification as a "métier of the generalist," in which the emphasis was on coordination and leadership rather than on specialization.[20] These were the standards with which Maurice de Broglie came to personal and family compromise when he resigned from the navy in 1908 in order to do physics.

[15] Mension-Rigau, *Aristocrates et grands bourgeois* (cit. n. 12), pp. 58–59, 99, 320 n 4.

[16] *Ibid.*, pp. 59–61, 78, 320; and Comtesse de Pange, *Comment j'ai vu 1900,* Vol. 1, pp. 27–31.

[17] Comtesse de Pange, *Comment j'ai vu 1900,* Vol. 1, p. 228. See also Varende, *Les Broglie* (cit. n. 11), p. 312; and Dominique de Broglie, *Les Broglie* (cit. n. 11).

[18] Mension-Rigau, *Aristocrates et grands bourgeois* (cit. n. 12), pp. 29–30, 300–316.

[19] *Ibid.*, pp. 117, 135, 365–367, 111.

[20] *Ibid.*, pp. 374–375.

THE DE BROGLIES AS SAVANTS

As was expected of him, Maurice completed studies at the Collège Stanislas, an elite Catholic secondary school, where he enjoyed very good instruction in mathematics and science. He matriculated at the Ecole Navale and entered the navy as an officer in 1897. Assigned to a ship in the Mediterranean, he studied physics, chemistry, and astronomy at the Sciences Faculty in Marseilles at just the time that X rays, uranium rays, and electrons were all in the news. He formally took a degree in the physical sciences in 1901.[21]

Maurice's grandfather had been ambassador to London and cabinet minister in that early period of the Third Republic often called the "république des ducs," when royalists and Bonapartists still hoped to fashion a republican regime in which a monarch played a role. Learning that Maurice was thinking of resigning his naval commission and embarking for the Cavendish Laboratory in England, this duke wrote his grandson, whom he rightly expected to become the sixth duc de Broglie, that his youth should be better spent: "You are always thinking about scientific studies and ending your military career. Science is an old woman that one can court later and who does not fear the tributes of old men. Academies do not make for happiness."[22]

In his will, the grandfather explicitly left to Maurice the portrait of the maréchal de Broglie and a copy of one of the historical lectures of his own father, the third duke. From these two examples, the grandfather wrote, Maurice should choose between the traditions of the family "which you head and of which you must be worthy." Maurice's first scientific publication, a paper on wireless telegraphy and electric waves, appeared in 1902, the year following his grandfather's death.[23]

Maurice de Broglie's decision to resign from the navy in 1908 came as no surprise to the family. For years he had been storing electrical batteries, coils, tubes, and sparking apparatus on the shelves of Louis XV armoires in the family residences in Paris and Broglie. He had taken a leave and married Camille de Rochetaillée in 1904, setting up both a residence and a laboratory in the rue Chateaubriand. His younger siblings Pauline and Louis spent a great deal of time visiting their brother's home and laboratory, where Maurice's valet Alexis Caro found a secondary avocation as a laboratory technician.[24]

The two youngest children were close companions, living at home with only their mother and grandmother after their father's death in 1906. Pauline was not inclined to follow the example of her elder sister Albertine, who had married and led a private life as was expected of her. In 1902, when Pauline was fourteen, she developed a passionate interest in geology and archaeology. A few years later, while staying with her sister's family at Beaurepaire, she wrote a small article on a nearby neolithic archaeological station and sent it to the journal *L'Homme Préhistorique.* Albertine's husband warned Pauline that nothing

[21] André Gougenheim, *Maurice de Broglie* (Paris: Académie de Marine, 1961), p. 7; and Pierre Lépine, *Notice sur la vie et les travaux de Maurice de Broglie (1875–1960)* (Paris: Institut de France, Académie des Sciences, 1962), pp. 6–7.

[22] Gougenheim, *Maurice de Broglie,* p. 7; see also Comtesse de Pange, *Comment j'ai vu 1900,* Vol. 1, pp. 213–214. The original French in Gougenheim reads: "Tu penses toujours aux études scientifiques et à la fin de ta carrière. La science est une vieille dame qu'on peut courtiser plus tard et qui ne craint pas les hommages des gens mûrs. Les Académies ne font pas les bonheur." The phrase "république des ducs" refers to the first period, 1871–1877, of the Third Republic.

[23] Gougenheim, *Maurice de Broglie,* p. 10. For Maurice's first scientific publication see Maurice de Broglie, "Application des galvanomètres thermiques à l'étude des ondes électriques, recherches faites à bord des bâtiments de guerre," *Comptes Rendus de l'Académie des Sciences,* 1902, *134:*349–352.

[24] Comtesse de Pange, *Comment j'ai vu 1900,* Vol. 1, pp. 167–176, Vol. 2, pp. 117, 121; and Wheaton, "Laboratory of Maurice de Broglie" (cit. n. 5), p. 29.

could do more harm to the reputation of a young girl than passing for a "bas-bleu" (blue-stocking). Within a few more years, he was accusing Pauline of discouraging suitors "by talking about dinosaurs."[25]

After the death of their father, with Maurice now holding the title of duc de Broglie, a decision was made that Louis would be sent not to the Collège Stanislas but to a state school, the Lycée Janson de Sailly, accompanied by his preceptor Father Chanet. Maurice strongly favored this plan because his former Marseilles physics instructor, Léopold Brizard, now taught at the lycée.[26]

By this time Maurice had begun working with Paul Langevin and had set up apparatus in his rue Chateaubriand laboratory to study the Brownian motion of ionized smoke particles. Using an ultramicroscope placed in an electric field, he could measure the particles' electric charge. This was the kind of project on which Robert Millikan, for example, was working at the University of Chicago. In 1908 Pauline, Albertine, Camille, and Louis all gathered for Maurice's thesis defense before the Sorbonne jury. That same year Maurice resigned from active duty in the navy.[27]

About this time, too, Pauline began to give in to her brother-in-law on the matter of scientific studies, although she never completely abandoned her interest in archaeology and continued to publish occasional pieces on ancient sites through the 1920s. Drawing upon the reservoir of family archives, she embarked on what would become a life of literary studies, first publishing letters from Napoleon's sister Elisa Bonaparte to the de Broglies' great-grandfather the comte de Ségur. The article appeared in September 1908 in the *Revue Hebdomadaire* under her name: Pauline de Broglie.[28]

She also attended lecture courses at the Sorbonne, Collège de France, and Ecole d'Anthropologie, always in the company of a chaperon. Efforts to marry her to an Italian prince came to nought, and in October 1910, only months after their first introduction, she married the comte Jean de Pange, a scholar and linguist who had first noticed her through the *Revue Hebdomadaire* essay. The newly married couple traveled often and widely, visiting Max Planck's laboratory in Berlin in the winter of 1913 in the company of Maurice's new English friend Frederick A. Lindemann.[29] Louis was now at home alone.

Recollecting his younger brother's activities around 1910, Maurice later said: "I refrained from imparting a rigid direction to the studies of my brother, although at times his vacillations gave me some concern. He was good in French, history, physics, philosophy, indifferent in mathematics, chemistry, and geography, poor in drawing and foreign languages."[30]

However, in 1911, following his baccalaureate and university studies in philosophy, mathematics, and science, new inspiration came to Louis de Broglie. When the first Solvay Council in Physics was organized in Brussels in autumn 1911, Langevin suggested that

[25] For Pauline's interest in geology and archaeology see Comtesse de Pange, *Comment j'ai vu 1900,* Vol. 2, p. 45. Her first article appeared in *L'homme préhistorique: Revue mensuelle illustré d'archaeologie et d'anthropologie préhistorique,* Vol. 7 (Paris: Schleicher Frères, 1905). The complaints of her brother-in-law are reported in Comtesse de Pange, *Comment j'ai vu 1900,* Vol. 3, pp. 20, 83–84, 108.

[26] See Abragam, "Louis de Broglie" (cit. n. 11), p. 26; and Lochak, *Louis de Broglie* (cit. n. 5), p. 37.

[27] See Wheaton, "Laboratory of Maurice de Broglie" (cit. n. 5), p. 29; Comtesse de Pange, *Comment j'ai vu 1900,* Vol. 3, p. 125; and Lépine, *Notice sur la vie et les travaux de Maurice de Broglie* (cit. n. 21), p. 11.

[28] Comtesse de Pange, *Comment j'ai vu 1900,* Vol. 3, p. 126. An incomplete list of the comtesse Jean de Pange's publications, emphasizing those bearing on the de Broglie heritage, can be found in Dominique de Broglie, *Les Broglie* (cit. n. 11), pp. 515–517.

[29] Comtesse de Pange, *Comment j'ai vu 1900,* Vol. 3, pp. 140–141, 228–230.

[30] Quoted in Abragam, "Louis de Broglie" (cit. n. 11), pp. 26–27, from Maurice de Broglie's remarks on the occasion of the sixtieth birthday of Louis de Broglie.

Maurice de Broglie serve as secretary and coeditor of the published volume of papers and minutes of discussions.[31] Maurice showed his younger brother the page proofs. Here Louis read scientific debates between French physicists whose names he knew—Perrin, Marcel Brillouin, Henri Poincaré, and Langevin—and foreign physicists whom his brother had just met—Planck, Einstein, Walther Nernst, Hendrik A. Lorentz, Arnold Sommerfeld, Ernest Rutherford, and Lindemann.

Pauline later reminisced that she soon found Louis holed up in a small room with manuals of mathematics. And she was not sure that she liked what she saw: "The amiable *petit prince* and charmer that I had known all through my childhood had disappeared forever. With a determination and an admirable courage he was transforming himself little-by-little every month into an austere scientist leading a monastic life."[32]

It was not easy. Although Louis had attended a course in special mathematics in preparation for the license in science, he had failed the part of the examination in general physics that dealt with periodic phenomena (sound and light waves). Now, inspired by his new acquaintance with the most up-to-date theories in physics, he passed the whole set of exams with distinction and received the degree in 1913.[33]

In August 1914 the war intervened. With her husband at the front, Pauline volunteered to collect funds and supplies in support of an ambulance service. The woman who had never left home unaccompanied before her marriage donned a short skirt and made thirteen train trips to the front in the next eighteen months.[34]

Maurice, who had worked in telegraphy in the navy, returned to a navy wireless station at Bordeaux before his transfer in 1915 to the Ministry of Inventions in Paris. (See Figure 2.) Louis de Broglie entered the war in the corps of engineers and became attached to the Service of Wireless Communication in Paris. While living with his mother and grandmother, he served in the wireless telegraph unit operating at the base of the Eiffel tower throughout the war.[35]

Their grandmother Célestine de Ségur died shortly after the armistice. With Alsace-Lorraine restored to France, Pauline and her husband moved to Strasbourg in 1920. There they spent six years organizing activities in support of the restored French University of Strasbourg. Conferences at their country villa promoted Franco-German reconciliation, with visiting lecturers including Thomas Mann and Maurice Barrès. The eighteenth-century salon was transformed into the twentieth-century conference.

While in Strasbourg, Pauline studied prehistoric artifacts and wrote a novel centered on the French return to Alsace, *Le beau jardin.*[36] When they returned to Paris in the late 1920s, Jean and Pauline continued their writing projects: he focused principally on historical themes, many of them mystical and Christian; and she eventually wrote a doctoral thesis (1938) on Guillaume Schlegel and Mme. de Staël that was printed in fifty thousand copies. Elected to the jury of the Prix Femina in 1943 and to the Legion of Honor in 1949,

[31] For the published volume see Paul Langevin and Maurice de Broglie, eds., *La théorie du rayonnement et les quanta* (Paris: Gauthier-Villars, 1912). See Wheaton, "Laboratory of Maurice de Broglie" (cit. n. 5), p. 30.

[32] Comtesse de Pange, *Comment j'ai vu 1900,* Vol. 3, p. 226.

[33] Abragam, "Louis de Broglie" (cit. n. 11), pp. 27–28.

[34] Comtesse de Pange, *Comment j'ai vu 1900,* Vol. 3, p. 253, Vol. 4, pp. 29–43, 71.

[35] See Paul Germain, *Louis de Broglie ou la passion de la "vraie" physique: Lecture faite 7 décembre 1987 par Paul Germain, sécrétaire perpétuel* (Paris: Institut de France, 1987), p. 13.

[36] See Comtesse Jean de Pange, "Ornements primitifs sur les parois extérieures de maisons paysannes alsaciennes," *L'Art Populaire en France,* 1929, *1:*217–220. The novel was published under the pseudonym "Songy," first in serialized form and then as a single volume: "Le beau jardin," *Revue des Deux Mondes,* 1923, *93:*290–331, 531–574, 806–843; then *Le beau jardin* (Paris: Plon-Nourrit, 1923).

Figure 2. *Maurice de Broglie, about 1914. Studio Eugène Pirou. (Courtesy of Archives de l'Académie des Sciences, Paris.)*

Pauline was also a successful guest lecturer abroad. (See Figure 3.) The couple's sympathy for Germany was ill paid, however. Jean de Pange was arrested by the Gestapo and imprisoned for six months in 1941.[37]

THE DE BROGLIES AND THE NEW PHYSICS

For Maurice de Broglie, the end of World War I meant a return to the laboratory that he loved and the establishment of a research school in physics independent of any formal university or school connection. He continued with work begun just before the war, when

[37] On the couple's activities and Pauline's honors see Jean de Pange to Frederick Lindemann, 16 Feb. 1940, 5 Jan. 1946, K:89, Lindemann Papers, Nuffield College, Oxford; on Jean de Pange's imprisonment see Jean de Pange to Lindemann, 6 Oct. 1944, *ibid.* Regarding their work see *Hommage à Jean de Pange* (Paris: Grasset, 1959); and "Commemoration du séjour à la Schlettenbach-Saverne (1920–1925) du comte et de le comtesse Jean de Pange," *Pays d'Alsace,* 12 Oct. 1975, no. 89 (offprint), and "Remise de la Croix de Chevalier de la Légion d'Honneur à la Comtesse Jean de Pange par son frère, le Duc de Broglie au cours d'une réunion organisée par la Société des études Staëliennes dans l'Hôtel de la Duchesse de Gramont, le 14 janvier 1950" (offprint), both in Bibliothèque Nationale, Paris. See also Dominique de Broglie, *Les Broglie* (cit. n. 11), pp. 162–163.

Figure 3. *Pauline de Broglie, the Comtesse Jean de Pange, about 1929. She completed a doctoral thesis in literary studies at the University of Paris in 1938, becoming with her brothers Maurice and Louis the first members of the family to take university doctoral degrees. (From the weekly* Les Nouvelles Littéraires Artistiques et Scientifiques, *14 September 1929, Volume 8, page 8.)*

he found that slow rotation of the crystal used for analyzing X rays reduces what Henry Moseley had called "the horrid diffraction fringes" of early diffraction pictures.[38]

[38] Bruce Wheaton, *The Tiger and the Shark: Empirical Roots of Wave-Particle Dualism* (Cambridge: Cambridge Univ. Press, 1983), p. 264. William Wilson credits Maurice de Broglie as the first scientist to study spectra with a revolving crystal: William Wilson, "Maurice, le Duc de Broglie," *Biog. Mem. Fellows Roy. Soc.*, 1961, 7:30–36, on p. 32.

During the course of the war Maurice had been able to continue experiments from time to time at the rue Chateaubriand. He maintained a correspondence with Lindemann, among others, about his work with the new Coolidge tubes, inquiring whether Lindemann had been able to do any work at his country estate at Sidholme. The two friends had coauthored three publications on X rays in 1913 and 1914. Maurice assured Lindemann that a room was always ready for him at the rue Chateaubriand and insisted that he must also visit the château at Broglie.[39]

By 1925, laboratory life on the rue Chateaubriand and an adjacent building on rue Lord Byron was so well resumed that Maurice de Broglie enlarged the facilities, with one section still devoted to X rays and another later opened for nuclear science, eventually including studies of cosmic rays. The laboratory staff was made up of young men who were completing their doctoral degrees or had recently done so. They assembled on Wednesdays for regular discussions and reports about Bohr's theory of the atom, X-ray diffraction and spectroscopy, the photoelectric effect, and the spectrography of electrons.[40]

In 1921 Maurice de Broglie received an honorary doctorate from the University of Oxford, where his friend Lindemann was now head of the Clarendon Laboratory. Maurice was nominated, but defeated, for election to the Academy of Sciences in late 1920, then successfully elected in 1924. His election was to the section of "académiciens libres," rather than to the physics section, in the academy's recent tradition of rewarding men, as the historian Maurice Crosland has put it, "whose careers transcended those of the ordinary specialist." The section for "académiciens libres" had been established in 1816 for the nobility. Henri Deslandres, in supporting de Broglie's candidacy at the academy in 1920, told his colleagues that Maurice de Broglie's was the only work on X-ray spectra that could be cited from France and that it was thanks to him alone that France had not remained completely outside this field of research. Maurice de Broglie had accomplished this, said Deslandres, as a "volunteer" for science, in his own laboratory, outside the educational establishment.[41]

The academician and physicist Paul Janet, like others, referred to Maurice de Broglie as a *chef d'ecole.* Researchers in the de Broglie laboratory in the 1920s and early 1930s included Jean-Jacques Trillat (1899–1987), who became director of a CNRS laboratory at Bellevue specializing in X-ray and electron diffraction; Jean Thibaud (1901–1960), who founded the Institute of Atomic Physics at Lyon and investigated the continuous spectrum of radiations from ultraviolet to X rays; René Lucas (1898–1990), who became director of the Ecole de Physique et de Chimie de Paris from 1947 to 1969 and professor of general

[39] There is extensive correspondence in Lindemann's papers with members of the de Broglie family, including both Pauline and her husband Jean, Maurice de Broglie, and Maurice's wife Camille de Rochetaillée. For the correspondence mentioned here see Maurice de Broglie to Lindemann, 17 July 1915, 18 Aug. 1916 (work during the war), D:43; 23 Mar. 1913, 2 Mar. 1914 (room at rue Chateaubriand), D:43; and 20 June 1919 (postcard; invitation to Broglie), A:23, Lindemann Papers. For the coauthored publications see Maurice de Broglie and F. A. Lindemann, "Sur les phénomènes optiques présentés par les rayons de Röntgen rencontrant des milieux cristallins," *Compt. Rend. Acad. Sci.,* 1913, *156:*1461–1463; Maurice de Broglie and Lindemann, "Observation fluoroscopique par vision directe des spectres des rayons de Röntgen," *ibid.,* 1914, *158:*180–181; and Maurice de Broglie and Lindemann, "Sur un nouveau procédé permettant d'obtenir très rapidement les spectres des rayons de Röntgen," *ibid.,* p. 944.

[40] On the enlarged facilities see Gougenheim, *Maurice de Broglie* (cit. n. 21), p. 13. For the Wednesday discussions see Louis de Broglie, *Savants et découvertes* (Paris: Albin Michel, 1951), p. 301; and Lépine, *Notice sur la vie et les travaux de Maurice de Broglie* (cit. n. 21), p. 19.

[41] Maurice Crosland, *Science under Control: The French Academy of Sciences, 1795–1914* (Cambridge: Cambridge Univ. Press, 1992), pp. 405–409, on p. 409; and Henri Deslandres, "Rapport sur les trauvaux de M. de Broglie: Candidat à une place vacante dans la Section des Académiciens libres, nov. 1920," 5-page handwritten MS, Dossier Maurice de Broglie, Archives, Académie des Sciences.

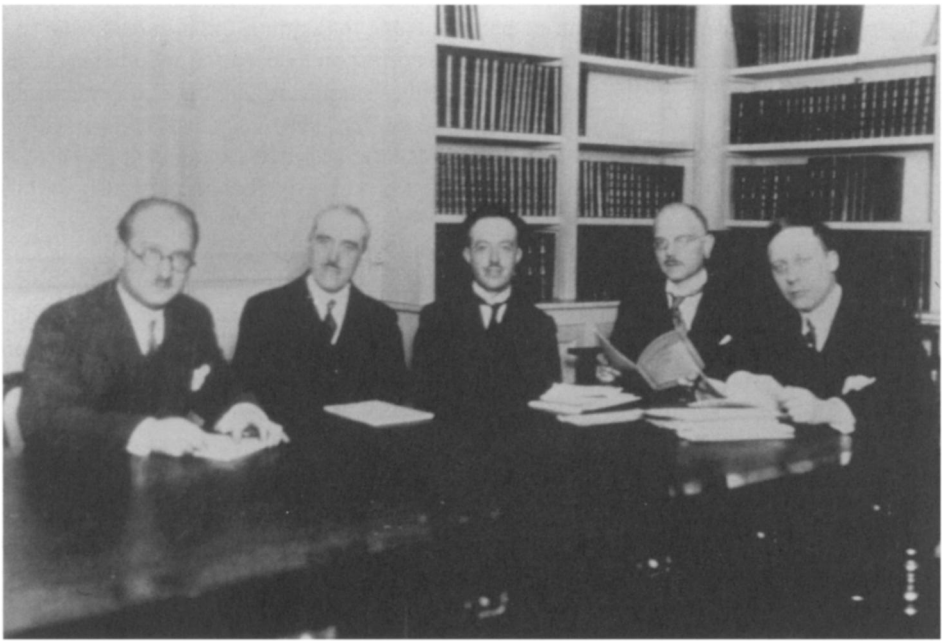

Figure 4. *The library and working room of Maurice de Broglie at his private residence on rue Chateaubriand, in 1925.* Left to right: *Jean Thibaud, Maurice de Broglie, Louis de Broglie, Alexandre Dauvillier, and Jean-Jacques Trillat. (Courtesy of Archives de l'Académie des Sciences, Paris.)*

physics at the University of Paris (1956–1968); Louis Cartan, a talented spectroscopist who taught at Poitiers and was assassinated by the Germans during Vichy; and Louis Leprince-Ringuet (b. 1901), who became professor at the Ecole Polytechnique in 1936 and professor of nuclear physics at the Collège de France in 1959, specializing in high-energy studies including cosmic rays. Leprince-Ringuet first visited the laboratory in 1929 in order to see his cousin Trillat. Maurice de Broglie recruited Leprince-Ringuet as a research assistant because his experience as an electrical engineer for the PTT (the national post and telecommunications office) nicely suited him for work with instruments to detect and count nuclear particles produced by artificial radioactivity.[42] (See Figure 4.)

Since de Broglie's laboratory did not have a chemist with radiochemical skills to prepare polonium sources, investigations increasingly moved toward the study of cosmic rays, leaving nuclear physics to the Curie Institute and the Collège de France. Pierre Auger (1899–1993) and the Soviet physicist Dmitry Skobeltzyn (b. 1892) collaborated with Leprince-Ringuet between 1929 and 1931 to study variations in intensity of cosmic radiation under the influence of magnetic fields. Bruno Rossi arrived at the laboratory in 1932 in order to learn techniques of work with the proportional amplifier and introduced, in turn,

[42] Paul Janet, "Rapport sur les titres et les travaux de M. Maurice de Broglie (février 1924): Comité secret du 18 février 1924," 2-page typescript, Dossier Maurice de Broglie. On the researchers at Maurice de Broglie's laboratory see *Inventeurs et scientifiques: Dictionnaire de biographies* (Paris: Larousse, 1994). For the recruitment of Leprince-Ringuet see Louis Leprince-Ringuet, "Louis, Maurice et le laboratoire," *Vie Sci.*, 1992, *9*:325–329, on pp. 326, 327; and "La vie et l'oeuvre de Jean-Jacques Trillat," *ibid.*, 1987, *5*:473–477, on p. 474. See also Jeffrey Alan Hughes, "The Radioactivists: Community, Controversy, and the Rise of Nuclear Physics" (Ph.D. thesis, Univ. Cambridge, 1993), p. 233.

the method of electronic coincident counters for the study of the secondary cosmic radiation in cascade showers.[43]

The funds for apparatus and materials at de Broglie's laboratory came not simply from the largesse of the de Broglie and Rochetaillée families, but through grants from the government's Caisse Nationale des Sciences and from private industrial firms like Thomson and Philips. The laboratory's cloud chamber, modified from a Cambridge Scientific Instruments Company apparatus, was the first in France. It eventually was moved to the CNRS laboratories center at Bellevue, where it could be used for studies of cosmic rays along with a powerful electromagnet belonging to the Academy of Sciences. Indeed, de Broglie was generous in letting his coworkers take instruments with them when they left his laboratory for positions elsewhere.[44]

As Bruce Wheaton has noted, Maurice de Broglie was interested in industrial collaboration to a much greater degree than was common among university scientists in France, perhaps because of his navy experience. Internships at de Broglie's laboratory were supported by French industry, including Electricité de France, Les Aciéries de Saint-Chamond, and Les Manufactures Saint-Gobain. Wheaton characterizes the de Broglie townhouse as an electronics research laboratory for industry.[45]

One of the principal researchers at the laboratory in the 1920s was Alexandre Dauvillier, later professor at the Collège de France. He interested himself not only in the absorption and emission of X rays but also in the velocity spectrum and kinetic energies of electrons expelled after X-ray absorption. Dauvillier used electron range in order to estimate electron energy. He arrived at the conclusion that the fastest electron emitted by a target bombarded with X rays possesses the same velocity as the fastest electron in the cathode beam that produces the X rays. Surprisingly, too, the energy of the expelled electron is independent of the distance over which the rays had traveled.[46]

Intrigued, Maurice de Broglie modified the design of a beta-ray velocity spectrometer (of the type used in studies of radioactivity at Rutherford's laboratory at Manchester) and began to study what he called electron particle velocity spectra. These are the patterns of bands formed by secondary electrons deflected into circular paths, thus representing electrons sorted by velocity. By March 1921 de Broglie had studied ten elements, ranging

[43] On the lack of a radiochemist see Hughes, "Radioactivists," p. 235. On the collaboration of Auger, Skobeltzyn, and Leprince-Ringuet see Dmitry Skobeltzyn [Dmitri Skobel'tsyn], "The Early Stage of Cosmic-Ray Research," in *The Birth of Particle Physics,* ed. Laurie M. Brown and Lillian Hoddeson (Cambridge: Cambridge Univ. Press, 1983), pp. 111–119; Pierre Auger, "Some Aspects of French Physics in the 1930s," *ibid.,* pp. 173–176; and Louis Leprince-Ringuet, "The Scientific Activities of Leprince-Ringuet and His Group on Cosmic Rays: 1933–1953," *ibid.,* pp. 177–182. Skobeltzyn was among those Soviet scientists in the early 1950s who rejected the Copenhagen interpretation of quantum mechanics and favored the Bohm and de Broglie interpretations of causality, determinism, and realism. On Rossi's work see Martha Cecilia Bustamante, "Les travaux de Bruno Rossi au début des années trente: Une étape décisive dans la physique des rayons cosmiques," *Archives Internationales d'Histoire des Sciences,* 1994, *44:*92–115; Leprince-Ringuet, "Notice nécrologique sur le duc Maurice de Broglie," *Compt. Rend. Acad. Sci.,* 1960, *251:*297–303, on p. 301; and Hughes, "Radioactivists," p. 241.

[44] On family resources, it was said by Jean Guitton that "les Rochetaillée, par leur fortune, ont permis au duc Maurice de créer à Paris le premier centre atomique": Jean Guitton, "Le duc Louis de Broglie: Témoignage sur l'homme que j'ai connu," *Vie Sci.,* 1992, *9:*331–334, on p. 331. For Maurice de Broglie's generosity with regard to laboratory instruments see Jean-Jacques Trillat, "Reminiscences sur la diffraction électronique," May 1980, photocopy of 5-page handwritten MS, in Dossier Louis de Broglie; and Leprince-Ringuet, "Notice nécrologique sur le duc Maurice de Broglie," p. 302.

[45] Wheaton, "Laboratory of Maurice de Broglie" (cit. n. 5), p. 31. See also Leprince-Ringuet, "Notice nécrologique sur le duc Maurice de Broglie"; and Hughes, "Radioactivists" (cit. n. 42), p. 232.

[46] René Ledoux-Lebard and Alexandre Dauvillier, *La physique des rayons x* (Paris, 1921), pp. 208, 399; reported in Wheaton, *Tiger and the Shark* (cit. n. 38), pp. 265–266.

from copper to ytterbium, and he had constructed formulas for calculating the energy level of a vacated Bohr orbit from the kinetic energy of the released electrons. He presented these results at the Solvay Council in Brussels in April 1921. The work excited considerable discussion, along with data for gamma rays reported by Charles Ellis of Manchester.[47]

The problematic aspect of these results was the following: if X rays are a wave spreading spherically from the point of production, it makes no sense that a segment of the wavefront can hit an electron with as much energy as possessed by the initial electron-producing wave. Here was support for Einstein's theory of the photoelectric effect. The radiation "must be corpuscular," wrote Maurice de Broglie in the final version of his Solvay paper, "or, if it is undulatory, its energy must be concentrated in points on the surface of the wave."[48]

Struck by the visual correspondence between the electron velocity spectrum and the X-ray spectra, Maurice de Broglie began to emphasize a formal correspondence between the behavior of electrons and radiations. In a 1922 book on X rays he wrote: "There is something *kinetic* in the vibratory radiation, and something *periodic* in the projections of corpuscles; all of this suggests, more and more every day, that the same reality manifests itself, sometimes under its kinetic face, some other times under its undulatory face."[49] This appears to be the first substantive suggestion of a symmetry in wave and particle phenomena for both electrons and radiations.

LOUIS DE BROGLIE'S WAVE MECHANICS

Louis de Broglie attended Langevin's courses on radiation and relativity theory at the Collège de France in the early 1920s. It seems likely that he heard Einstein lecture at the Collège de France in April 1922, since Langevin invited Einstein. Louis de Broglie later recalled the insistence with which his elder brother directed his attention "to the importance and the undeniable accuracy of the dual particulate and wave properties of radiation." Among their collaborations in this period was a series of papers on the Bohr atom, the photoelectric effect, and what they called "corpuscular spectra." This work caught the attention of physicists at Bohr's institute: Hendrik Kramers criticized the way in which Louis had applied Bohr's correspondence principle, although the results were correct.[50]

In 1922 Louis de Broglie sketched out an analogy between mathematical laws of radiation and a wavelike law of hydrodynamics that governs the macroscopic behavior of large numbers of water molecules. He thought a good deal about statistical mechanics. He

[47] Wheaton, *Tiger and the Shark,* pp. 267, 268.

[48] Maurice de Broglie, "La relation hν = E dans les phénomènes photoélectriques," in *Atomes et électrons* (Paris: Gauthier-Villars, 1923), pp. 80–100, on p. 89. See Wheaton, "Laboratory of Maurice de Broglie" (cit. n. 5), p. 32; and Wheaton, *Tiger and the Shark,* p. 270. See also Olivier Darrigol, "Strangeness and Soundness in Louis de Broglie's Early Works," *Physis,* 1993, *30:*303–372, on pp. 319–321.

[49] Maurice de Broglie, *Les rayons x* (Paris: Blanchard, 1922), p. 17; quoted in Darrigol, "Strangeness and Soundness," p. 321 (emphasis added). See also Wheaton, "Laboratory of Maurice de Broglie," p. 32, who cites, in addition, Maurice de Broglie, "X-Rays and Beta-Rays," in *British Association for the Advancement of Science: Report* (London: Murray, 1992), pp. 352–353.

[50] Louis de Broglie, *Savants et découvertes* (cit. n. 40), p. 302. For the collaborative articles see Maurice de Broglie and Louis de Broglie, "Sur le modèle d'atome de Bohr et les spectres corpusculaires," *Compt. Rend. Acad. Sci.,* 1921, *172:*746–748; Maurice de Broglie and Louis de Broglie, "Sur les spectres corpusculaires des éléments," *ibid., 173:*939–941; and Maurice de Broglie and Louis de Broglie, "Remarques sur les spectres corpusculaires et l'effet photoeléctrique," *ibid.,* 1922, *175:*1139–1141. On the Copenhagen criticism see Darrigol, "Strangeness and Soundness," pp. 316–317.

reviewed Einstein's papers on the nature of light and considered how relativistic effects might be incorporated into a theory of particles and waves, and he began to feel that any results for atoms of light must be applied to atoms of matter as well.[51]

"Suddenly, at the end of the summer of 1923," Louis de Broglie later recalled, "all of these ideas seemed to crystallize in my mind." Every particle of matter or of light, he suggested, is accompanied by a wave so that there is a moving point in space where the frequency reported by a stationary observer and the frequency reported by an observer on the moving particle always remain in phase as a point of constructive interference. In 1923 he published three papers in the weekly *Comptes Rendus* of the Academy of Sciences that attempted to reconcile quanta, relativity, and the electron. The following year he defended a doctoral thesis before a Sorbonne jury.[52]

Reasoning by analogy from the quantum theory of radiation and the photon theory of light, de Broglie proposed to associate a real physical wave with any moving particle like an electron. Using relativistic arguments, he derived the value of a wavelength,

$$\lambda = h/mv,$$

in relation to the quantum of action and momentum of the electron, thus associating a wavelength directly with a particle for the first time. He predicted at his thesis defense that a group of electrons that passes through a small aperture should show diffraction effects.[53]

An often-repeated story appears to be true. Meeting the philosopher Léon Brunschvicg in the Quartier Latin after having first glanced at the thesis, Langevin commented, "I am taking with me the little brother's thesis. Looks far-fetched to me." A closer reading and a brief encounter with his friend Einstein in Geneva led Langevin to instruct the thirty-one-year-old "little brother" to mail the thesis to Einstein. Langevin soon had Einstein's opinion: "He has lifted a corner of the great veil."[54]

Among the audience at the thesis defense was R. J. Van de Graaff (1901–1967), who was studying at the Sorbonne. "Never," he said later, "had so much gone over the heads

[51] He also drew some ideas from recent work of Marcel Brillouin explaining how an electron describing a continuous orbit might be subject to discontinuous quantum laws. See Wheaton, *Tiger and the Shark* (cit. n. 38), p. 287. On the analogy see *ibid.,* p. 276. For pertinent publications see Louis de Broglie, "Rayons x et équilibre thermodynamique," *Journal de Physique,* 1922, *3:*33–45; and Louis de Broglie, "Sur les interférences et la théorie des quanta de lumière," *Compt. Rend. Acad. Sci.,* 1922, *175:*811–813.

[52] Louis de Broglie, "Vue d'ensemble sur mes travaux scientifiques," in *Louis de Broglie: Physicien et penseur,* ed. André George (Paris: Albin Michel, 1953), pp. 457–486, on p. 461; quoted in Wheaton, *Tiger and the Shark,* p. 288. The jury for the Sorbonne defense included the crystallographer Charles Mauguin, the mathematician Elie Cartan, Jean Perrin, and, as external examiner, Paul Langevin.

[53] See Wheaton, "Laboratory of Maurice de Broglie" (cit. n. 5), p. 33; Louis de Broglie, "Ondes et quanta," *Compt. Rend. Acad. Sci.,* 1923, *177:*507–510; Louis de Broglie, "Quanta de lumière, diffraction et interférence," *ibid.,* pp. 548–550 (see p. 549); and Louis de Broglie, *Recherches sur la théorie des quanta* (Paris: Masson, 1924).

[54] Abragam, "Louis de Broglie" (cit. n. 11), p. 30; and Darrigol, "Strangeness and Soundness" (cit. n. 48), p. 355. Pauline de Broglie claimed that Jean Perrin remarked to Maurice about the thesis: "All that I can say is that your brother is very intelligent." Comtesse de Pange, *Comment j'ai vu 1900,* Vol. 4, p. 174. For Langevin's report on the thesis, signed by Jean Perrin, see the photocopy reprinted in *Louis de Broglie que nous avons connu* (Paris: Fondation Louis de Broglie/Conservatoire National des Arts et Métiers, 1988), unnumbered pages preceding p. 1. This report is also reprinted in Bensaude-Vincent, *Paul Langevin* (cit. n. 13), pp. 161–164. Einstein's interest appears to have been provoked especially by de Broglie's treatment of fluctuations at a time when Einstein was rethinking S. N. Bose's application of statistical mechanics to light quanta. See Darrigol, "Strangeness and Soundness," p. 356; and Abraham Pais, "De Broglie, Einstein, and the Birth of the Matter Wave Concept," *Einstein Lived Here* (Oxford: Clarendon, 1994), pp. 42–53.

of so many." Within a year Paul Dirac asked Louis de Broglie for a copy of the thesis. It was studied in Munich by Arnold Sommerfeld and in Göttingen by Werner Heisenberg, Max Born, and Pascual Jordan. In March 1926 Erwin Schrödinger wrote de Broglie that he had extended de Broglie's ideas into a new theory of his own.[55]

As Louis de Broglie, encouraged by his elder brother, grappled with these problems, the Nobel Prizes for 1921 and 1922 were announced in late 1922: the first to Einstein and the second to Niels Bohr. In his rationale for these awards, the Swedish physicist C. W. Oseen noted that Maurice de Broglie's X-ray investigations formed the link between Einstein's and Bohr's work. Building on the theory of the photoelectric effect, Maurice de Broglie's results verified Bohr's atomic structure down to the innermost shells of the atom.[56]

Three years later, in 1925, both Louis de Broglie and Maurice de Broglie were nominated for the 1925 Nobel Prize in Physics by the Leningrad physicist Orest Khvol'son (b. 1852), who cited their work in the field of X rays. Again in 1926 Khvol'son nominated the two brothers. In 1928 he nominated Louis alone, mentioning his investigations in X rays but pointing especially to his foundation of wave mechanics, which, Khvol'son said, resolves the twenty-year struggle between the wave theory and the quantum theory of light. In that same year Maurice was nominated by Hjalmar Tallqvist and Jarl A. Wasastjerna of Helsinki for his contributions in X-ray diffraction and absorption, as well as secondary beta rays. In 1929, the year that Louis de Broglie received the Nobel Prize in Physics, he had twelve separate nominations and Maurice none.[57] (See Frontispiece.)

By this time the experimental effects that were predicted for the wave theory of matter had been confirmed. Photographs of electron interference were obtained by Clinton J. Davisson and Lester H. Germer at Bell Laboratories in New Jersey and by George P. Thomson, son of J. J. Thomson, in Aberdeen. These results were available for the Solvay physics conference of 1927, although a 1925 paper by James Franck's student Walter Elsasser led some physicists to think that Davisson and C. H. Kunsmann's experimental results of 1921 to 1923 on the reflection of electrons also registered their wave character. Another candidate for confirming evidence was the transparency of noble gases to slow electron beams (the Ramsauer effect).[58]

In his letter nominating Louis de Broglie for the 1929 Nobel Prize, Jean Perrin enclosed a photographic plate of electron diffraction obtained at Paris by Maurice Ponte, clearly emphasizing that de Broglie's theoretical work had been confirmed experimentally.[59] Louis de Broglie, hoping for confirmation at his brother's laboratory, had asked Dauvillier to

[55] Van de Graaff is quoted in Abragam, "Louis de Broglie," pp. 29–30. On others who were interested see Lochak, *Louis de Broglie* (cit. n. 5), pp. 118–119.

[56] Cited from C. W. Oseen, "Den Borska atomteorien," 34-page recommendation of Niels Bohr for the 1922 Nobel Prize in Physics, Nobel Archives, Royal Swedish Academy of Sciences, Stockholm, in Wheaton, *Tiger and the Shark* (cit. n. 38), p. 281.

[57] Orest Chwolson [Khvol'son] to Nobel Committee for Physics, 8 Jan. 1925, 11 Jan. 1928; and Hjalmar Tallqvist and Jarl A. Wasastjerna to Nobel Committee for Physics, 21 Jan. 1928, Nobel Archives. See Elisabeth Crawford, J. L. Heilbron, and Rebecca Ullrich, *The Nobel Population, 1901–1937* (Berkeley: Office for History of Science and Technology, Univ. California; Uppsala: Office for History of Science, Uppsala Univ., 1987).

[58] Louis Michel, "Louis de Broglie: Le savant," *Vie Sci.,* 1992, *9:*335–340, on p. 338; Arturo Russo, "Fundamental Research at Bell Laboratories: The Discovery of Electron Diffraction," *Historical Studies in the Physical Sciences,* 1981, *12:*117–160; and Darrigol, "Strangeness and Soundness" (cit. n. 48), p. 357. Walter Elsasser's paper was "Bemerkungen zur Quantenmechanik freier Elektronen," *Naturwissenschaften,* 1925, *13:*711.

[59] Jean Perrin to the Nobel Committee for Physics, 26 Jan. 1929, Nobel Archives. In this letter Perrin explicitly reiterated that it was Louis and not Maurice de Broglie whom he was nominating, noting that Maurice had made contributions in the different domain of X rays.

give it a try. After some failures, Dauvillier abandoned the project.[60] Had the confirmation come from Maurice de Broglie's laboratory, the Nobel Prize might well have been a joint award to the two brothers.

Certainly the family expected that the brothers would be honored with joint award of the prize, and some members of the French scientific community later expressed surprise that a Nobel had not honored both Maurice's experimental work and Louis's theoretical work.[61] There were, after all, precedents for family awards: the 1903 Nobel Prize in Physics to wife-and-husband Marie and Pierre Curie (along with Henri Becquerel) and the 1915 award to father-and-son William Henry Bragg and William Lawrence Bragg.

It is possible that there were doubts about the consistent reliability of experimental work done in de Broglie's laboratory. If so, they arose from an argument during the 1920s between the Copenhagen team of Dirk Coster and George Hevesy and the Paris collaborators Georges Urbain and Alexandre Dauvillier. At issue was the accuracy of spectral lines recorded at the de Broglie laboratory and, thereby, the priority for discovery of chemical element number 72. Bohr and Rutherford privately shared the notion that Dauvillier's reported observations might be the result of self-delusion, a clear slur rooted in the N-ray episode that had damaged the reputation of French scientific work in the early 1900s.[62]

Thus it is conceivable that even if Dauvillier had been able to confirm Louis de Broglie's prediction of electron diffraction, it would not have received much credence in the broader scientific community, particularly among the Copenhagen group, which already had prejudices about French competence in quantum physics. In his letter to the Swedish Academy of Sciences nominating Davisson and Louis de Broglie as third-ranked choices for the 1929 Nobel Prize, James Franck specifically evaluated the work of Schrödinger, Heisenberg, and Born more highly than that of de Broglie.[63]

In December 1929 Pauline and Maurice accompanied Louis to Stockholm for the Nobel award ceremony; Pauline's friend Thomas Mann was also receiving a Nobel Prize. Pauline bantered in a letter to Lindemann afterward that she was working hard on lectures and books and meant also to have the Nobel Prize one day. She added that she supposed her brother Maurice would receive one soon and that it would be good to have three in the family.[64]

[60] Louis de Broglie, *Notice sur les travaux scientifiques* (Paris: Hermann, 1931), p. 30. After visiting de Broglie's laboratory at Easter of 1924, Charles Ellis proposed to Rutherford that they try the test at Manchester, but Rutherford thought his laboratory lacked the proper instrumentation. While at Göttingen at the time that Elsasser published his article, Patrick Blackett attempted a diffraction experiment but gave up after two weeks. Davisson was persuaded to take up diffraction experiments by discussions with Max Born, James Franck, and Douglas Hartree at Oxford in 1926, following Born's lecture on de Broglie's theory and Schrödinger's new wave mechanics at the annual meeting of the British Association for the Advancement of Science. See Russo, "Fundamental Research at Bell Laboratories" (cit. n. 58), pp. 141–145.

[61] Comtesse de Pange, *Comment j'ai vu 1900,* Vol. 4, p. 179; and Maurice d'Ocagne, "Une grande famille académique," *Echo de Paris,* 31 Jan. 1935, in Dossier Maurice de Broglie.

[62] On the dispute about element 72 see Helge Kragh, "Anatomy of a Priority Conflict: The Case of Element 72," *Centaurus,* 1980, *23:*275–301. The dispute was resolved in favor of hafnium (Copenhagen) rather than celtium (Paris). For Bohr's letter to Rutherford see *ibid.,* p. 284. Paul Forman and V. V. Raman have argued that it was Louis de Broglie's association with Dauvillier that "gave him a bad reputation among leading atomic physicists and contributed to the relative neglect of his revolutionary ideas on matter-waves": Paul Forman and V. V. Raman, "Why Was It Schrödinger Who Developed de Broglie's Ideas?" *Hist. Stud. Phys. Sci.,* 1969, *1:*291–314. On the N-rays episode see Mary Jo Nye, "N-Rays: An Episode in the History and Psychology of Science," *ibid.,* 1980, *9:*125–156.

[63] James Franck to the Nobel Committee for Physics, 27 Nov. 1928, Nobel Archives.

[64] Comtesse Jean de Pange to Lindemann, 24 Jan. 1930 (in English), K:90, Lindemann Papers. Mann's Nobel Prize is mentioned in Comtesse de Pange, *Comment j'ai vu 1900,* Vol. 4, p. 188.

DUTY, AVOCATION, MARGINALIZATION

It is too bad that the Nobel award did not come a year earlier. Their mother, with whom Louis still lived, died in 1928, taking to her grave, according to Pauline, the image of Louis as a "ne'er-do-well" who would never give her the heir she longed for. Maurice's only child, a daughter, had died at the age of seven. There were no de Broglie sons. After his mother's death, Louis de Broglie sold their Paris home and moved to the fashionable bourgeois suburb of Neuilly. In the same year he was appointed lecturer at the University of Paris; he became a professor in 1931. When he was named to the Sorbonne, one of his closest friends remarked, "Thus, you have become a *fonctionnaire!*"[65]

In 1931 Louis de Broglie inaugurated a seminar. There were three participants: Claude Magnan, André George, and Jean-Louis Destouches. By the 1950s as many as fifty people gathered for the seminar, which for forty years met every Tuesday afternoon at 3:00. Guests included Max Born, George Darwin, Paul Dirac, Albert Einstein, and Enrico Fermi.[66]

De Broglie's lecture courses at the university's Institut Poincaré were large and formal. The respectful crowd stood as he entered the room and listened in silence as he read in a high-pitched, monotonous voice from a text written in longhand on a sheaf of large sheets. If you wanted to ask a question, recalled the nuclear physicist Anatole Abragam, you requested an appointment, but "after a while rather than attend the lectures you preferred to study his beautifully written books." Michel Eberhardt felt that Louis de Broglie was "by a natural inclination . . . a solitary man, almost marginal, who cared more about making his lectures than about making a school."[67]

Of Louis de Broglie's students, or what might be called the de Broglie "school," Abragam harshly said that, with a few exceptions, they were "disciples" "who were not of the highest intellectual calibre and perhaps not always of the highest intellectual honesty." The atmosphere was one of adulation, he claimed; "wave mechanics," rather than "quantum mechanics," was the preferred subject. "Wave mechanics," the discovery of Louis de Broglie, was thought by this French audience to be highly abstract and difficult conceptually, in contrast to the practice abroad of quantum mechanics as an "everyday tool of the rank and file physicist."[68] The adoption of Louis de Broglie's realist quantum me-

[65] See Abragam, "Louis de Broglie" (cit. n. 11), p. 39; and Lochak, *Louis de Broglie* (cit. n. 5), pp. 148–152, on p. 150.

[66] Lochak, *Louis de Broglie,* pp. 160, 205.

[67] *Ibid.,* p. 211; Abragam, "Louis de Broglie" (cit. n. 11), p. 37; and Michel Eberhardt, "La France a perdu un génie," *Science et Vie,* May 1987, no. 836, pp. 10–25, on p. 19, in Dossier Louis de Broglie. De Broglie wrote more than thirty books. He said of Paul Langevin, in an éloge in 1947, that Langevin had been wrong not to edit and publish his courses, thus depriving future generations of his insights: Louis de Broglie, "Notice sur la vie et l'oeuvre de Paul Langevin par M. Louis de Broglie, secrétaire perpétuel," 48-page handwritten MS, on p. 42, in Dossier Louis de Broglie.

[68] Abragam, "Louis de Broglie," p. 37; and Abragam, *Time Reversal* (cit. n. 4), pp. 58–60, 135. The physics that Louis de Broglie taught in his lecture courses from roughly 1928 to the early 1950s was the Copenhagen framework for quantum mechanics, including wave-particle duality (complementarity), indeterminism, and acausality. As already noted, at the Solvay conference of May 1927 Louis de Broglie had presented a refinement of the original theory of the pilot wave, introducing a "double solution." The square of the amplitude of the wave (expressed as ψ) was regarded as an expression of statistical information about the behavior of an ensemble of particles represented by a mobile point or, equivalently, probabilistic information about the behavior of a single particle whose initial location (the "hidden variable") is unknown or uncertain. The phase of the wave (expressed as ϕ) determined the trajectory followed by the particle. This theory, like Schrödinger's attempt at a visualizable wave mechanics and Einstein's ensemble approach, was forced into retreat before the persistent arguments of Bohr, Heisenberg, and Pauli at the May 1927 meeting. Key to this outcome were the uncertainty relations discovered by Heisenberg. See Thomas Bonk, "Why Has de Broglie's Theory Been Rejected?" *Studies in the History and Philosophy of Science,* 1994, *25*:375–396; and Cushing, *Quantum Mechanics* (cit. n. 2), esp. pp. 119, 127.

chanics by French communists in the 1950s created a peculiar situation in which de Broglie's work was lauded by Soviet ideology, while mainstream quantum mechanics—for example, its application in chemistry by Linus Pauling and other theoretical chemists—was excoriated. The adoption of a French aristocrat by the successors of Marx and Lenin constituted a strange alliance, as Wolfgang Pauli put it, of the black and the red.[69]

Maurice had retired from active scientific work in 1946, when a grand jubilee celebration was organized to honor him at the Sorbonne. All through the years, in addition to his scientific work, Maurice de Broglie had carried out the traditional social and civic responsibilities attendant on his rank. These duties included the mayoralty of Broglie, oversight of the property at Saint-Amadour, and representation of the family on state occasions—for example, a trip to the United States with Pauline in 1931 to mark the 150th anniversary of the Yorktown victory, in which a de Broglie had served with Lafayette.[70]

Maurice served briefly on the faculty at the Collège de France, from 1942 to 1944, having been asked by Frédéric Joliot to stand as a candidate after Paul Langevin was arrested, forced to retire in 1941, and kept by the Gestapo under house surveillance in Troyes for four years because of his antifascist activities. De Broglie's inaugural lecture, delivered with police representatives in the hall, praised Langevin's scientific work.[71]

Maurice de Broglie's scientific office was his private laboratory, and he also had hours of reception at the Academy of Sciences. Students and collaborators at his laboratory remembered him as nonauthoritarian, respectful, and sensitive to those around him. The English physicist William Wilson praised him for training "so many clever young men." Leprince-Ringuet recalled him as "extremely affable, with nothing of the haughty about him, he put the person with whom he was speaking at ease: you sensed in him the discretion, the fundamental modesty of the true scientist, a balanced judgment on events and on men that he described . . . with a cheerful, even caustic, humor." When Maurice de Broglie died, at the age of eighty-five, representatives from the academies and the French government were at the funeral, as were representatives from the Catholic Church, among them the bishop of Evreux. The obituary notice in *Le Figaro* mentioned prominent family members in attendance, although there was no mention of Louis, who now became the seventh duc de Broglie.[72]

The prince Louis de Broglie, unmarried and solitary, had become a civil servant by

[69] On the French communists' adoption of de Broglie's theories see Cushing, *Quantum Mechanics,* p. 150; and Lochak, *Louis de Broglie* (cit. n. 5), pp. 214–215. In 1942, while in Berkeley, David Bohm joined the Communist Party for a period of nine months. He left the United States in 1951 because of his unwillingness to testify in the McCarthy hearings, settling in England in the late 1950s after stays in Brazil and Israel. See John Horgan, *The End of Science* (New York: Broadway, 1996), p. 84; and F. David Peat, *Infinite Potential: The Life of David Bohm* (Reading, Mass.: Addison-Wesley, 1997), pp. 58–59, 120, 164, 213. See also Loren Graham, "A Soviet Marxist View of Structural Chemistry: The Theory of Resonance Controversy," *Isis,* 1964, *55:*20–31; and Stephen F. Mason, "The Science and Humanism of Linus Pauling (1901–1994)," *Chemical Society Reviews,* 1997, *26:*29–39, on p. 36.

[70] On the celebration for Maurice see Lépine, *Notice sur la vie et les travaux de Maurice de Broglie* (cit. n. 21), p. 15; on the trip to America see Comtesse de Pange, *Comment j'ai vu 1900,* Vol. 4, pp. 221–226.

[71] Remarks by Edmond Faral, in *Jubilé scientifique de M. Maurice de Broglie, célébré à la Sorbonne, 13 juin 1946* (Paris: Gauthier-Villars, 1946), pp. 36–39, on p. 37.

[72] For reminiscences of Maurice de Broglie see François Dupré la Tour, "Le duc de Broglie, *La Liberté,* 25 July 1934, in Dossier Maurice de Broglie; Wilson, "Maurice, le Duc de Broglie" (cit. n. 38), p. 32; and Leprince-Ringuet, "Louis, Maurice et le laboratoire" (cit. n. 42), p. 328. Maurice de Broglie's residence was at 27, rue Chateaubriand, and his laboratory office at 29, rue Chateaubriand, adjacent to additional laboratory space on rue Lord Byron. The report on those present at his funeral comes from the obituary notice in *Figaro,* Dossier Maurice de Broglie. Louis de Broglie wished no publicity at his death. On the occasion of the funeral Leprince-Ringuet wrote that the church at Neuilly was only half full, with no minister, no official delegation, and only a small number of academicians present: Leprince-Ringuet, "Louis, Maurice et le laboratoire," p. 325.

seeking and accepting an appointment as a faculty member at the University of Paris, a state institution conferring certificates considerably less prestigious than those of the Ecole Navale, the Ecole Polytechnique, or the Collège de France. Unlike Maurice, he had a job. He kept his distance from the students who found inspiration in his written lectures, but he also came to have considerable power within the French academic establishment.

Louis de Broglie rarely traveled, though he did attend the Brussels Solvay meetings of 1927 and 1933 and went to Stockholm in 1929 and to England at least once. The Russian émigré George Gamow provided a now-familiar story of an encounter with de Broglie in the late 1920s, when Gamow, who was working with Rutherford, arranged by correspondence to visit de Broglie during the Christmas holidays at his home in Neuilly:

> De Broglie, wearing a silk house coat, met me in his sumptuously furnished study, and we started talking physics. He did not speak any English; my French was rather poor. But somehow, partly by using my broken French and partly by writing formulas on paper, I managed to convey to him what I wanted to say and to understand his comments. Less than a year later, de Broglie came to London to deliver a lecture at the Royal Society, and I was, of course, in the audience. He delivered a brilliant lecture, in perfect English, with only a slight French accent.[73]

Louis de Broglie took his leave from the university in 1962. He remained active in the scientific community until the autumn of 1975, when he made his last public appearance at a seminar of the Fondation Louis de Broglie, which he established in 1973 for the pursuit of investigations in microphysics. The family château at Broglie and the civic duties associated with its ownership had long been ceded to Jean de Broglie, the grandson of Maurice and Louis's uncle François de Broglie.[74]

Pauline's autobiographical account of her childhood, in which she recreated the everyday life of the aristocracy and showed its transformation after World War I, began to appear in 1962. The four volumes of *Comment j'ai vu 1900* present a compelling history of Pauline and her siblings.

They chose different paths. The eldest, Albertine, accepted a traditional, private role in marriage and family; she disappears from the public record. The younger sister, Pauline, discouraged from her first love for archaeology, fashioned a successful and significant public life as a novelist and literary scholar. Maurice, the second child and eldest son, fulfilled the family obligations that were expected of him, never allowing his scientific passions to undercut his duties as prince and duke. His scientific life was not a "job." He lived it largely within the confines of his private residence; like the country houses of Lord Cherwell, Lord Rayleigh, and Lord Salisbury, the laboratory of de Broglie was gloriously outfitted with the most modern scientific equipment.[75]

[73] George Gamow, *Thirty Years That Shook Physics: The Story of Quantum Theory* (New York: Doubleday, 1966), pp. 85–86. I. Bernard Cohen has recalled that Gamow's spoken English was not easily understood and suggests that Louis de Broglie may have preferred to keep to French on that account. On Louis's travels see Abragam, "Louis de Broglie" (cit. n. 11), p. 38.

[74] Lochak, *Louis de Broglie* (cit. n. 5), p. 240. Jean de Broglie (1921–1976), who was secretary of state for Algerian affairs under the ministry of Georges Pompidou and an intimate of Valéry Giscard d'Estaing, was assassinated in the rue des Dardanelles in December 1976. See Jesus Ynfante, *Un crîme sous Giscard: L'affaire de Broglie: L'Opus dei/Matesa* (Paris: Maspero, 1981); and Jacques Bacelon, *L'affaire de Broglie* (Paris: Editions Jean Picollec, 1981).

[75] On Rayleigh, Salisbury, and other English gentleman scientists see Simon Schaffer, "Physics Laboratories and the Victorian Country House," in *Making Space for Science: Territorial Themes in the Shaping of Knowledge,* ed. Crosbie Smith and Jon Agar (Basingstone: Macmillan, 1998), pp. 147–180. Maurice de Broglie kept in touch with the fourth baron Rayleigh as well as with Lindemann, writing Lindemann after the Allied invasion in 1944 that Lord Rayleigh's son Captain Strutt had just visited him following the liberation of Paris: Maurice de Broglie to Lindemann, undated [in response to a letter from Lindemann dated Sept. 1944 and delivered by diplomatic pouch], D:45, Lindemann Papers.

Louis de Broglie, like Robert Boyle three hundred years earlier, was the youngest son of a noble family. As Steven Shapin writes of Boyle as a young man, so it might have been presumed of Louis de Broglie that "the freedom and formal irresponsibility of the younger son" could incline him to "idle courses."[76] And apparently there was some concern about Louis's future, as we have seen.

The youngest son who, like Robert Boyle and Louis de Broglie, ultimately chose a life of serious study could equally be subject to family concern that he had become overly ascetic and even eccentric. Of Boyle it was said that he did not look well, that he was thin and emaciated, but that this very fragility was a form of refinement and even strength. Louis's sister Pauline worried that her brother's discovery of theoretical physics was destroying his natural high spirits and gaiety. She noted that he had abandoned his youthful mode of dressing in "costumes recherchés." The life he led, recalled the academy's secretary Paul Germain, was extremely regular in habits and quasi-monastic.[77]

An accomplished painter, the Catholic philosopher Jean Guitton, recalled trying to capture the likeness of Louis de Broglie in a charcoal drawing: "I began by drawing the two symmetric triangles of his wing collar. How difficult to render this immaterial face, this fading splendor! I was aided by a 'coquetterie,' the drooping eyelid of his right eye, which accentuated his distracted air of the contemplative."[78]

Yet, according to Guitton, it would not be correct to characterize Louis de Broglie as shy. His reserve was not timidity but something else, a *pudeur* which "draws up a veil, a distance." Louis de Broglie, reminisced Guitton, was characterized by elegance: the elegance of feminine modes, the elegance of geometric theorems. He was a monklike man who, "like kings and popes," was inhabited by the idea that it is necessary to be a "serviteur des serviteurs."[79]

If Louis de Broglie was a reluctant revolutionary, he was by no means the only one in the history of quantum mechanics. Schrödinger, Einstein, Planck, and Max von Laue all consistently expressed misgivings about acausality, indeterminism, and complementarity. Yet these Berliners were not written out of the history of the new physics with quite the same spirit of marginalization as was de Broglie. While Louis de Broglie failed to contribute to the development of the Copenhagen framework of quantum mechanics after 1927, he continued to participate in the public discussion of its experimental basis and philosophical implications. It is hard not to conclude that de Broglie's social rank, in combination with his personal temperament, played a role in the perception that he was an outsider to the scientific establishment.

Maurice, while directing one of the most important laboratories in nuclear physics in France in the 1920s and 1930s (and one in which foreign scientists were welcomed), inevitably fell under the rubric of the "gentleman" scientist who worked outside the framework of the universities and the schools. Given the centralization of French scientific institutions since the time of Louis XIV's minister Jean-Baptiste Colbert, as well as the commitment of the Third Republic bureaucracy to antimonarchist and anticlerical policies

[76] Shapin, *Social History of Truth* (cit. n. 8), p. 141.

[77] On Boyle see John Evelyn, quoted *ibid.*, pp. 153–154: "[His body was] so delicate that I have frequently compared him to a chrystal, or Venice glass; which, though wrought never so thin and fine, being carefully set up, would outlast the hardier metals of daily use." On Louis de Broglie see Varende, *Les Broglie* (cit. n. 11), p. 332 (quoting Pauline); and Germain, "Louis de Broglie" (cit. n. 5), p. 14.

[78] Guitton, "Duc Louis de Broglie" (cit. n. 44), p. 332.

[79] *Ibid.*, pp. 332, 332–333. On extroversion and introversion in temperament and the reluctant revolutionary see Sulloway, *Born to Rebel* (cit. n. 9), pp. 162–194. He defines shy people as "*anxiously* introverted" (p. 173).

traditionally at odds with the interests of the aristocracy, it was substantially more difficult in France than in Great Britain, for example, for a gentleman and an aristocrat to flourish in public esteem in educational circles. Among the other few aristocratic scientists in modern France was Armand A. Agénor, the comte de Gramont (1879–1962), a descendant of the kings of Navarre. De Gramont took a doctoral degree at the Sorbonne in 1911 and founded the Institute of Theoretical and Applied Optics after the war, becoming an expert in electronics and electron microscopes.[80]

However, de Gramont simply demonstrates the unique conditions required for an aristocrat to take an interest in modern science. First, de Gramont had the example of a father, Antoine Arnaud X. L. de Gramont (1861–1923), who had studied organic synthesis with Georges Friedel and coauthored a work on spectroscopy with P. E. Lecoq de Boisbaudran, the discoverer of Mendeleev's "eka-aluminum" (gallium). Moreover, Armand de Gramont married into the Greffulhe side of the de Broglie family, taking as his wife the daughter of the comtesse Greffulhe. The countess herself had scientific interests, visiting the laboratory of Edouard Branly in order to see his equipment for wireless telegraphy and corresponding with him over a period of almost four decades.[81] Thus, the circle of aristocrats in French science was small.

Had there been sons of Maurice and Louis de Broglie—or daughters—an aristocratic scientific dynasty might have developed. In the one generation, the influence and collaboration between the two brothers turned out to be crucial in the younger brother's development of the bold theory of the matter wave. This idea was supported by both the conceptual and the experimental interests of the older brother, not opposed by him.[82]

That de Broglie's thesis turned out to be less radical than the rapidly changing views of members of the Copenhagen circle does not make him unusual among physicists, especially physicists of his age. Heisenberg, Dirac, and Pauli were all about ten years younger than Louis de Broglie; and even as radicals, they sought the approval and patronage of Niels Bohr and Max Born. And, of course, Paul Forman and some other historians have argued that German physicists' apparently radical ideas about acausality and indeterminism were an accommodation to politically conservative prejudices in a postwar Weimar culture that demanded a renunciation of traditional mechanism and materialism.[83]

In conclusion, the choices for their lives that the de Broglies made as aristocrats in the twentieth century were unusual, but not baffling. The de Broglies' family tradition was

[80] Gramont was a student of Paul Appell, Gabriel Lippmann, Jean Perrin, and Henri Moissan. He took a license in science in 1902 before the doctoral degree. See M. Prévost *et al.*, eds., *Dictionnaire de biographie française,* Vol. 16 (Paris: Librairie Le Touzey, 1985), pp. 926–927. On the effects of republicanism and anticlericalism on scientific careers see the cases of Paul Sabatier and Pierre Duhem in, respectively, Mary Jo Nye, *Science in the Provinces: Scientific Communities and Provincial Leadership in France, 1860–1930* (Berkeley: Univ. California Press, 1986); and Stanley Jaki, *Uneasy Genius: The Life and Work of Pierre Duhem* (The Hague: Nijhoff, 1984).

[81] Philippe Monod-Broca, *Branly: Au temps des ondes et des limailles* (Paris: Bélin, 1990), pp. 258–273. Lecoq de Boisbaudran was not a member of the aristocracy but from a family in the wine business.

[82] Pauline de Broglie's eldest son Maurice de Pange died of meningitis at the age of fifteen. Devoted to his uncles Maurice and Louis de Broglie, Maurice de Pange aimed to become a physicist or an engineer and intended to study at Oxford. See foreword by Pauline de Broglie in Maurice de Pange, *The English School Days of a French Boy: Letters from Maurice de Pange* (London: John Lane, Bodley Head, 1928), p. 12.

[83] Paul Forman, "Weimar Culture, Causality, and Quantum Theory, 1918–1927: Adaptation by German Physicists and Mathematicians to a Hostile Intellectual Environment," *Hist. Stud. Phys. Sci.,* 1971, *3:*1–115. On the rapidly changing philosophical interpretations in quantum mechanics during the 1920s see Mara Beller, "The Rhetoric of Antirealism and the Copenhagen Spirit," *Philosophy of Science,* 1996, *63:*183–204; and especially two papers given at the Atlanta History of Science Society meeting in 1996: Cathryn Carson, "Interpreting the Quantum Revolution: Heisenberg as a Popular Speaker," and Alexei Kojevnikov, "Philosophy in Early Quantum Mechanics: High Principles, Rhetorical Strategies, and Academic Ritual."

more progressive and intellectual than was the case in many French noble families. Their sympathies for both English and German culture were long standing, established since the time of Mme. de Stael. The widespread scientism at the turn of the century taught them that service to science was the highest form of service to humanity and to the nation. And, in physics, the late nineteenth-century discoveries of radioactivity, X rays, and electrons provided the opportunity for men and women of reasonable means to set up laboratories at the forefront of physical research.[84]

Maurice de Broglie's laboratory disappeared after World War II. For those interested in the history and philosophy of science, the de Broglie name largely became attached to Louis de Broglie and to his bold thesis of 1924 on the wave nature of matter. His subsequent work lay outside the mainstream of developments in quantum mechanics, although his name has remained indelibly printed in the history of wave mechanics.

One cannot help but muse that the three youngest children of the fifth duc de Broglie adopted in turn the traditional roles prescribed for the sons of the aristocracy, but with specific adaptations to the twentieth century and to the appeals of science. Pauline, with her considerable interest in archaeology and some participation in feminist intellectual circles, followed the *académicien*'s practice of writing social science, history, and literature. Maurice, in both his family responsibilities and his scientific work, behaved as befit a naval officer, managing the affairs of his family and laboratory, expanding technical expertise, and training young men. Louis, in his theoretical and philosophical writings, adapted to scientific interests what might have been the church's call to an ascetic and contemplative life. Social class and aristocratic culture divided the de Broglies from the mainstream of scientific life in modern France, but mutual support within their immediate family network resulted in unusually high intellectual accomplishments for this scientifically oriented family of aristocrats.

[84] On turn-of-the-century scientism see David Knight, *The Age of Science* (London: Basil Blackwell, 1986); on the new opportunities in physics see Mary Jo Nye, "Gustave LeBon's Black Light: A Study in Physics and Philosophy in France at the Turn of the Century," *Hist. Stud. Phys. Sci.,* 1972, *4:*163–195.