CHAPTER 5

J.J. THOMSON'S LEADERSHIP AND THE DEVELOPMENT OF THE CAVENDISH SCHOOL, 1901-1914

> The theory is not an ultimate one; its object is physical rather than metaphysical. From the point of view of the physicist, a theory of matter is a policy rather than a creed; its object is to connect or co-ordinate apparently diverse phenomena, and above all to suggest, stimulate and direct experiment. It ought to furnish a compass which, if followed, will lead the observer further and further into previously unexplored regions.
>
> J.J. Thomson[1]

> I feel I owe a great deal to the Laboratory and to you [J.J.] personally for whatever success has attended my work. It was in the Cavendish that I was first incubated with the spirit of research & it was there I made my first investigations under your guidance. The work for which the [Nobel] Prize is awarded was begun in the Cavendish Laboratory and I recall that the α particle was born and cherished in one of the lower rooms.
>
> E. Rutherford[2]

> It was his boundless enthusiasm, his endless fertility in suggestion, and his unequaled knowledge of the literature that made him such an inspiring teacher . . . We might perhaps laugh at his little peculiarities; but we knew he was a great man, and we all loved him.
>
> R. J. Strutt[3]

5.1. J. J. Thomson's Research in the New Century

During the first two decades of the new century, J.J. Thomson researched a number of subjects, including corpuscles (electrons), electric discharge and conduction, ionization, radioactivity, radiation, atomic structure, and positive rays and their applications in chemistry. He published more than 80 papers and seven

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[1] J.J. Thomson, *The Corpuscular Theory of Matter* (London: Archibald Constable & Co., 1907), 1.

[2] CUL MSS ADD 7654 R68 (18 January 1909): Rutherford's reply to J.J.'s telegram congratulating him on his receipt of the 1908 Nobel Prize in Chemistry.

[3] Strutt, *Life of J.J. Thomson*, 150-151.

books, including three textbooks that he co-authored with his old friend, J. H. Poynting. In Table 5.1 these works are classified into five general categories: (a) corpuscles and ionization, (b) radioactivity and radiation, (c) atomic structure, (d) positive rays and their applications in chemistry, and (e) other fields. All these works served J.J.'s search for the ultimate relationship between electricity and matter.

Although the peak of J.J.'s interest in corpuscles, electric discharge and conduction, and ionization had passed with the turn of the century, he continued to show interest in these phenomena until the 1920s. J.J. redetermined the charge of corpuscles, measured the velocity of secondary cathode rays, determined the number of corpuscles in an atom, worked on the nature of electric discharge and conduction, and refined ionization theory. After J.J. and H. A. Wilson independently measured the charge of corpuscles in 1903,[4] J.J. shifted his focus to the applications of corpuscles, particularly in thermionics. Many Cavendish researchers were soon attracted to this new field when, in a 1901 lecture at

Table 5.1. J.J. Thomson's Research Papers during 1901-1918

Subject	*1901-02*	*03-04*	*05-06*	*07-08*	*09-10*	*11-12*	*13-14*	*15-18*
cathode rays/ corpuscles/ ionization/ electric discharge & conduction	7	3	4	3	3	1	1	4
radioactivity radiation/light	2	5	3	5	2	2	1	3
structure of the atom	0	2	2	0	0	1	5	2
positive rays/ its application in chemistry	0	0	1	6	4	7	6	0
electricity, magnetism, etc.	1	2	0	2	5	0	0	4
	10	12	10	16	14	11	13	13

[4] J.J. Thomson, "On the Charge of Electricity carried by a Gaseous Ion," *Phil. Mag.* 5 (1903): 346-355; H. A. Wilson, "A Determination of the Charge on the Ions produced in Air by Röntgen Rays," *Phil. Mag.* 5 (1903): 429-441.

the Royal Institution, J.J. discussed the "existence of free corpuscles or negative electricity in metals" and pointed out that "the corpuscles disseminated through the metal will do more than carry the electric current, they will also carry heat from one part to another of an unequally heated piece of metal."[5] In his 1903 book, *Conduction of Electricity through Gases*, and in its subsequent two editions in 1906 and 1927/1933, J.J. well summarized the research conducted in this area by himself and the Cavendish researchers in the early twentieth century.[6] This book became a standard text for the various researchers at the Cavendish, who often used it as a source of research topics. Figure 5.1 shows the second edition's table of contents. For this edition, J.J. rewrote "a considerable part" of the first edition, adding new material and deleting "some matter fully treated by Rutherford."[7]

During this period, radioactivity and radiation were other major research topics for J.J., who performed experiments to examine induced radioactivity, tested the presence of radioactivity in ordinary substances, and reviewed the nature of radium. J.J.'s correspondence with Rutherford during the early 1900s indicates that J.J. closely followed his distinguished pupil's work on radiation. J.J. was particularly concerned about the source of radioactive energy and, in a 1903 article about radium published in *Nature*, he suggested the following interesting idea:

> The changes we are considering are changes in the configuration of the atom, and it is possible that changes of this kind may be accompanied by the liberation of very large quantities of energy. Thus, taking the atomic weight of radium as 225, if the mass of the atom of radium were due to the presence in it of a large number of corpuscles, each carrying the charge of 3.4 by 10^{-10} electrostatic units of negative electricity, and if this charge of negative electricity were associated with an equal charge of positive, so as to make the atom electrically neutral, then if these positive and negative charges were separated by a distance of 10^{-8} cm., the intrinsic energy possessed by the atom would be so great that a diminution of it by 1 per cent would be able to maintain the radiation from radium as measured by Curie for 30,000 years.[8]

Although many former and present Cavendish researchers, particularly Rutherford, enthusiastically cultivated the study of radioactivity. J.J. remained a minor player in this pursuit, as demonstrated by the number and depth of the papers he published on this topic.

His investigations into the nature of radiation, especially X-rays and γ-rays, were more serious. J.J. showed great interest in these mysterious rays, produced several stimulating papers on the topic, and encouraged his students to join the debate on the nature of these rays. His primary goal was to build plausible theories

[5] J.J. Thomson, "The Existence of Bodies Smaller than Atoms," *Not. Proc. Roy. Inst. 16* (1901): 574-586 on 582.

[6] The third edition was written by J.J. and his son, G. P. Thomson. The first volume of the third edition appeared in 1927 and the second in 1933.

[7] J.J. Thomson, *Conduction of Electricity through Gases*, second edition (Cambridge: Cambridge University Press, 1906), vii.

[8] J.J. Thomson, "Radium," *Nature 67* (1903): 602.

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Figure 5.1. Table of Contents of <u>*Conduction of Electricity through Gases*</u>*, second edition (1906).*

explaining radiation and light, which made some of his work highly theoretical and even speculative.[9] Although J.J. was one of the first to advance the impulse theory

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[9] See, J.J. Thomson, "On a Theory of the Structure of the Electric Field and its Application to Röntgen Radiation and to Light," *Phil. Mag. 19* (1910): 301-313; "On the Theory of Radiation," *Phil. Mag. 20* (1910): 238-247; "Radiant Energy and Matter," *Engineering 91* (1911): 319-321, 353-354, 386-388, 421-422, 454-455; "The Unit Theory of Light," *Proc. Camb. Phil. Soc. 16* (1912): 643-652.

of X-rays, he nonetheless considered other possible explanations and endeavored to build a grand theory uniting all the different opinions that had been put forward. The result was a swing between Newtonian corpuscular theory and Maxwellian electromagnetic theory, or between Planck's quanta and J.J.'s old etherean vortex ring model. In a 1912 paper, J.J. pointed out the difficulties as follows:

> On the unit theory of light, radiant energy is supposed to have a molecular structure and to be made up of a finite number of units . . . In every case in which this conception of the unitary character of light is helpful we are concerned, I think, with transformation of energy, while when we are dealing with purely optical phenomena, such as interference and the like, the same conception leads us into great difficulties, and in the present state of the subject at any rate is a hindrance and not a help.[10]

Thirteen years later J.J. caricatured the battle between the two competing interpretations as "something like one between *a tiger and a shark*, each is supreme in its own element but helpless in that of the other."[11] Sixty years later, historian of science, Bruce R. Wheaton, adapted this image for the title of a book, *The Tiger and the Shark: Empirical Roots of Wave-Particle Dualism*.[12]

During the early decades of the twentieth century, J.J. centered his major research on positive rays and their applications. Beginning in 1905, he spent most of his time and energy studying positive rays and devoted more than a quarter of his papers to this topic. In a 1909 paper, he announced his goals in pursuing this line of research: "The most important questions to be settled as to the nature of positive electricity are: —(1) Does a definite unit of positive electricity exist? (2) If so, what is the size of the unit?"[13] To measure the deflection of positive rays under the influence of electric and magnetic fields, J.J. used a new apparatus in which at first a fluorescent Willemite screen at the end of the tube, and from 1910 on a photographic plate within the tube, was positioned to record the trace of positive rays (Figure 5.2). From these distinctive traces, which had parabolic shapes, J.J. could calculate the values of e/m for the corresponding positive rays.[14]

J.J.'s search for a "definite unit of positive electricity" did not progress as smoothly as his prior research on corpuscles. It was not simply because J.J. was "in his middle fifties, and increasingly involved in the public affairs of science, besides

[10] J.J. Thomson, "The Unit Theory of Light," 643.

[11] J.J. Thomson, *The Structure of Light: The Fison Memorial Lecture 1925* (Cambridge: Cambridge University Press, 1925), 15. Emphasis added.

[12] Bruce R. Wheaton, *The Tiger and the Shark: Empirical Roots of Wave-Particle Dualism* (Cambridge: Cambridge University Press, 1983).

[13] J.J. Thomson, "Positive Electricity," *Phil. Mag. 18* (1909): 821-845 on 821.

[14] For earlier research on positive rays before 1910, see J.J. Thomson, "Some experiments on Canal-strahlen," *Proc. Camb. Phil. Soc. 13* (1905): 212-214; "Rays of Positive Electricity," *Not. Proc. Roy. Inst. 18* (1907): 577-592; "On Rays of Positive Electricity," *Phil. Mag. 13* (1907): 561-575; "Rays of Positive Electricity," *Phil. Mag. 14* (1907): 295-359; "The Carriers of Positive Electricity," *Not. Proc. Roy. Inst. 19* (1908): 171-201; "Positive Rays," *Phil. Mag. 16* (1908): 657-691; "On the Carriers of the Positive Charges of Electricity emitted by Hot Wires," *Proc. Camb. Phil. Soc. 15* (1908): 64; "Positive Electricity," *Phil. Mag. 18* (1909): 821-845.

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