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A TERMINOLOGY DYNAMIC AND THE GROWTH OF KNOWLEDGE: A CASE STUDY IN NUCLEAR PHYSICS AND IN THE PHILOSOPHY OF SCIENCE

1. Introduction

The study of how science works or should work and how science develops logically, sociologically and psychologically are the central concerns of the philosophy of science. Philosophers of science and historians of science study the written texts produced by (usually) epoch-making individual scientists. These texts include *informational*, detached texts, like papers in learned journals, and texts with *interpersonal* focus like personal letters.

Learned papers, and to a lesser extent, popular science articles and scientist-to-scientist letters, are sometimes written to produce a critique of existing concepts, ontologies, taxonomies and partitive relations, for instance. Such a critique is developed to question established criteria of certainty, identity and truth in a given specialist discipline (some argue that this is true of almost all writing in that a writer, inevitably or deliberately, produces a critique of his or her society, the world, and so on). Scientific writing plays an important role in disseminating what is perceived to be *scientific reality* at a given time by (a group of) scientists.

Every age has its own scientific theories and scientific facts and scientists in every age describe a collection of facts and enunciate theories by a set of competing or conflicting terms. These terms may already exist, or they may be retronyms, that is novel interpretations of words and phrases in general or special language, or they may simply be coined for one description here or another hypothesis there: at all times this competition or conflict in the choice of terms is recorded in scientific texts. One may argue that scientific writing is a manifestation of a *terminology dynamic*. Such a dynamic may be defined as a rational or irrational choice of terms by scientists. Furthermore, the terminology dynamic determines the subsequent embodiment of the terms in the lexicogrammar of languages of scientists who coin, modify and redefine terms, and make terms obsolete. The terminology dynamic, in the above two senses, can then be regarded as a key determiner of scientific or technological change.

In this paper we present an analysis of texts in nuclear physics and texts in the philosophy of science to argue that the in-text deconstruction and reconstruction of scientific reality, mainly through manipulating the terminology of a given specialist domain, plays an important role both in the genesis of science and in the genesis of the philosophy of science. The terminology dynamic studied here involves terms that heralded nuclear physics; in particular, we describe the genesis of the term *atom* and indicate that this major change in physics may be detected through a diachronic study of the publications of an eminent scientist, like Rutherford for example.

The philosophers of science tell us what motivates one or more scientists to put forward novel ideas, how and why the scientists conduct mind-boggling experiments, how and why they confront existing orthodoxy, and eventually how a scientific thought tends to be more popular and more abiding than others. Such accounts are usually based on the analysis of the writings of scientists. But what about the writings of the philosophers of science? It is possible to argue that here also there is a dynamic, a dynamic that has its roots in history and ideology, and a dynamic that can be monitored through the terminology used to construct the reality of philosophy of science. Ludwik Fleck's notion of a *thought collective* (c.1935) finds its way some 30 years later in Kuhn's *paradigm*. But the reception to Kuhn was quite hostile in some quarters: Margaret Masterman finds the term *paradigm* polysemous; Lakatos, Laudan and Feyerabend take issue with the Kuhnian philosophy that manifests through the term, and coin their own terms to suggest how science develops. In the meantime (c.1981-1993), Kuhn has redefined the term *paradigm* and now much prefers to talk about *lexicons* of science that help him to understand the cognitively significant language changes in the development of science.

Philosophers of science, bibliometrists and scientometrists appear not to deal with the lexical and pragmatic aspects of how terms are coined, evolve and become obsolete. Terminologists, with their empirical understanding of the terms of specialist disciplines, can help in devising a methodology of dealing with (evolving) terminology in science, technology and beyond to the three disciplines, philosophy of science, bibliometry and scientometry.

2. Methodological Preliminaries

Scientific texts in a narrow sense can be viewed as texts that either help to consolidate existing concepts and norms in a given scientific discipline or they can be viewed as texts which are used to challenge established concepts and norms in a discipline. Some argue that scientific texts show how scientists deconstruct texts. Here, Gentzler's views on translated texts and literary criticism appear quite apt: '[D]econstruction challenges limits of language, writing and reading by pointing out how the definitions of the very terms used to discuss concepts set boundaries for the specific theories they describe' (Gentzler, 1993: 145).

Verschuuren, who introduces philosophy of science through exemplar scientific theories and innovations in life sciences, argues that despite massive shifts in the meanings of terms scientists are still able to talk to each other. Verschuuren has collected a number of examples that indicate that different conceptual systems bring to light different facts. For instance, pre-Darwinian biology stressed that the distinction between species was absolute, but Darwin suggested that there is evolution of species; for Brahe sunrise was caused by a rising Sun, but Kepler suggested that sunrise is caused by a turning earth. In a range of disciplines, scientists have decided to keep the same term but change its meaning totally: a kind of lexical inversion (see Table 1). Rutherford, a New Zealand born, native English speaker, inverted the meaning of the term *atom* to introduce, with many other scientists, the concept of nuclear atom. But more of this later.

Table 1: Lexically 'inverted' terms based on Verschuuren (1986: 83-4).

Term/ 'Concept'	**Associated Proposition**	
	Before	**After**
Perception	***In perceiving one sees***	
	beams coming from an object (Aristotle)	beams leaving the observer's eyes (Pythagoras)
Motion	***Objects move because of***	
	an in-built tendency to move (Aristotle)	something exerts 'attraction' (Galileo)
Solar Cycle	***Sunrise is caused by***	
	a rising Sun (Brahe)	a turning earth (Kepler)
Combustion	***Burning an object (say O) in air means***	
	The mass of O decreases by losing *phlogiston* to air (Priestley)	The mass of O increases by gaining *oxygen* from air (Lavoisier)
Photosynthesis	***Glucose *produced by plants during photosynthesis was***	
	Carbon combined with water to form carbohydrates ($C_6(H_2O)_6$) (Ingenhousz)	Hydrogen combines with Carbon di-oxide to form carbohydrates ($(CH_2O)_6$) (Van Neil)
Ventilation	***Expiration (during breathing) is facilitated by***	
	expansion of chest as a consequence of heating (Galen)	contraction of chest as a consequence of higher pressure (Harvey)
Heartbeat	***Blood circulation is caused by***	
	an explosion during diastole of the heart (Descartes)	a compression during systole of the heart (Harvey)
Species	***The distinction between species is***	
	an absolute phenomenon that has been determined in the past (Linnaeus)	a contemporaneous phenomenon with borders between the species (Darwin)

*Note that the modern chemical formula for Glucose is $C_6H_{12}O_6$

Rorty, writing about philosophy, and literary history and criticism, has analysed developments in physics. He notes with some wryness that '[A]fter each pedestrian period of normal science, they dream up a new model, a new picture, a new vocabulary' (1978:141). 'Revolutionary science', to use the Kuhnian term, or 'error eliminated' science to use Popper's term, includes, it appears, terminology coinage and terminology revision and updating: For example, the notion that the 'atom' was indivisible, an etymological and physical 'truth', was challenged by Rutherford and the atom is, despite its etymological history, now considered 'divisible'.

The link between scientific discourse and innovation in science has been argued strongly by Frawley. Despite his polemical style and overt sympathies for Kuhn, he presents a plausible narrative focusing on the primacy of text, and the role terminology plays in scientific discovery. According to Frawley, 'science is a sign system, a method of creating representations of the world and of institutionalising these representations into coherent systems of extended talk: science is discourse' (1986:68).

More recently, Halliday and his colleagues have been assessing the role of scientific writing. Halliday has coined the term *writing science*. Based on a textual analysis of scientific texts, ranging from Chaucer on the *Astrolobe* to Newton's *Treatise on Opticks*, from John Dalton’s *New System of Chemical Philosophy* to James Clark Maxwell's *Treatise on Electricity*, from popular science articles to school text books on geography and meteorology, Halliday talks about how a scientist uses the grammatical resources, the so-called *lexicogrammar*, of his or her language, to create a discourse 'that moves forward by logical and coherent steps, each building on what has gone before' (Halliday and Martin 1993:64).

Let us now observe Rutherford and others writing (nuclear) physics.

3. Rutherford and the Genesis of the Nuclear Atom

The American Heritage Dictionary (3rd Edition, 1992) defines an atom as:

> 1a. A part or particle considered to be an irreducible constituent of a specified system. 1b. The irreducible, indestructible material unit postulated by ancient atomism. 2. An extremely small part, quantity or amount. 3a. A unit of matter, the smallest unit of an element, having all the characteristics of that element and consisting of a dense, central, positively charged nucleus surrounded by a system of electrons. The entire structure has a diameter of 10^{-8} centimetres. 3b. The unit that is regarded as a source of nuclear energy.

Definition 3a is based on the famous Bohr-Rutherford model for the atom and its 'constituents' - nucleus and electrons, and carries a significant amount of history with it. Such baggage is clearly delineated in *The Shorter Oxford English Dictionary* (1973). The OED traces the roots of the word *atom* to a Middle-English (c. 1450-1550) word *atomus* - smallest particle, the changes in its meaning over the next four hundred years make interesting reading (see Table 2a below).

Table 2a. From *Atomus* to *Atom*. (Source *Shorter OED, 1973)*

1477	An atom is a <u>hypothetical body</u>, so small as to be incapable of further division; and thus to be one of the ultimate particles of nature.
1650	<u>Physical Atoms</u>: The supposed ultimate particles in which matter actually exists (without reference to its stability).
1819	<u>Chemical Atoms</u>: The smallest particles in which the elements combine, or are known to possess the properties of a particular element.

The interesting point to note here is the distinction between the physical and chemical atoms, a distinction which is not generally referred to in the current texts in science and technology. This distinction played a key role in establishing the concept of modern nuclear atom. During the first decade of 20th century it became clear that a wide range of physical and chemical phenomena could not be explained by the then held views about the nature of matter: from the inertness of noble gases and chemical volatility of some elements, from the emission of fixed wavelengths by chemical elements when excited to the observation of radioactive disintegration.

Some scientists of the period were keen to retain the distinction between physical and chemical atoms. Nye (1986), a historian of science, has compiled key publications related to the development of the atomic theory of matter and her compilation shows that the doubts about this distinction can be found as far back as 1858. In summarising work over 20 years on developing a model of the nuclear atom, Rutherford noted that during the 19th century ‘it was generally accepted that the atoms of the chemist and the physicist were permanent and indestructible’

(1921:389). Rutherford then argues that these notions of permanence and indestructibility of atoms cannot possibly be true because radio-active elements like Uranium and Thorium 'were undergoing a veritable transformation, spontaneous and quite uncontrollable by the agencies at our disposal' (*ibid*). He finishes his summary by noting that not only an atom is indivisible but that atoms of heavier elements may contain lighter elements (1921:394). Rutherford retains the term *atom* but changes its definition totally.

But Rutherford was one amongst many scientists whose input was crucial to the development of the nuclear atom. It is said that J.J. Thomson re-interpreted Aepinus's one fluid theory of electricity in an article entitled *Aepinus Atomised*, by arguing that an atom is essentially electrons within a sphere of positive electricity. Thomson based his argumentation on the supposition that 'the mass of an atom is the sum of the corpuscles it contains' (Thomson 1904:237 cited in Conn and Turner 1965:104). The notion of corpuscles, which we now 'know' as electrons, was originally used by Isaac Newton in his 'corpuscular theory of light'; Newton's corpuscles are now known as *photons*. Nagaoka (1914) contemporaneously with Thomson published his Saturnian theory of atom, a theory that had its roots in astronomy. According to Nagaoka, who was influenced by James Clerk Maxwell, the atom is a system which consists of a large number of particles of equal mass arranged in a circle at regular intervals and repelling each other with forces inversely proportional to the square of the inter-particle distance; and at the centre of this atom there is a 'particle of large mass attracting the other particles according to the same law of force' (Nagaoka 1904:445 cited in Conn and Turner 1965:113). Rutherford benefited from the work of Thomson and Nagaoka and his work was carried on by Niels Bohr. This interactive process in which one scientists' discovery is a reinterpretation or modification of his or her peers' beliefs or theories, involves a choice between competing or conflicting terms (see Table 2b).

Table 2b. Establishing a 20th century definition of *atom* (from Conn and Turner 1965)

Year	'Discovery'	Reinterpreted/Modified
1899	Thomson's atomic structure	Aepinus one fluid theory of electricity
1904	Nagaoka's 'Saturnian' atom	Maxwell's observations about the planet
1906	Rayleigh's infinite electron atom	Thomson's atomic structure
1909	Rutherford's 'nucleus' theory	Nagaoka's and Crookes' observations
1913	Bohr's theory of atomic structure	Rutherford's scattering experiments

It was Rutherford's earlier papers which show a *lexical* struggle in that whilst he is happy with the etymological history of the word *atom* - an indivisible unit of matter - he has, due to the overwhelming weight of 'scientifically' collected experimental data, to posit that an atom has constituents. Chadwick (1962, 1963, 1965) has organised a collection of Rutherford's papers published between 1894-1937. The large majority of these were learned papers, published in *Philosophical Magazine* and *Nature*: he produced 100 papers in a 10-year period from 1900. His other output included writings for magazines like *Harper's*, *The Electrician* and *Technics*. He made a number of speeches, which were subsequently published, at the UK Royal Society and the Manchester Literary and Philosophical Society. Rutherford also worked on the development of laboratory standards for Radium, a newly discovered and radioactive metal. These papers can be viewed as a repository of a terminology dynamic which was used to present matter in a new light.

In almost all these publications, from 1894 to 1937, the year of his death, Rutherford talks about radioactive decay of elements and the possible constitution of the atom (c.1894-1910), and the *atomic nucleus* dominates Rutherford's writing between 1910-1930, and includes references to *protons* (1925) and *neutrons* (1927). He wrote a set of landmark papers, four in all, in 1919, where he described the results of his experiments in which atoms of Hydrogen, Oxygen and Nitrogen were bombarded with alpha particles and the result was the emergence of 'swift Hydrogen nuclei' (latterly *protons*). Rutherford notes that the experiments with Nitrogen show 'an anomalous effect' in that the Nitrogen atom breaks up, not spontaneously nor under the control of agencies 'beyond our control', but in a controlled fashion which can be organised by humans: Rutherford presented 'one of the most momentous experiments in the history of science [...] unostentatiously, without emphasis, or any sensational claim' (Feather 1963:33). Towards the end of his life he reported on the 'energy released in nuclear transmutation' (Rutherford 1933 cited in Chadwick 1965). The compound *nuclear transmutation* completes the lexical inversion of the original meaning of the term *atom.* (It is not only the single word terms like 'protons', 'neutrons' and so on, but a range of interesting collocations used by Rutherford that comprise the terminology dynamic of nuclear physics[1].)

Rutherford's papers show a terminology dynamic: from an indivisible atom to spontaneously breaking up atoms; from an *atom* based on the original *atomus*, a unity, to a constituent structure comprising electrons and nuclei with positive charge; from a nucleus to its constituents; from the light or heavy nuclei that would be scattering incoming beams of 'swift Hydrogen atoms' to nuclei that would transmute under such beams; from the concept of static and inert atoms to the notion of energy released during their transmutation.

This 20th century view of matter, that is, that all matter comprises a group of elementary particles (protons, neutrons, electrons, neutrinos, mesons and photons in the first half of this century and *quarks, gluons, partons* and onwards to a grand unification over the last 40 years) was developed by many scientists including Max Planck, Ernest Rutherford, Niels Bohr, Albert Einstein, Enrico Fermi. What heralded nuclear physics was Rutherford's experiments, Planck's Quantum Theory, Einstein's Relativity Theory, Bohr's nuclear model of the atom and Fermi's refinement of the model. The terminology dynamic can be seen in texts on quantum mechanics and relativity theory where notions of non-determinism, duality of matter and waves, frames of references conditioned by velocity and acceleration, give rise to interesting neologisms and archaisms. Despite their apparent love of neologisms, pejoratively called jargon, scientists are generally quite conservative in their choice of terms. For instance, Bohr argued that 'however far the phenomena transcend the scope of classical physical explanation, the account of all evidence must be expressed in classical terms [...], must be expressed in unambiguous language with suitable application of the terminology of classical peoples' (Bohr, 1987: 39, see also Favorholdt's critique (1993, 1994), of Bohr's 'philosophy' and his view of language).

4. Of paradigms, thought collectives, myths, scientific theories and lexica.
Kuhn's attempt to revolutionise the philosophy of science by predicating a structure of scientific revolutions follows a research tradition that was *operationalised* by, amongst others, Ludwik Fleck. Fleck, a neo-Kantian scientist, attempted to argue that the *genesis and development of a scientific fact* (Fleck 1935/1979) involved 'thought styles' and 'thought collectives' that show sociological conditioning as vital to the consolidation of scientific facts. The term *thought collective* ('Denkkolektiv') is defined as 'a community of persons mutually exchanging ideas or maintaining intellectual interaction and [....... the thought collective] also provides the special "carrier" for the historical development of any field of thought, as well as for the given stock of knowledge and level of culture' (Fleck 1979:39). A *thought style* ('Denkstil') 'is a definitive constraint on thought and even more; it is the entirety of intellectual preparedness or readiness for one particular way of seeing and acting and no other [...] scientific facts [depend] upon thought style' (Fleck 1979:64).

Fleck was aware of the developments in the atomic theory of matter (c. 1900-30) and commented that 'the concepts of the elements and of the atom can thus be constructed from historical factors as well from those of the thought collective. Such concepts are derived from the collective imagination.' (1979:83). Thus for Fleck, Thomson, Rutherford, Nagaoka, Rayleigh and Bohr were members of a *thought collective* and had roughly similar *thought styles* (see Table 2b). Kuhn notes that although he is not certain what effect Fleck has had on him, he acknowledges that 'Fleck's text helped me to realise that the problems which concerned me had a fundamentally sociological dimension' (Kuhn 1979:viii).

A *research paradigm* (Kuhn 1970) was defined originally by Kuhn to 'suggest that some accepted example of actual scientific practice - examples which include law, theory, application and instrumentation together - provide models from which spring particular coherent traditions of scientific research' (1970: 10).

The initial, formally-recorded reaction to Kuhn's theories by Popper and Lakatos was rather hostile. Such hostility showed in two ways: First was to deny the existence of the term *research paradigm* by arguing that it is so polysemous as to be a fictional term coined by the 'historian-poet' Kuhn (Masterman, 1970). Masterman asked one pertinent question and made an observation about the Kuhnian term *paradigm*:

> **Question: 'Is there, philosophically speaking, anything definite or general about the notion of a paradigm which Kuhn is trying to make clear or is he just an historian-poet, describing different happenings which have occurred in the course of the history of science, and referring to them all by using the same word "paradigm"? (Masterman 1970: 65)**
> **Observation: The definition of the term 'paradigm' is in some respects rather circular: first we define a paradigm as an already finished achievement [...] then from another point of view, describe the achievement as building up round some already existent paradigm' (*ibid.*: 69).**

Table 3a. Kuhn's 21 senses of the term *paradigm*. (Masterman, 1970: 61-65).

Orientation	**Possible interpretations of the proposition: A paradigm is**
Metaphysical	a successful metaphysical speculation (Kuhn 1970:2)
	a set of beliefs (*ibid*:4)
	a myth *(ibid*:17)
	a standard *(ibid*:102)
	a map *(ibid*:108)
	a new way of seeing things *(ibid*:117-121)
	an organising principle governing perception *(ibid*:120)
	something which determines a large area of reality *(ibid*:128)
Sociological	a universally recognised scientific achievement (*ibid*:x)
	a concrete scientific achievement *(ibid*:2)
	(like) an accepted judicial decision *(ibid*:23)
	(like) a set of political institutions *(ibid*:91)
Constructural or Artefactual	(like) a textbook *(ibid*:10)
	(like) an analogy (*ibid*:14)
	a universally recognised scientific achievement *(ibid*:21)
	a grammatical paradigm *(ibid*:23)
	a conceptual and instrumental tools *(ibid*:37, 76)
	a device or type of instrumentation *(ibid*:59, 60)
	(like) a gestalt figure *(ibid*:63)
	an anomalous pack *(ibid*:85)

The textual criticism levelled by Masterman on Kuhn's *The Structure of Scientific Revolutions* includes the observation that there are at least 21 different senses of the term *paradigm* (in *The Structure*) (see Table 3a) and implying that the term can mean almost anything: from a myth to a tool, from a standard to a gestalt figure and so on.

Toumlin has argued that although Kuhn has persuaded many philosophers (of science) to appreciate the 'full profundity of the conceptual transformations which have, at times, marked the historical development of scientific ideas' (1970:39), particularly 'thought provoking' were the terms 'revolutionary science' and 'dogma'. Such profundity and provocation does not hold good on closer examination: the 'very effectiveness of [Kuhn's argumentation] sprang from a certain built-in rhetorical exaggeration or play upon words. ([For Kuhn] To say 'all normal science rests on a foundation of dogma' was like saying 'we are all mad really; which can make a point on a particular occasion, but ....)' (*ibid*). The terminology dynamic here is to deny the existence of the term *paradigm*.

The second way in which hostility to Kuhn’s *paradigm* was expressed shows itself in the writings of Lakatos, Laudan and even Feyerabend (who has a very independent position and criticises both Popper and Kuhn). These authors put forward alternative theories in an attempt to explain how science develops and should develop and work. Thus we have *research programme* (Lakatos 1970), a programme of (research) work that includes both discovery and its justification; *research tradition* (Laudan 1977), a tradition in which a scientist solves problems of very specific types with a view to the seriousness of the problem, and *methodological anarchism* - a term coined by Feyerabend. The terminology dynamic adopted by the three authors is to create neologisms and in effect attempt to replace one neologism, *paradigm*, by their own. And not to be outdone, Kuhn himself was also involved in the coining of neologisms.

Kuhn's position has shifted over the last quarter century and this has led him to argue that conceptual and linguistic change during scientific revolutions are amongst the key changes. During the last 10 years Kuhn has brought terms like *lexicon* and *lexical structure* into what has otherwise been an historical and sociological analysis of how science works and develops. Every scientific theory, according to Kuhn (1991), has its idiosyncratic structured taxonomic lexicon organised within a particular network whose links comprise structural relationships such as that between genus and species. A lexicon is defined to be the 'module in which members of a speech community store the community's kind-terms' (Kuhn 1993:325). The scientific lexicon is the essential precursor for the formulation of scientific problems and their solutions, the description of nature and the order within it: significant changes in the lexicons of scientific theories indicate whether or not a 'revolution' has taken place within a subject specialism.

Kuhn's use of the sharper terms, *lexicon* and *lexical structures,* instead of the vague term 'paradigm', has helped him to distinguish between the phenomenal world and 'world in itself, which is epistemically inaccessible to the cognizers'. Psillos (1994) in his review of Horwich (1993) and of Hoyningen-Heune (1993) notes that Kuhn's notion of a scientific lexicon 'is constitutive of a phenomenal world in the sense that it creates a taxonomy of kinds corresponding to the concepts available to the speech community living in the phenomenal world' (Psillos 1994:925). (More recently, there has been a terminology-centred attempt to reconcile Kuhn's and the positivists' position, especially that of Carnap see, for instance, Irzik and Grünberg 1995).

5. Conclusions and Future Work

A learned paper, when made available to the public at large, is a highly polished piece of writing: cohesive in its argumentation, coherent in its presentation, mindful of the target audience, careful in its historical analysis, and responsible in its predictions for the future. No wonder that to a logically-minded philosopher of science, the logic of the written text is merely the reflection of the underlying logic of science, of the basic rational premise of human argumentation, of the zeal of humans constantly to improve their lot (cf. Carnap, Popper). And, equally we should not be amazed when a society-minded, historically-aware philosopher of science, having access to the informal output of the scientists, like letters and other correspondence, being aware of the social dynamic within a given period in history, takes issue with the primacy of the logic of science and insists on the societal factors that govern the society of scientists and indeed society at large, as important contributory factors to how science works, should work and develops (cf. Kuhn).

We believe that a study of terminology dynamic can also provide useful insight into the work of scientists. Such a study can be conducted systematically, for instance, by keeping statistics about frequency of usage to monitor neologisms, established terms and archaisms in a scientific discipline. The change in the lexicogrammar of an innovative scientist must provide some clue to his or her discoveries. We hope to test the efficacy of this notion by an in-depth terminological analysis of a corpus of texts consisting of the writings of Ernest Rutherford and Niels Bohr. The intention is to monitor change in 19-20th century Physics by compiling a frequency-indexed diachronic terminology of the corpus. This diachronic terminology will help us to monitor ‘winning’ and ‘losing’ terms, most cited and least cited scientific workers, and by inference ‘winning’ and ‘losing’ concepts and percepts. The question here is this: Can a terminology dynamic be the basis of work in philosophy of science (Favorholdt 1994, Horwich 1993), in scientometry (Courtial 1994) and bibliometry (Kragh and Reeves 1991)? This is a question we wish to investigate further.

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[1]An analysis of collocations in two of Rutherford's papers, one published in 1920 and the other in 1927, shows that in the earlier paper the frequent collocates of atom are *atomic number* and *atomic weight;* these are used only once in the the 1927 paper. The collocates for the term *nuclear* and *nuclei*, in 1920, include *nuclear charge*, a few references to *nuclear constitution*, two to *helium nuclei* (alpha particles), and none to *atomic nuclei*. However, in 1927 there are fewer references to *nuclear charge* and many

more (0.2% of the text) to *nuclear structure* and to *helium nuclei* and *heavy* nuclei. (Ahmad *in preparation*).

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