Conceptual Development and Dynamic Realism

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This paper focuses on Thomas S. Kuhn's work on taxonomic concepts and how it relates to empirical work from the cognitive sciences on categorization and conceptual development. I shall first review the basic features of Kuhn's family resemblance account and compare to work from the cognitive sciences. I shall then show how Kuhn's account can be extended to cover the development of new taxonomies in science, and I shall illustrate by a detailed case study that Kuhn himself mentioned only briefly in his own work, namely the discovery of X-rays and radioactivity.

Keywords: Kuhn, scientific concepts, family resemblance, conceptual change, taxonomies, categorization

1. Introduction

How concepts divide entities into categories and how concepts develop over time is an ongoing concern of cognitive psychologists, cognitive anthropologists as well as philosophers. A central question for all of them is to what extent concepts and categories reflect structures of the world and to what extent they are constructed by the human categorizers. Investigating this question, cognitive anthropologists have conducted cross-cultural studies to examine the roles of environment and culture, nature and the human intellect in establishing concepts and categories. Similarly, cognitive psychologists have conducted experiments to illuminate to what extent concepts are given by structures in the environment and to what extent they are created through processes on behalf of the human categorizer. Among philosophers the question has been the focus of the longstanding "realism debate", where philosophers have discussed whether our concepts are approximately correct characterizations of some world of theory-independent entities, or whether what we refer to as "the world" is a product of a mutual accommodation between experience and language.

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In this paper, I shall focus on the work of Thomas Kuhn and how he attempted to integrate insights from cognitive science and philosophy in developing an account of concepts that could substantiate his intermediate position in the philosophical realism debate. An important theme in Kuhn's work after *The Structure of Scientific Revolutions* were to refine and substantiate the claims advanced in *Structure* on concepts and conceptual structures. Kuhn worked on this for several decades during which he published several journal articles,[1] but the book manuscript he was working on towards the end of his life remained unfinished and has so far not been published.[2] This article will focus on his work on taxonomic conceptual structures as "a more general sort of categorizing module" (Kuhn 1990, 5) in which "certain sorts of expectation about the world are embedded" (cf. Kuhn 1990, 8), and on the deeply historically rooted position on realism that can be inferred from this work. As a piece of work in philosophy of science in practice, this paper shall especially focus on how Kuhn's account can explain researchers practices when discovering new phenomena and developing new scientific concepts to describe them, and on how Kuhn's account compares to work from cognitive science on humans' use of concepts in general.

2. A Similarity-Based Account of Concepts

On Kuhn's view, taxonomic concepts build on relations of similarity and dissimilarity between perceived objects. Kuhn here ascribed a special importance the features which differentiate between instances of *contrasting* concepts, that is, concepts whose instances are more similar to one another than to instances of other concepts and which can therefore be mistaken for each other (see e.g. Kuhn 1979, 413. Because the instances of contrasting concepts are more similar to one another than to instances of other concepts, such a set of concepts will in itself also form a family resemblance class at the superordinate level. In this way, family resemblance concepts form hierarchical structures in which a general concept decomposes into more specific concepts that may again decompose into yet more specific concepts, and so forth—in other words, taxonomies.

In one of his unpublished talks, Kuhn illustrated this with a "fragment of a lexicon for physical things" where he showed by use of his favourite example on waterfowls how a superordinate concept decomposes into a group of contrasting concepts, and how this decomposition is determined by sets of features (figure 1).

[1] For an overview, see (Andersen forthcoming).

[2] Only a few people have had access to the manuscript. However, at the MIT Archive, notes can be found from a course he gave on the developing manuscript in the last semester before he retired.

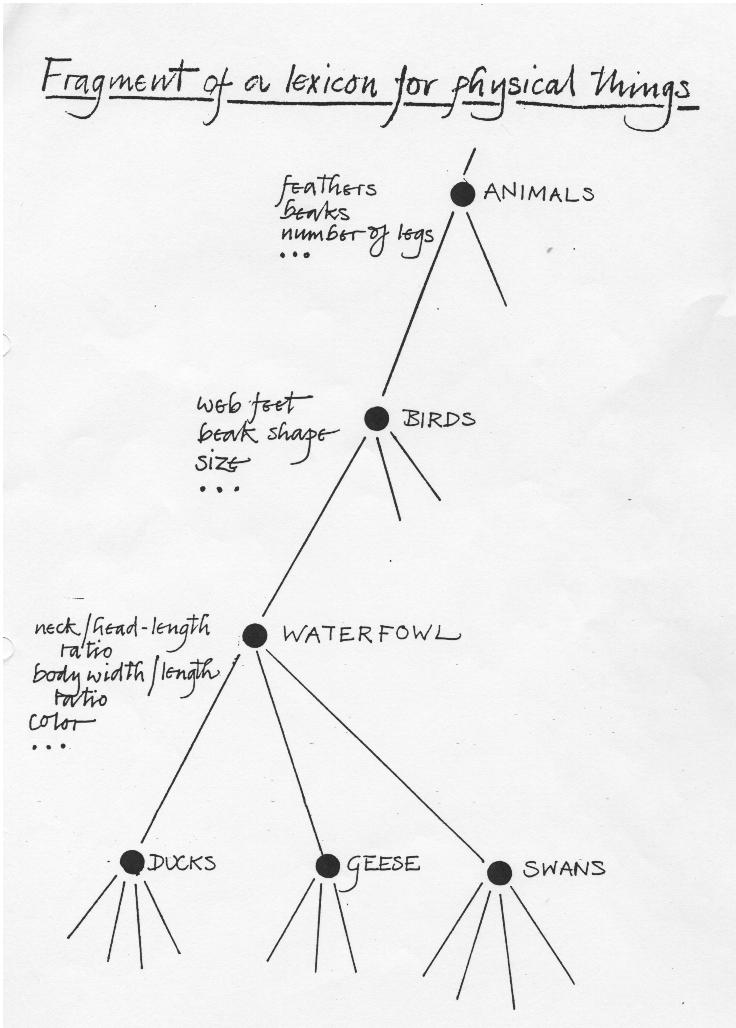

Fig. 1. *From T. S. Kuhn: An Historian's Theory of Meaning, Talk to Cognitive Science Colloquium, UCLA 4/25/90.*

Thus, Kuhn described that in his figure, "to each node in a taxonomic tree is attached a name . . . and a set of features useful for *distinguishing* among creatures at the next level down". Thus, the features attached to a name in the figure "function as differentiae for the next level down" (Kuhn 1990, 5, emphasis in the original).[3]

[3] In this simple example about waterfowl differentiae are all purely visual features, such as the neck/head-length ratio, body width/length ratio and colour listed in the figure. Kuhn never went beyond simple examples like that of waterfowl, but he repeatedly claimed that

According to Kuhn's account, the conceptual and perceptual subdivision of the world into objects and phenomena is thus constituted by similarity and dissimilarity relations. Kuhn claimed that these relations of similarity and dissimilarity are "immediate" (Kuhn 1970, 197, fn. 14) or "primitive" (Kuhn 1970, 190) in the sense that they are not based on a similarity-conferring third and that this immediacy is possible because there is an "empty perceptual space between the families to be discriminated" (Kuhn 1970, 197, fn. 14). Thus, instead of some "world's-real-joints" as postulated by standard realist accounts, Kuhn here draws on the joints of the phenomenal world to substantiate the claim of the immediacy of the similarity and dissimilarity relations. Kuhn was very explicit that this seemed to be a necessary premise for adopting a similarity approach to concepts and categorization, arguing that if there were no such empty perceptual spaces, definitions would be necessary to establish the boundaries of categories and a family resemblance account therefore impossible:

> Only if the families we named overlapped and merged gradually into one another—only, that is, if there were no *natural* families—would our success in identifying and naming provide evidence for a set of common characteristics corresponding to each of the class names we employ (Kuhn 1970, 45).

At the same time Kuhn wanted to avoid the traditional realist position that there is one set of the world's real joints such that all relations of similarity and dissimilarity can be read off the world itself. Thus, although Kuhn's position implies empty perceptual space between the families to be discriminated, there may be empty perceptual space along many different dimensions that do not all discriminate between the same families.

As described in detail by Hoyningen-Huene (1993), in order to understand Kuhn's position it is important to distinguish to notions of *the world*: the *phenomenal world* which is a "perceived world" (Kuhn 1970, 128), and the *world-in-itself* which is a "hypothetical fixed nature" (Kuhn 1970, 118, cf. Hoyningen-Huene 1993, ch. 2.1). On this view, "the referential relationship is between words and objects which are co-constituted by subject-sided and object-sided moments" (Hoyningen-Huene et al. 1996, 139f). Hence, this phenomenal world is perceptually and conceptually subdivided in a certain way, but contrary to a traditional realist view, this subdivision is not read off from the world in itself, instead, it is a structure which is imposed on the world by means of the concepts applied to it. Further, although this conceptual and perceptual subdivision is constituted by a grouping in similarity

basically the same account would hold for scientific concepts as well (see e.g. Kuhn 1974, 313).

classes of the perceived objects referred to by the concepts, the underlying similarity relations are not theoretical same-kind-as relations determined by internal structural traits of the "world's-real-joints", discoverable by scientific investigations. Instead, the similarity relations are constitutive of the structure of the phenomenal world, that is, of which objects exist in this world. Thus, different sets of similarity relations may constitute different ontologies.[4]

Kuhn's family resemblance account of concepts is very similar to accounts developed in cognitive psychology and cognitive anthropology.[5] Inspired by Wittgenstein, the notion of family resemblance was advanced within psychological research on concepts in the early 1970s, most notably by Eleanor Rosch (1973a,b), Rosch and Mervis (1975), Rosch et al. (1976). During the 1970s Rosch and her collaborators carried out a wide range of experiments, all showing that instances of a concept vary in how good examples of the concept they are. This result has since been used by several cognitive scientists as an argument for adopting an account of concepts based on similarity and dissimilarity between instances instead of an account based on definitions in the form of necessary and sufficient conditions. This research on graded structures was based on the assumption that "the world does contain 'intrinsically separate things'" (Rosch et al. 1976, 383), or, as Rosch and her collaborators elaborated,

> The world is structured because real-world attributes do not occur independently of each other. Creatures with feathers are more likely to have wings than creatures with fur, and objects with the visual appearance of chairs are more likely to have functional sit-on-ableness than objects with the appearance of cats. That is, combinations of attributes of real objects do not occur uniformly. Some pairs, triples, or ntuples are quite probably, appearing in combination sometimes with one, sometimes another attributes; others are rare; others logically cannot or empirically do not occur (Rosch et al. 1976, 383).

However, their view was not as purely realist as it might seem. Although they explicitly talked about the "concrete world" (Rosch et al. 1976, 382) containing "intrinsically separate things" (Rosch et al. 1976, 383) or stated that "the material objects of the world possess high correlational structure" (Rosch et al. 1976, 428), they later in the same paper conceded that "our claim that there is structure 'out there' in the world is not a metaphysical claim about the existence of a world without a knower, but an empirical claim which includes the knower" (Rosch et al. 1976, 429). Or as Rosch later phrased this non-realist claim: "we are talking about the *perceived* world and

[4] See also (Andersen 2001) for a detailed exposition of this position.

[5] See also (Andersen 2004) for further details.

not a metaphysical world without a knower" (Rosch 1978, 29, italics added). What they had in mind with this qualification was that the kind of attributes that could be perceived could well depend on several things. First, only "given a knower who can perceive the complex attributes of feathers, fur, and wings, it is an empirical fact 'out there' that wings co-occur with feathers more than with fur" (Rosch et al. 1976, 429). Thus, the perceived attributes could depend on the perceiving subject and could, for example, be different for different species (cf. Rosch 1978, 429). In addition, among these species-specific potentially perceivable attributes, it also depends on the functional needs of the knower which attributes actually are perceived. The category system therefore does not reflect the correla-tional structure of the environment in itself, but "the correlational structure of the environment, modified by selective ignorance and exaggeration of the attributes and structure of that environment" (Rosch et al. 1976, 435). On this view, objects result from an interaction between the potential structure provided by the world and the human categorizer, but this interaction is not unrestricted. Instead, the environment places constraints on categorizations. As Rosch and collaborators phrased it, "human knowledge cannot provide correlational structure where there is none. Humans can only ignore or exaggerate correlational structures" (Rosch et al. 1976, 430).

3. Elaborating Kuhn's Account

As Kuhn developed his account of scientific concepts, he kept emphasizing the importance of contrast sets and the features useful for differentiating between them. A key point in his account is that concepts are projectible in the sense that they imply hypotheses about how their instances behave, and this projectibility may develop gradually as new features are discovered. But although in this way he kept emphasizing that the use of a concept may be governed by several different criteria and that their coexistence represent knowledge about "the situations that nature does and does not present" (Kuhn 1970, 191), he did not himself pursue the implications of these correlations between criteria in much detail.

But Kuhn's basic idea of differentiating features has been adopted and elaborated upon by others, including the historian of science Jed Buchwald (1992) and the philosopher of science Xiang Chen (1997). They have shown how instruments and experiments play an important role in distinguishing kinds, including in the development of *new* scientific kinds. Both Buchwald and Chen see instruments and experiments as sorting devices that distinguish instances of contrasting concepts by determining specific properties which differ for instances of contrasting concepts. Initially, a new concept may be introduced just on the basis of a single differentiating feature that distinguishes its instances from instances of a known concept. As Buchwald has described this situation, "a novel taxonomy may emerge as someone attempts to grapple with a particular device" (Buchwald 1992, 44). In the case described later, we shall see an example of exactly this kind of process. But it usually takes more than just different behaviours of a single device to posit new categories. Whereas the first device is used to establish a contrast between two phenomena, it will then be attempted to find *additional* ways to establish the same contrast, for example by using different devices or experiments. Thus, Buchwald also added the qualifying notion of the "strength" or "robustness" of a taxonomy which to some extend reflects its device independence, "the ease with which it can be separated from the device" (Buchwald 1992, 44). Hence, although concepts may be introduced on the basis of just a single differentiating feature, it is at the same time crucial that "a robust taxonomy is also compatible with many other devices that do what the taxonomy considers to be the same thing that the first one does but in entirely different ways" (Buchwald 1992, 44). In the process, additional differentiating features may be introduced, and as more of such details are added, the concept will be perceived as more and more "robust". In other words, a concept becomes increasingly "robust" or entrenched as more and more features or combinations of features determined by the use of different instruments of experiments select the same category. Similar considerations on when to posit a new entity have been advanced by, among others, Arabatzis (2008, forthcoming). He argues that when scientists consider whether or not to posit the existence of an hidden entity, "the over-determination of a hidden entity's properties in different experimental systems is often an important reason in favor of its existence" (Arabatzis 2008, 14). However, robustness is not only related to device independence and the correlation of characteristics. While initial, explorative research is a new area is often focused on empirical examinations of possible correlations of characteristics, the next step is often to develop reasons for these correlations, that is, theories that explain why these particular characteristics are correlated.

This urge to derive theories that explain the correlation of characteristics is not specific for scientific concepts, but has been the topic of general discussion in cognitive science. Cognitive scientists such as Murphy and Medin have argued that, generally, people tend to deduce reasons for attribute correlations; a view that has become known as the theory-theory of concepts.[6] Thus, they believed, that "feature correlations are partly supplied by people's theories and that the causal mechanism contained in theories are the means by which correlational structure is represented" (Murphy and

[6] Note that theory-theorists cover a variety of different views on what count as theories; see (Laurence and Margolis 1999) for a brief overview.

Medin 1999, 431); a belief they soon sought to vindicate empirically (e.g. Medin et al. 1987). As indicated by Laurence and Margolis (1999, 45), the theory-theory's focus on underlying causal explanations of the correlation of surface attributes may encourage essentialist views. However, there is no overall agreement among theory-theorists whether this essentialism has to be interpreted metaphysically or psychologically. On the one end of the spectrum, scholars like Medin and Ortony restricted their essentialist view to psychological essentialism, that is, the *idea* that surface features are constrained or generated by deeper parts of the concept in question (cf. Medin and Ortony 1989, 180). Similar views are expressed by e.g. (Malt 1990). Thus, they emphasized that psychological essentialism "would not be the view that *things* have essences, but rather the view that people's *representations* of things might reflect such a belief (erroneously as it may be)" (Medin and Ortony 1989, 183). On their view, the features that appear essential are not so because of the structure of the world, but because they are the features that are most central to our understanding of the world (cf. Murphy and Medin 1999, 454). By the same token, later versions of the theory-theory such as the causal status interpretation of attribute centrality emphasizes that the causal status hypotheses differs from metaphysical essentialism in not necessarily assuming that causal attributes are defining and in not dichotomizing attributes into essential and surface attributes, and that "the causal status effect arises as a result of specific knowledge people have about causal relations, whereas some essentialists argue that essential properties are independent of our knowledge of them" (Ahn 1998, 163).

4. Illustration: Revisiting the Discovery of X-rays and Radioactivity

On the account developed above, a central idea in conceptual development is the introduction of new, rudimentary concepts that initially capture a general idea but still is in need of further articulation; what Carey (2009) refers to as "placeholder concepts" or "placeholder structures". This kind of conceptual development is what takes place in what Steinle has called exploratory experimentation, that is, experimentation that is "driven by the elementary desire to obtain empirical regularities and to find out proper concepts and classifications by means of which those regularities can be formulated" (Steinle 1997).

To illustrate, let us consider a relatively simple case study that was treated as an example only briefly by Kuhn in *Structure*, namely the discovery of X-rays.[7] In Structure, Kuhn merely described how Röntgen one day noticed

[7] Cf. (Kuhn 1970, 57f).

that a barium platinocyanide screen at some distance from a cathode ray tube glowed when the discharge was in process, and that this effect had to be due to some new agent. In his brief description, Kuhn considered the question at what point in Röntgen's investigation one could say that X-rays had been discovered. He discarded the view that the initial observation of the glowing screen would suffice, and he also discarded the view that it was by the end of the hectic weeks of research during which Röntgen had explored the properties of the new radiation that he had already discovered. Instead, Kuhn thought that X-rays emerged at some point during these weeks. While Kuhn primarily drew on this example to illustrate that discovering a new phenomenon is a complex event that involves recognizing both *that* something is and *what* it is (cf. (Kuhn 1970, 55), in the following section I shall revisit this case and provide an account of how new experiments gradually led to the introduction of a whole new taxonomy.

In the 1890es, physicists had made experiments with discharges between electrodes in evacuated glass tubes for decades, investigating the light phenomena that arose. In 1895 the German physicist Wilhelm Conrad Röntgen (1845–1923) wanted to investigate cathode rays emitted from the cathode when the pressure in the glass tube was very low. During an experiment with a cardboard-shrouded tube he discovered that an object across his laboratory began to glow. The object was a coated screen used to detect fluorescence caused by the cathode rays, but it was placed so far away from the tube and behind various items that Röntgen did not think the fluorescence could be caused by cathode rays. Instead he hypothesized that the fluorescence could be caused by a new kind of rays. Thus, it is at first the simple features of "far away" and "penetrating various things on their way", and the clear difference from cathode rays with respect to these features that made Röntgen posit a new kind.

But Röntgen immediately began investigating the new rays systematically, examining this special feature of penetrating power. It turned out that they penetrated most materials, but to different degrees (Röntgen 1896a, 3). Paper was very transparent; even a book of about one thousand pages would not stop the rays. Wood was also quite transparent, but aluminum less so. Thin plates of lead would almost stop the rays completely. But bone would also produce shadow pictures. Thus, if a hand was held between the tube and a fluorescent screen, one would see the dark shadows of the bone. The rays were also found to blacken a photographic plate, and in his first publication on the rays, a communication to the *Sitzungsberichte der Würzburger Physik-medic. Gesellschaft* from December 28, 1895, Röntgen described various photographs, among them one of the bones in a hand.[8]

[8] Whereas the photographs were only described in Röntgen's original publication in Ger-

Röntgen's discovery was totally unexpected, and scientists around the world started explore the nature of these new and unforeseen rays. In February 1896, only two months after Röntgen's first publication of his result, research activity was so intense that the journal *Nature* declared that "so numerous are the communications being made to scientific societies that is difficult to keep pace with them, and the limits of our space would be exceeded if we attempted to described the whole of the contributions to the subject, even at this early stage" ("The Röntgen Rays", 377).[9]

The French Academy of Science was one of the places at which Röntgen's discovery was immediately discussed. During the discussion it was suggested that, since the tubes emitting X-rays were fluorescent, other fluorescent bodies might also emit the new kind of rays (Poincaré 1896). Several scientists immediately began investigating various fluorescent bodies, among them Henri Becquerel (1852–1908).[10]

In his first experiment, Becquerel placed sheets of uranium salt on a photographic plate that was wrapped in heavy black paper. This was placed in the sun for several hours so that the uranium salt became fluorescent. Afterwards the photographic plate was developed, and there was a black silhouette of the sheets at the photographic plate (Becquerel 1896b). Becquerel could therefore conclude that the fluorescent uranium salt did indeed emit radiation. Thus, the experimental investigation of the new taxonomic concept initially focused on possible similarities in the form of empirical correla-

man (Röntgen 1896a), two of them were included in the translation of the report that was published in *Nature* the following month (Röntgen 1896b) and one in the reprint of the translation published in *Science* (Röntgen 1896c).

[9] One of the important questions with respect to novelties, namely how to communicate the results when *everyone* is a novice, has evidently not been a problem in this case. As a precondition for successful communication of novelties Gooding (1986, 224, 226) suggest that "[a]t the outset, a construal of novel information may be communicated primarily by example, or as a set of instructions about how to proceed with an experiment" and that further explorative success "involves inventing new experiments and constructing new instruments" that "modify, utilize or apply an effect to produce new information about it, or new phenomena". The condition for communicative success has easily been fulfilled by the photographs included in the early communications.

[10] Charles Henry and Gaston Henri Niewenglowski also conducted experiments to investigate fluorescent bodies. Both reported to have confirmed the hypothesis (Henry 1896, Niewenglowski 1896) by experiments in which they used zinc sulfide irradiated with X-rays and calcium sulfide exposed to sunlight and observed blackenings of wrapped photographic plates corresponding to the fluorescent materials. However, others had difficulties confirming these experiments, and Curie reported in her monograph *Recherches sur les substances radiactives* that these experiments "have not been reproduced, in spite of numerous attempts to this end. It cannot therefore be considered as proved that zinc sulfide and calcium sulfide are capable of emitting, under the action of light, invisible rays which traverse black paper and act on photographic plates" (Curie 1961, 5).

tions: was the phenomena correlated to fluorescence, independently of its source.

Becquerel soon found out that radiation was emitted even when the uranium salt was not fluorescent. In the days following his initial experiment the sun appeared only intermittently, and he placed his wrapped photographic plates as well as the sheets of uranium salt in a drawer. After a few days he developed the photographic plates, expecting to find only very weak images. But the images turned out to be quite intense (Becquerel 1896c). In conclusion of his report, Becquerel noted:

> A hypothesis that presents itself very naturally to the mind would be to suppose that these radiations, the effect of which have a great analogy to those produced by the radiations studies by [Philip] Lenard and Röntgen, would be invisible radiations created by phosphorescence whose time of persistence would be infinitely greater than that of the luminous radiations emitted by these bodies. However, the experiments presented, while not being contrary to this hypothesis, do not authorize one to formulate it. (Becquerel 1896c, 503; translation from Kipnis 2000, 73).

Thus, as an initial step Becquerel noted the difference between the visible phosphorescence of the uranium salt and the rays that produced the image on the photographic plate. The next step was to investigate the intensity of this invisible radiation over time, where he found that the intensity showed no noticeable decrease after his uranium salt has been kept in darkness for 15 days (Becquerel 1896d) or even two months Becquerel (1896a). Likewise, Becquerel examined uranium salts known to be non-fluorescent when dissolved and found that also in this case were the new kind of rays emitted (Becquerel 1896d). After several weeks of experimenting with various salts of uranium and various other fluorescent minerals he concluded that the emission of the rays was due to the presence of the element uranium (Becquerel 1896a).[11]

Hence, originally hypothesised by analogy to X-rays, a new concept—by Becquerel termed *Uranium rays*—was being formed. Uranium rays were not triggered by or dependent upon a special state of the emitting source, they were simply intrinsic to the material that emitted them. The new concept was about to form a new branch as it now differed from the originating concept with respect to exactly that feature that had initially created the new area of inquiry. Further characteristics were added to this new branch as experiments proceeded. Thus, in one of Becquerel's first communications of

[11] For detailed discussions of Becquerel's experiments, see (Badash 1966), (Badash 2005), (Kipnis 2000).

the new rays he reported to have observed that the rays would discharge an electroscope (Becquerel 1896e).

Becquerel had suggested that the new kind of rays were only emitted by uranium compounds. However, in 1898 Marie Curie reported from studies of the conductivity of air when various substances were placed between two plates of a condenser that all uranium compounds were active emitters of the rays, and in general the more active the more uranium they contained, and that thorium compounds were very active too (Curie 1898). Thus, the concept was extended to include rays emitted by more substances that just uranium. Examining the increase of radioactivity with the increase of uranium present, Marie Curie and her husband Pierre Curie (1859–1906) also discovered that the mineral pitchblende was much more radioactive than its uranium content would indicate Curie and Curie (1898). They hypothesized that the mineral contained another element that would be more radioactive than uranium, and named it polonium. A few months later they found that pitchblende contained yet another highly radioactive element which they named radium (Curie et al. 1898). Later a third radioactive substance, actinium, was identified (Debierne 1899, Debierne 1900, Giesel 1902, Giesel 1903; on the priority of this discovery, see Kirby 1971). The concept of radioactivity and the internal correlations between emitting elements and the intensity of the radiation had now become so strong that it could be used to hypothesize new elements.

The early investigations of radioactivity were of a very explorative nature. It was a completely new phenomenon with no theory to guide expectations, so the approach was experimental, focusing on the collection and classification of data. Through experiments physicists and chemists tried to unravel lots of questions: What was the nature of the new rays? Were they emitted by all elements, or only by some? Was the activity affected by chemical processes, or by physical changes such as changes in temperature? How did it all fit into the periodic system of the elements?

Becquerel had noted in his first experiments that while the rays penetrated paper, sheets of aluminum or copper would decrease their intensity. On the basis of a series of similar absorption experiments, the New Zealand-British physicist Ernest Rutherford (1871–1937) showed that the rays emitted from uranium were complex and contained at least two distinct types of radiation: one which was very readily absorbed and which he termed α-radiation, and another of a more penetrative character which he termed β-radiation (Rutherford 1899). In 1900, the French physicist Paul Villard (1860–1934) found a third kind of radiation that was even more penetrating than β-radiation and which was termed γ-radiation (Villard 1900a,b). But the classification of radiation included more than just penetrating power, and deflection in magnetic fields as well as the presence of radioactive gas were soon included among the examined characteristics.[12]

Further, with the development of nuclear physics it became clear that the nucleus was not an elementary particle, and that α- and β-radiation was the result of the spontaneous disintegration of the nucleus, whereas β-radiation was the result of a transition of the nucleus from an excited state to a state of lower energy.[13] Models of the α- and β-particles *explained* the correlations of features—both were particles with specific weights and specific charges, and this explained both their deflection in magnetic fields and their penetrating power in various materials. Hence, these models explained the correlations of features for each concept in the contrast set.

This case showed how experiments can act as sorting devices, both in creating new concepts and in establishing additional differentiating features of existing concepts. In this way, the case illustrates how a placeholder concept that is first introduced on the basis of only a single differentiating feature develops into a full-blown taxonomy as more and more empirical regularities are articulated.

5. Dynamic Ralism

As described above, on Kuhn's position the conceptual and perceptual subdivision of the world into objects and phenomena is constituted by similarity and dissimilarity relations that are immediate in the sense that they are not based on a similarity-conferring third and that there is an "empty perceptual space between the families to be discriminated." At first sight, this may seem circular: delineated categories secure the immediacy of the relations of similarity and dissimilarity, but at the same time the relations of similarity and dissimilarity are constitutive of the categories. However, this apparent circularity vanishes once we adopt a historical, or dynamic, view. On such a view, the phenomenal world is never structured *from scratch* by its inhabitants. Instead, the inhabitants of any phenomenal world have always been born into some version of it. As Kuhn explained, they originally found this world "already in place, its rudiments at their birth and its increasingly full actuality during their educational socialization, a socialization in which examples of the way the world is play an essential part. . . . Creatures born into it must take it as they find it. They can, of course, interact with it, altering both it and themselves in the process, and the populated world thus altered is the one that will be found in place by the generation which follows" (Kuhn 1991,

[12] See (Trenn 1976) for an overview showing how the development of the classification scheme for radioactive rays accommodated fundamental conceptual changes concerning the nature of the several types of rays.

[13] On the development of the transmutation theory, see i.e. (Malley 1979) and (Romer 1958).

10). Hence, concepts and categories are inherited by any generation from their predecessors and are therefore in place, ready to secure the immediacy of the relations of similarity and dissimilarity for the new generation. But once the new generation has gained access to this particular phenomenal world they may start reshaping it by introducing new relations of similarity and dissimilarity and abandoning old ones, and thus provide a different set of concepts and categories to their successors than the set they inherited themselves.

An important aspect of this dynamic realism is that in this dynamically developing world, new concepts referring to new kinds are also introduced *gradually*. This is a point that Kuhn only hinted upon by discussing the difficulties of determining when a phenomenon is actually discovered when the discovery process extends from the first discovery of something new and strange to the later exploration of its properties (cf. Kuhn 1970, 57f). As argued above, a concept becomes more and more entrenched as more and more features or combinations of features select the same category. But as also argued above, there is more to entrenchment than just device independence and correlation of different feature. If we look at the case study, admittedly the initial explorative research was focused on empirical examination of various possible correlations of features: which features seem to be correlated, which new concepts based on these feature correlations arise, and so on. But what would soon follow was the development of *reasons* for these correlations, *theories* that would explain why specific features were correlated.[14]

But although the dynamic realism developed here includes a gradual development of underlying explanations of those surface features that initially have served as the primary *differentiae* in introducing the new kind concept, it still differs in important ways from the causal theory of reference. On the causal theory of reference, reference is established in an original naming ceremony in which the object or kind to which the concept in question shall refer is singled out by ostension or by a description, and in subsequent use the concept continues to refer to the entity to which it was attached on the occasion of its introduction. The same-kind-as relation therefore refers back to the original naming ceremony. Further, the same-kind-as relation is taken to be a theoretical relation determined by the internal structural traits of the objects to which the term refers, and the details of the relation can be discov-

[14] It is important to note that although the development of explanations will be an essential part of stabilizing new concepts, the mere correlation of features can be an important research topic in itself, even though these regularities may (initially) be unexplained—an aspect of experimentation that, as Steinle has noted "has not found much attention" (Steinle 2002, 420).

ered by scientific research (Putnam 1975, Boyd 1993). In this way, the causal theory of reference is thus based on the realist assumption that there exists some fixed realm of "theory-independent entities", (Putnam 1975, 236) and that the aim of science is to improve the accordance between our concepts and these entities, to "cut the world at its joints" (Boyd 1993, similarly Putnam 1975). In contrast, on the dynamic realist account developed here, the relations of similarity and dissimilarity are not purely determined by some internal structural traits of the "world's real joints" to be discovered by scientific investigations. Instead, as argued in section 2 above, the relations of similarity and dissimilarity are constitutive of which objects exist in the world that we perceive so that different sets of similarity and dissimilarity relations may constitute different ontologies.

This dynamic view may at first sight seem to evoke the question how the process gets off the ground, how does the "first" taxonomy get established. But once we recognize that conceptual structures are dynamic entities that have evolved through history, we can imagine that, theoretically, an initial conceptual structure may be established by conjecture. By investigating the categorized objects, other features additional to those used when conjecturing the categorization may prove relevant for category membership. In addition, as new objects are investigated and as more features are involved in judging category membership, anomalies may be encountered necessitating changes of conceptual structure. In this way the conceptual structure continuously develops in order to provide consistent categorizations of all known objects within the object domain. However, although establishing conceptual structures in an initial act is therefore possible, dismissing the developmental perspective and the shift of emphasis from synchronic constitution to diachronic transmission is too hasty a conclusion. By keeping the developmental perspective, the continuous development of conceptual structures is a phylogenetic process in which conceptual structures keep developing to continuously provide consistent classifications of an ever growing number of known objects. On this view, the interesting issue is not how the phenomenal world was initially *established*, but only how the phenomenal world *continuously develops*.

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