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ARTICLE

An intellectual history of P.C. Ray's papers on the nitrites of mercury

Subrata Dasgupta[1]

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Abstract
Prafulla Chandra Ray's contribution to the birth and development of an 'Indian school of chemistry' is well documented. But much of this recognition is situated in the realm of the social history of science. My aim in this essay is to view Ray through the lens of intellectual history and, above all, to shed fresh light on his *actual* contribution to the chemistry of the nitrites of mercury. Toward this end the focus here will be on five of Ray's earliest papers on this family of compounds. We will see that the received narrative that Ray *discovered* mercurous nitrite is problematic. Examining the texts of his early papers it will be seen that Ray's main contributions to the nitrites of mercury were (i) his apparently serendipitous discovery of a method of synthesizing mercurous nitrite; and (ii) the identification of and solutions to a series of interrelated Kuhnian normal science problems pertaining to this family of compounds. Furthermore (iii) the tools of intellectual history will help discern an underlying 'plot structure' informing the tenure of his work; and finally (iv) we will see that the centre-periphery model that attends the social historiography of science in colonial and post-colonial India plays no role in illuminating Ray's early creative work on the nitrites of mercury.

Keywords P.C. Ray · Mercurous nitrite · Intertextual space · Plot structure · Intellectual history · Inorganic chemistry · Centre-periphery model

1 Introduction

It is well known that the years 1895–96 were profoundly significant in the history of the experimental physical sciences in India. In 1895 Jagadis Chandra Bose (1858–1937) published a paper on the quasi-optical properties of radio waves in the *Journal of the Asiatic Society of Bengal* (Bose, 1895). This was the first published paper in modern physics—meaning the physics that had emerged from the realm of the Scientific Revolution of the sixteenth and seventeenth centuries (Cohen, 1994)—by an Indian scientist.

In 1896, Prafulla Chandra Ray (1861–1944), Bose's friend and colleague in Presidency College, Calcutta (now Kolkata) published in the same journal a paper bearing the title "On Mercurous Nitrite" (Ray, 1896). Mirroring Bose's publication, this was the first paper in modern chemistry authored by an Indian scientist—here, 'modern' meaning the chemistry that was the legacy of what came to be called the 'Chemical Revolution' inaugurated in the eighteenth century by the likes of Lavoisier in France and Priestley in England—what Butterfield (1957, p. 191 *et seq*) called the "Postponed Scientific Revolution in Chemistry".[1]

Ray's contribution to the birth and development of modern chemistry in India, and the founding of an 'Indian school of chemistry' is well documented (see, e.g., Majumdar, 2010; Choudhuri & Singh, 2018) as is his contribution to the rediscovery of Indian alchemy (Ray [1902–06] 2002; Eliade, 1978, pp. 127–141). But much of this recognition is situated in the realm of social history.[2] My aim in this essay, however, is to view Ray through the lens of *intellectual history* and to shed fresh light on his *actual* contribution to the chemistry of the nitrites of mercury. Towards this end my focus will be on five of Ray's earliest papers on mercurous nitrite and its related compounds. As we will see, the

✉ Subrata Dasgupta
subratadasgupta1044@gmail.com

1 School of Computing & Informatics, University of Louisiana at Lafayette, Lafayette, LA 70504, USA

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[1] But see also Golinski 1990 who argued that the beginnings of the chemical revolution can be located in the works of Boyle and others in the seventeenth century.

[2] Indeed, Dhruv Raina (1997) ascribes the birth of the social history of Indian science to Ray's great 2-volume treatise on the history of Hindu chemistry.

conventionally received understanding that Ray *discovered* mercurous nitrite is problematic at the very least.

2 Unraveling textual meaning

The performance of science has many faces but ultimately its definitive products are the published scientific *papers*, 'literary inscriptions' as Bruno Latour and Steve Woolgar (1986) described them. It is these papers that are the repository of whatever new knowledge—facts, apparatus, procedures, equations and formulas, ideas, theories, interpretations—that scientists produce. They constitute what scientists call the archival material of science. They are the sources of the scientists' own understanding of their particular specialities. If there are arguments or disagreements concerning a piece of scientific work, it is always the text reporting this work that must be scrutinized. But—and this is what interests us here—unraveling the meanings of archival texts also constitutes the domain of intellectual history. These same texts—in particular in the present context, scientific papers—afford an interface between the scientist and the intellectual historian.

Elsewhere in the pages of this journal, after reviewing the modern (and complicated) literature on intellectual historiography (see in particular White, 1978; LaCapra, 1983; Brett, 2002; Whatmore & Young, 2016; Whatmore, 2016). I summarized its central features as a 'working definition' (Dasgupta, 2022) in the context of history of science as follows:

> The 'central stuff' of intellectual history is the realm of past **ideas** represented by linguistic entities called **texts**. The objective of intellectual history is to recover or discover the **meanings** of past texts—thus of represented ideas—taking into account the **language** in which the texts are written. Such recovery/discovery entails relating the text to one or more **contexts** and, in particular, other past and contemporaneous texts. Furthermore, what the text may mean will depend on what the text's author **intended** to mean. The end product of a work of intellectual history is a **narrative** that explicates the meaning of a text within a **plot structure**.

It is fair to say that reading a scientific paper, attending to its text, its language, its meaning, its textual context, its constituent plots ('emplotment'), its narrative structure, its authorial intent—in other words engaging with the scientific paper as a constituent of intellectual history, a certain picture, a certain understanding of the practice of science emerges that are quite distinct from the social–historical or the sociological picture.

In this context, we also note that in the realm of science studies, a distinction is made between 'internalist' and 'externalist' investigations of scientific practice. Broadly speaking, internalism refers to the contents of science itself in relation to methodology, epistemology, ontology and creativity, while externalism addresses the socio-political-economic-cultural accounts of episodes in science. In the context of the modern history of science in colonial India externalist studies abound, prominent examples being Baber (1996), Kumar (1997), Chakrabarti (2004), Raj (2007), Sur (2011), Anderson (2010) and the anthology edited by Habib and Raina (2007). I take Subbarayappa (2013) and (to a large extent) Choudhuri (2018) as exemplars of internalist history. While to some extent this binary has diminished in significance (Hess, 1997, p. 127) it still persists.[3] More to the point one should not conflate internalist history with intellectual history. This is because the intellectual history of science actually *straddles the internal and the external*. Its 'internal' relates to the singular texts, their narrative contents, emplotment, authorial intentions and textual contexts (that is, other texts to which a given text is linked), all of which contribute to one's understanding of the meaning of a piece of scientific work, the knowledge it encodes and the underlying reasoning, while its 'external' connects to the language employed, and plot structures, these being elements of the shared or public culture of science (in the anthropological sense of the word 'culture').

3 "On Mercurous Nitrite"

Ray's first paper on mercurous nitrite began with the statement:

> Having recently had occasion to prepare mercurous nitrate in quantity by the action of dilute nitric acid in the cold on mercury, I was rather struck by the appearance of a yellow crystalline deposit. At first sight it was taken to be a basic salt, but the formation of such a salt in a strongly acid solution was contrary to ordinary experience. A preliminary test proved it, however, to be at once a mercurous salt as well as a *nitrite* [italics in the original]. The interesting compound promised thus to repay an investigation (Ray, 1896, p. 1).

This introductory paragraph immediately communicates to the reader that the relevant location of the phenomenon described here is a chemical laboratory. Ray was living what Latour and Woolgar (1986) called a "laboratory life". But there is something more this text reveals. Ray was "struck

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[3] One reviewer of this writer's recent book *The Second Age of Computer Science* (2018) referred to it as resembling "Kuhn-inspired internalist histories of science and technology from the 1970s." (C.C.M. Mody, *ISIS*, Vol. 111, 2, June 2020, pp 439–440.

by the appearance of a yellow crystalline deposit." This was an *unexpected* phenomenon, one he had not anticipated as an outcome of the reaction, one that surprised him. A further test revealed that the crystalline matter was both a mercurous salt as well as a nitrite. Ray italicized the latter emphasizing the unexpectedness of the compound.

So, had Ray *discovered* this compound? Discovery entails something that has never been known before, what creativity researchers call 'historically original' (Boden, 1991; Dasgupta, 2018). Did he believe so? He makes no such explicit claim in the paper.

However, in the opening paragraph he notes that this was an "interesting" compound deserving further investigation. Furthermore, in the next section, titled "Historical" he mentions several chemists, most notably the Swiss chemist Jean Charles Gatissard de Marignac who had studied the effect of nitric acid on mercury "under varying circumstances" (p. 1). Unfortunately, Ray tells us, he did not have access to these researchers' original papers but "a complete resumé of Marignac's work is to be found in Frémy's *Encyclopédie Chimique*". The information therein on mercurous nitrite "is scarcely worth anything" (ibid). So, in effect, the reader is left in the dark on whether Ray had actually discovered a hitherto unknown salt or whether he believed he had done so.

There is, of course, another clue: the fact that he had written a paper on the compound and his investigation of it and submitted for publication in a learned journal. He would not have done so if he hadn't believed that he was producing new chemical knowledge.

Many years later in his autobiography, *Life and Experiences of a Bengali Chemist* (1932), Ray writes that "The *discovery* of mercurous nitrite opened a new chapter in my life" (p. 113; italics added). He also quotes there a notice published in the British science journal *Nature* concerning "a paper by Dr. P.C. Ray of the Presidency College, Calcutta on mercurous nitrite that is worthy of note" (Quoted in Ray, 1932, p. 113). Again there is ambivalence here: the notice in *Nature* says nothing of why Ray's paper was "worthy of note"; whether this noteworthiness lay in the discovery of a new compound. Ray seems to make the case for a discovery stronger when he writes in the historical section of his 1896 paper that.

> Roscoe and Schorlemmer in their well-known treatise do not so much as mention this compound, nor is there any reference to it to be found in the latest edition of Watt's *Dictionary of Chemistry* (p. 2).

We can only conclude that when Ray wrote this paper he believed that even if not entirely unknown, mercurous nitrite had scarcely touched the consciousness of inorganic chemists of the time. For all intents and purposes, he believed this to be a sufficiently unfamiliar compound that needed to be studied. I will return to this matter of discovery later in this essay.

But Ray's paper of 1896 was much more: the next few sections were devoted to the method whereby the salt was synthesized and the fact that the "new compound"—witness this phrase—responded in specific ways to various tests and procedures. For instance, having described the basic method of preparation—"Yellow nitric acid... is diluted with water [and]... a large excess of mercury is... poured into the liquid... [and] in the course of about an hour yellow needles... begin to appear on the surface of mercury" (p. 2)—he describes how, instead of decanting off the remaining mercury and the mother liquor,

> . . . if the salt is allowed to remain in contact with the mercury and the mother liquor, it gradually disappears and in its place transparent, perfectly colorless, crystals are formed , which grow in size (p. 2).

Ray identifies these crystals as 'Marignac's salt', that is, mercurous *nitrate* ($Hg_2(NO_3)_2$). So he also described how the nitrate could be generated from the nitrite.

In an important section titled "Evidence as to the salt being a nitrite pure and simple" Ray, after mentioning the method called the Crum-Frankland process to estimate nitrites and nitrates, dismisses it as unable to distinguish between the two, and deploys a different process involving "the well-known reaction between urea and nitrous acid" (p. 6).

Chemists, when confronted with a new compound, whether unexpectedly or not, desire to know the mechanism of its formation. In the final and lengthy section "Discussion of the Results and Theoretical Considerations", Ray poses this problem:

> The traces of nitrous acid [HNO_2] present in the yellow nitric acid [HNO_3] no doubt start the reaction but how to account for the continued formation of mercurous nitrite? (p. 8)

For, the small quantity of nitrous acid would soon be used up. Ray surmises that "There must be a parallel reaction going on to keep up the supply of nitrous acid". Drawing an analogy with a reaction between copper and nitric acid, elucidated by two other chemists, Ray then explains:

> Adopting this view, the mercurous *nitrite* [italics in the original] would continue to be formed for some time and being soluble in the menstruum [i.e., liquid solvent] would be precipitated; while mercurous nitrate would remain in solution (p. 8).

4 Situating "On Mercurous Nitrite" in intertextual space

A reader of "On Mercurous Nitrite" will glean nothing about the social–historical circumstances under which this body of new chemical knowledge—mercurous nitrite as yellow crystalline matter, the method of its synthesis, the chemistry of its formation—was obtained. Issues such as the fact that Ray was working in a colonial environment in a science that had been created in a European milieu, that Ray did not belong to the 'invisible college' that was the privilege of the center, or that Ray was the quintessential colonial scientist—in Basalla's (1967) sense—were not only not visible in this paper; they were completely irrelevant.

Rather, what the paper manifests is a feature common to almost all scientific papers that have ever been published; it is a feature that literary theorists might well recognize: that Ray's, 1896 paper resides in an *intertextual space.*[4] By this I mean that to understand the meaning of this paper, to make sense of what Ray is saying, to comprehend Ray's intention in performing the scientific investigation represented in this paper, the reader must recognize that the paper and its contents are *linked to other papers and their contents*. Bruno Latour (1987), an anthropologist of science, observes this fact and notes that in one particular case, a paper by a biomedical scientist he is discussing is linked to some thirty two other papers (p. 33). So also, the meaning of the text of "On Mercurous Nitrite" is entwined with the meanings of other scientific texts. There is a particular intertextual space in which "On Mercurous Nitrite" is situated and only by considering these other texts in this space can readers—in particular other chemists, readers I would call 'peer consumers' (Dasgupta, 2018)—understand the meaning of this particular text.

This particular intertextual space contains, in addition to "On Mercurous Nitrite", as other occupants the papers Ray cites in his paper: the resumé of Marignac's work reported in Fremy's *Encyclopédie Chimique*; the unspecified "well-known treatise by Roscoe and Schorlemmer"; Watt's *Dictionary of Chemistry;* papers in the *Journal of the Chemical Society* by Percy F. Frankland, Edward Divers and three other chemists; and papers in the journals *Comptes Rendu* and the *Proceedings of the Royal Society*.

There is one property of this intertextual space that demands particular attention. On the one hand, this space had evolved in time; Warrington's contribution to it occurred in 1879, Divers's in 1885, Meyer's in 1894, Ackworth and Armstrong's in 1887, Veley's in 1890, and so on. In this sense the intertextual space was *diachronic*. (In the case of Latour's subject scientist mentioned earlier, we see that this intertextual space is also diachronic, spread over a period from 1948 to 1971 (p. 33). On the other hand, though, for Ray, writing this paper in 1896, the elements of this space were, so to speak, 'frozen in time'. All the components mentioned in Ray's paper were present in 1896. In this sense the intertextual space was *synchronic*, a static snapshot of the diachronically changing state of the space.

This synchronicity is important because this is what was 'visible' of the intertextual space to Ray in the course of his investigation in 1896. But the diachronicity is significant in the context of the matter of *priority*: who discovered what when. The diachronic attribute of the intertextual space thus pertains to what I referred to in the previous section as the historical originality (H-originality) of the construction of a scientific fact, theory or procedure.

Indeed, there is a further aspect of the intertextual space that becomes evident *apropos* Ray's paper "On Mercurous Nitrite":The synchronic intertextual space pertaining to the relevant chemistry visible to Ray in 1896 was not a complete snapshot of the *actual* diachronic intertextual space. There was a crucial component from the actual diachronic space that was apparently invisible to Ray in 1896. As noted earlier, Ray's, (1896) paper equivocated on the H-originality of his work. As per his text, the synchronic intertextual space as was visible to him *seemed* to imply that the discovery of the compound mercurous nitrite was *his* discovery. The reader is given the impression that Ray believed this to be the case.

But, in fact, Ray's synchronic view of the intertextual space in 1896 is erroneous. A paper is missing from it: almost a decade before his "On Mercurous Nitrite" was published in the *Journal of the Asiatic Society of Bengal* (and republished the same year, as it turned out in the German journal on inorganic chemistry, *Zeitschrift für anorganische und allgemeine Chemie*), the British *Journal of the Chemical Society* published a paper by Edward Divers and Tamemasa Haga titled "The Reaction between Sulphides and Nitrites of Metals other than Potassium" (Divers & Haga, 1887). The second paragraph of this paper begins with the sentence "First, we found that silver nitrite and mercurous nitrite were both decomposed by sulfurous acid added in moderate excess..." (p. 659).

Thus, by 1887, the salt mercurous nitrite was a known compound; Divers and Haga, however, inserted a footnote to the effect that "Concerning the preparation and properties of this *new* salt (my italics) we have yet to publish an account" (ibid). So it was deemed a new salt in 1887. But we note that Divers and Haga were also ambiguous in their footnote: was it the case that they had not studied its preparation or properties or was it that they had done so but had yet to publish on it? If they were not the first to have discovered the salt

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[4] For brief introductions to the concept of intertextuality in literary theory see, e.g., Butler, 2002, p. 24, 31–32; Culler, 2011, pp.34–35. For a more detailed discussion see Harvey 1990, pp. 49–51 and elsewhere.

someone before them had. The rest of the Divers-Haga paper makes no further mention of mercurous nitrite.

By 1897 Ray *was* aware of the Divers-Haga paper: in what was apparently his first of many publications in the *Journal of the Chemical Society,* titled "Nitrites of Mercury and the Varying Conditions under which they are formed" (Ray, 1897a) he began with a section titled "Mercurous Nitrite, $Hg_2 (NO_2)_2$" to which he appended a footnote that referred to the Divers-Haga paper of 1887. Ray's synchronic version of the relevant intertextual space in 1897, thus included this paper with its reference to mercurous nitrite. It would seem that not only had Ray *not* discovered the compound but he was, by 1897, aware of this fact. Indeed, some years later in a paper published in 1907 he would again refer to the Divers-Haga paper (Ray, 1907).

5 On the epistemic complexity of Ray's early papers

Scientific papers are *artifacts*; human inventions. But they are not *material* artifacts in the way most technological or aesthetic artifacts are. Material artifacts are subject to the ravages of nature; they are subject to, and victims of, physicochemical laws. And while scientific papers, like all texts, require material substrates for their storage (or representation)—as inscriptions on clay in remote antiquity, on parchment, paper and, in our own time, on semiconductor devices—they are intrinsically resistant to the laws of physical nature. Texts, including scientific papers, are symbol structures, thus *abstract* artifacts.[5] They can be freely transferred from one material substrate to another; the latter are themselves material artifacts but the symbol structures they hold are not.

Both material and abstract artifacts, however, share a certain important property. They are repositories of knowledge. The making of an artifact is a knowledge-rich process. Its maker (generically we may call him or her the 'artificer') brings to the act a rich network of facts, theories, values and beliefs which collectively we designate as 'knowledge': a part of this serves as input to the making of the artifact, a part is the knowledge produced by way of its making—new facts, new theories, new concepts and ideas, new insights. Knowledge is thus also the output of the making of the artifact.

In other words, an artifact holds knowledge that both contributes as input to its making and is generated as output of its making. The richness of the (input/output) knowledge and their connections constitute what we may call the artifact's *epistemic complexity* (Dasgupta, 2019, p. 39).

The originality and significance of an artifact will be a function of its epistemic complexity. Consider Ray's, (1896) paper: its epistemic complexity lies not only in the knowledge it drew upon as represented by the synchronic intertextual space in which it found a location—its input knowledge—but also in the output knowledge it encoded and thus became *its* contribution to this intertextual space. Thus, we may say that the H-originality of the paper "On Mercurous Nitrite" lay in its epistemic complexity, in the manner in which it represented how Ray drew upon its input knowledge and thereby produced new knowledge: its preparation as a stable crystalline form, explanation of the mechanism of its formation, the process by which mercurous nitrate was produced from the nitrite, the means by which the nitrite was unequivocally identified, and a range of chemical and physical changes effected under different conditions. The H-originality of this paper thus lay in its epistemic complexity, regardless of the fact that the compound was known as early as 1887 to Divers and Haga.

6 On plot structure

In the course of the *fin de siècle,* and through the ensuing first decade of the twentieth century, Ray (singly and later with his students) published many papers on the nitrites of mercury and other metals, mostly in the *Journal of the Chemical Society* and the Chemical Society's *Proceedings.* The inorganic chemist Animesh Chakravorty, an authority on Ray's chemical researches, has described in recent years this work and its influence on other chemists of a later time (Chakravorty, 2014).[6] Our particular interest here lies in the earliest papers devoted to the nitrites and nitrates of mercury, beginning with his seminal "On Mercurous Nitrite" (1896), followed by a series of papers in the Chemical Society's *Journal* (Ray, 1897a, 1897b, 1902, 1904, 1907).

In the summary of the method of intellectual history earlier in this essay, I noted that the end product of a work of intellectual history is to construct a narrative that explicates the meaning of a text within a plot structure. Let me explain this further.

Literary theorists and intellectual historians in the humanities are concerned with the reader's response to a writerly text. The intellectual historian of science is no exception. The all-important difference between the responses to texts in the humanities and to scientific texts is that while in the

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[5] For detailed discussions of the nature and taxonomy of artifacts, see Dasgupta (2019), especially pp. 13–27, and the articles in Margolis and Laurence (2007).

[6] See also the bibliography of Ray's scientific papers in his obituary notice in the *Journal of the Indian Chemical Society,* XXI, 1944, pp. 253–259 — a journal which Ray himself had founded in 1923.

former readers may entertain widely varying interpretations, such latitude (at least ideally and in principle) is unacceptable in the realm of scientific texts. In the latter, what is demanded are precision of thought, unambiguity of concepts and ideas, a shared vocabulary, and a commonly understood language. Every reader—at least the 'peer' reader (a fellow scientist or specialist)— should be able to, indeed must, understand a scientific text in roughly identical ways. In the case of a textual description of an experimental result this enables, at the very least, another scientist to repeat the experiment to confirm or refute its results and interpretations (as was Ray's original experiments of 1896, repeated 115 years later by a team of chemists at the Indian Association for the Cultivation of Science (Samanta et al., 2011).

The intellectual historian Hayden White (1978) made the point that the historian's task was to "[make] stories out of *mere* chronicles... by an operation... called 'emplotment' [his italics]". By the latter word he meant "the encodation of facts contained in the chronicle as components of specific *kinds* of plot structures" (p. 83) [emphasis in the original]. To make a 'story' or a narrative out of a scientific text would then demand *emplotting* the text according to one or more plot structures..

The idea of a plot structure is by no means foreign to the historiography of science, although the term 'plot structure' itself is not commonly used. Reaching back to the nineteenth century, philosophers and historians of science have proposed a variety of 'models' of scientific inquiry (see, e.g., Cohen, 1994 on the historiography of the Scientific Revolution). In most recent times, the most influential models are no doubt the 'conjecture & refutation' model due to Karl Popper (1968) and Thomas Kuhn's (2012) 'paradigm-normal science' model, but there are others, such as the concept of a 'research tradition' proposed by Larry Laudan (1977), Imre Lakatos's (1978) 'methodology of research programmes', the 'mangle model' of Andrew Pickering (1995) and the 'actor-network' theory due to Latour (1987) and others. Each has its own considerable following. At any rate, echoing Hayden White, one of the tasks of the intellectual historian of science is to elicit a plot structure underpinning a scientific text and thereby render a narrative out of a scientific 'chronicle'.

7 Finding plot structure and narrative in Ray's papers

To read a text as a chronicle is to read it serially: as the occurrence of 'one damn thing after another'. For example, in volume IV of his monumental, 16–volume treatise on *Inorganic and Theoretical Chemistry* (1922), J.W. Mellor is essentially presenting a (partial) chronicle of Ray's contribution to the chemistry of mercury nitrites and nitrates:

> According to P.C. Ray, when mercury is covered by a 10 cm layer of nitric acid of sp. gr. 1.11 at 15 degrees and at a temp. of 30–35 degrees, bright yellow crystals of mercurous nitrite are formed. A part of the nitric acid is reduced to nitrous acid; some of the nitrite is decomposed by the nitric acid, and the proportion of nitrous acid in the solution rapidly increases until mercurous nitrite and nitrate are accumulated in equi-molecular proportions; the proportion of nitrous acid in the solution then remains constant and acts as a catalytic agent in the reaction between mercury and nitric acid . . . He further assumes that when nitric acid and mercury are left in contact for a long time, the following salts may form. . . (p. 758)

There follows a list of the chemical formulas of nine nitrite and nitrate salts of mercury. Mellor ends by cautioning that "not all of these salts have been isolated" (ibid). No mention is made of Ray having *discovered* mercurous nitrite.

Eliciting a plot structure from a chronicle is to extract its meaning, what it is 'about'; to tell a story. So what is the story Ray tells in these papers?

When we inspect the five papers under consideration (Ray, 1896, 1897a, 1897b, 1902, 1907), we discover that Ray had identified a set of related yet discrete *problems*, all having to do with mercurous nitrite and other closely related mercury salts. Here is a subset of these problems:

1. How do the yellow crystals of mercurous nitrite respond if left in contact with mercury and the mother liquor (dilute nitric acid)? (Ray, 1896).
2. How to account for the continuous formation of mercurous nitrite? (That is, what is the mechanism of its continuous formation?) (Ibid)
3. What is the evidence that the salt is a nitrite? (Ibid).
4. Does mercurous nitrite change to mercurous nitrate? If so, how? (Ibid).
5. What happens when mercurous nitrite is allowed to slowly dissolve in the mother liquor? (Ibid).
6. What happens if the mercurous nitrite is diluted with a large quantity of water? (Ray, 1897a).
7. What is the behavior of nitric acid (HNO_3) of different strengths on mercurous nitrite? (Ibid).
8. What is the effect of of the presence of *nitrous* acid (HNO_2) in promoting the formation of the nitrite? (Ibid).
9. What happens if dilute nitric acid is poured on mercurous nitrite and the solution is warmed? (Ibid).
10. What are the circumstances under which mercurous nitrite is transformed into mercurous *nitrate* ($Hg_2(NO_3)_2$)? (Ibid).

11. To describe the nature of *mercuric* nitrite obtained from the progressive reaction of water on mercurous nitrite (Ibid).
12. To study the transformation of mercurous nitrite into ‘Marignac’s salt’ (Ibid).
13. What happens if a solution containing mercurous nitrite and mercuric nitrite is treated with a dilute solution of sodium hyponitrite? (Ray, 1897b).
14. To separate out the mercuric hyponitrite from the solution of mercurous and mercuric hyponitrite (Ibid).
15. To study the effect of dilute and concentrated nitric acid on mercuric hyponitrite (Ibid).
16. To compare the effect of heat on the hyponitrites of mercury with that of heat on the nitrites and nitrates of mercury (Ibid).
17. To isolate mercuric nitrite in the solid state (Ray, 1902).
18. To study the effect of heat on the decomposition of mercuric nitrite (Ibid).
19. To compare the effect of heat on mercuric nitrite and mercurous nitrite (Ibid).
20. Preparation of pure mercuric hyponitrite $Hg_2N_2O_2$ (Ray, 1907).

The philosopher of science Larry Laudan began his monograph *Progress and Its Problems* (1977) with the bald statement “Science is essentially a problem solving activity” (p. 11). In contrast, for physicist–philosopher John Ziman in *Real Science* (2000), “The function of science is to produce knowledge” (p. 83). These are, if you wish, complementary views: science solves problems so as to advance knowledge of the physical world. But scientists are not interested in solving just any old problems, but rather what we may call *problems of interest* which elsewhere I characterized as follows (Dasgupta, 2018, p. 273):

> A problem of interest in science is a problem that (a) has never been encountered before; or (b) even if encountered has never led to a solution; or © even if solutions are known to exist, none are deemed satisfactory according to some investigator’s or the relevant community’s standards.

A problem of interest, in other words, if solved, promises to pay significant dividends. A solution to a problem of interest we may call a *creative* solution (ibid)—that is a solution that demands creativity on the part of some researcher. Problems of interest form a hierarchy: some address larger, more all-encompassing issues such as the nature of time or space or energy or combustion or speciation or computation. Their solutions are creative in the sense Thomas Kuhn (2012) described as paradigm-shifting and paradigm-defining. But what Kuhn identified as ‘normal science’ entails finding solutions to problems of interest of much more limited scope, within the confines of a Kuhn-style paradigm. Solutions to such problems are also creative but of a more restrictive scope.

The set of twenty problems listed above are of the latter sort. Each was a problem of interest but of a restricted scope. When we consider them collectively, a certain narrative emerges:

> Over the first decade or so of his active career as a post-doctoral professional research chemist, Ray identified a diachronic network of problems of interest pertaining to mercurous nitrite and related compounds within the framework or paradigm governing fin de siècle inorganic chemistry, and obtained creative solutions to each of them them. The outcome was that he created a subspace for himself in a part of the intertextual space in inorganic chemistry.

The plot structure underpinning this (albeit succinct) narrative is one we may designate ‘*identifying and solving normal empirical problems of interest*’. As his papers between 1896 and 1907 reveal, Ray did not articulate a major theory or hypothesis and set out to corroborate or (as Popper (1968) would insist) refute it. He did not execute ‘extraordinary’ or paradigm-shifting science in Kuhn’s sense. He did not postulate an axiomatic structure and attempt to formally demonstrate its validity. Rather, he practiced systematic, empirical, structured (but *original)* normal science the outcome of which was a body of new chemical knowledge in the domain of a family of mercury compounds. His originality and creativity as a chemist lay in the space he created within the intertextual space by way of his solutions to a series of problems of interest.

8 Concluding remarks

In this essay I have explored the intellectual history of the early work of Prafulla Chandra Ray by examining his first few papers on the nitrites of mercury and related compounds. A number of significant notions emerged from this study:

One. There is evidence that almost a decade before Ray’s seminal paper of 1896 mercurous nitrite had been identified as a “new” salt by Divers and Haga. Thus it cannot be said that Ray *discovered* the salt mercurous nitrite. Indeed his 1896 paper makes no such explicit claim though in later papers by him as well as in his autobiography Ray does assert that he had discovered the compound.: “The discovery of mercurous nitrite opened a new chapter in my life” (Ray, 1932, p. 113). Rather, it is more accurate to assert that Ray had discovered *serendipitously* a particular *method* of synthesizing a stable, crystalline form of mercurous nitrite involving what Ray’s modern interlocutors describe as “an apparently counter-intuitive reaction" between mercury and dilute nitric acid (Samanta et al., 2011, p. 137). Mellor's (1922) description seems to recognize this fact: "According to P.C. Ray, when mercury is covered by a 10 cm layer of nitric acid... at a temp. of 30–35 degrees, bright yellow crystals of mercurous nitrite are freely formed" (p. 758). There is no suggestion in Mellor's account that Ray had discovered a new compound. The serendipity of Ray's discovery was also recognized by Chakravorty (2014, p. 1205) who, incidentally, did not mention Divers and Haga's (1887) earlier identification of the "new" salt.

Two. Furthermore, Ray's main contributions to the enrichment of the relevant intertextual space were the identification of a series of interrelated problems of interest and their attendant solutions, all pertaining to the nitrites and nitrates of mercury. In the preceding section I have listed twenty of these problems of interest and suggested that their identification and solutions constituted 'textbook' examples of Kuhnian normal problem-solving.

Three. Reading Ray's first papers between 1896 and 1907 and identifying his main problems of interest and their solutions, we are able to discern a plot structure—'identifying and solving normal empirical problems of interest'—that informs these texts and the tenure of his work. We are able to construct a ('short') story as an abstraction of what Hayden White called a 'chronicle' as, for example, Mellor's brief account of 1922 represents. This resulting story or narrative is presented in the section above and need not be repeated. Suffice to repeat that the plot structure reveals Ray as a 'normal' problem solver (in Kuhn's specific sense)—but an acute one—whose solutions were a corpus of new (H-original) chemical facts in the realm of mercury compounds.[7]

Four. Over the past half-century or so, the social historiography of colonial and post-colonial science in India has been attended by the 'centre-periphery' (or metropolis-province) model—Europe being the centre and non-Europe the periphery—and its role in the development of a scientific ethos in modern India, the latter as a quintessential instance of the periphery (see, e.g., MacLeod, 1987; Raina, 1996; Kumar, 1997; Chakrabarti, 2004; D. Dasgupta, 2021). However, as our examination of Ray's earliest papers shows, the centre-periphery binary plays no part here. Neither the chronicle as embedded in the papers nor the abstracted plot structures nor the resulting narrative appeals to the centre-periphery model. There are no geographic or social spaces constituting centre or peripheries that contribute to our understanding of the textual contents of these papers or Ray's intentions in pursuing his particular problems of interest or the plot structures or the abstracted narrative suggested above. All that mattered was the intertextual space Ray's papers created for themselves within the larger intertextual space of inorganic chemistry. If we are to speak to Ray's contribution to the evolution and growth of inorganic chemistry, the centre-periphery model is not necessary. What matters, as I have suggested in the foregoing, was his contribution to the intertextual space.

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[7] However, as Chakravorty (2014) has so well illuminated, Ray's 'normal science' had *consequences*: not only did it initiate a flourishing 'school of Indian chemistry' (see Majumdar, 2010)—especially in the realm of nitrites of mercury and other metals (see also Mellor, 1922, pp 758–759)—but it also stimulated other chemists in more recent times to refer to Ray's original papers in their own investigations. In this sense Ray was not only H-original (that is, original with respect to his past history) but was also what I have termed C-original ('consequentially original'): his work had consequences or implications for the future history of the field (Dasgupta, 2018).

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