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Systematicity: The Nature of Science

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Abstract This paper addresses the question of what the nature of science is. I will first make a few preliminary historical and systematic remarks. Next, I shall give an answer to the question that has to be qualified, clarified and justified. Finally, I will compare my answer with alternative answers and draw consequences for the demarcation problem.

Keywords Systematicity · Demarcation problem · Pseudo-science

Preliminaries

Historical Preliminaries

Is it appropriate to ask the question about the nature of science at the beginning of the 21st century? I think it is, and the reason is our specific situation with regard to this question. I suggest that the history of answers to our question, when viewed in the most schematic way, has four phases. The first phase starts around the time of Plato and Aristotle and extends until the 17th century. In this phase, the specificity of scientific knowledge was seen in its absolute certainty. There was an essential contrast between *episteme* (knowledge) and *doxa* (belief), and only *episteme* qualified as science. Its certainty was established by proof from evident axioms. The second phase that stretches well into the 19th century is continuous with the first in its posit of certainty for scientific knowledge. However, the means to establish

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certainty have been generalized to include inductive procedures as well. The whole set of rules has been called "the scientific method" (or "scientific methods"). Scientific methods were mostly conceived as strict rules of procedure. The third phase begins in the second half of the 19th century and ends sometime in the late 20th century. Empirical knowledge produced by the scientific method(s) was now assessed to be fallible. However, a special status was still ascribed to it due to its distinctive mode of production.

At present, we are in the fourth phase, which started around the last third of the 20th century. In this phase, belief in the existence of scientific methods of the said kind has eroded. Historical and philosophical studies have made it highly plausible that scientific methods with the characteristics as posited in the second and third phase do not exist. Skeptics such as Paul Feyerabend have drawn the (unwarranted, as I believe) conclusion that scientific knowledge is completely on a par with any other sort of knowledge. Be that as it may, the fact is that at the beginning of the 21st century there is no consensus among philosophers or historians or scientists about the nature of science. If one at least entertains the hypothesis that scientific knowledge has indeed special characteristics, and that it is, in certain respects, a unique cultural product, then one should ask the question about the nature of science anew.

Systematic Preliminaries

A few remarks are now in order how the question 'What is science?' is understood in this paper. First, with respect to disciplines, I want to understand the question in its broadest possible sense. Not only all the sciences in the sense of the natural sciences shall be included, but also the social sciences and the humanities, resulting in an understanding of the term 'science' equivalent to the German term *'Wissenschaft.'* In other words, all research fields typically taught at a university are comprised. In want of a better word, 'science' will be used in the following in this very wide sense.

Second, with respect to focus, I want to concentrate on science in the sense of scientific knowledge. This excludes a particular sociological focus on science as a social system, or on science as it is embedded in a wider social, political or economic context. This is an abstraction, isolating some aspects of an enterprise that is fundamentally social and that is strongly connected with other aspects of society. Whether this abstraction is useful cannot be judged at the beginning, but only at the end of the investigation.

Third, with respect to contrasts, my question should not be understood in the same way as it has been predominantly understood during the 20th century. The question 'What is science?' was usually meant as a request for a demarcation criterion for science with respect to metaphysics and pseudo-science (of course, Karl Popper was very influential in this respect). Here, however, the dominating contrast is the contrast between science and other forms of knowledge, especially everyday knowledge. The question then becomes: By which features is science most characteristically distinguished from other forms of knowledge? This does, of course, not dismiss the question about a demarcation criterion, but this specific question will not guide our investigations from the very beginning.

What is Science?

A thesis with some qualifications

The **main thesis** that shall be explicated and defended in this paper reads:

> Scientific knowledge differs from other kinds of knowledge, especially from everyday knowledge, by its higher degree of systematicity.

Before going on to an explication of this thesis and its central terms, I would like to qualify it.

First, this thesis is not new. It may be found at various places in the literature of various disciplines where it is typically stated without much comment, as if it was simply taken for granted. But nowhere has this thesis been systematically explicated, elaborated and investigated with regard to its consequences, and this is what the present paper aims at.

Second, by granting scientific knowledge a higher degree of systematicity than other forms of knowledge, these other forms of knowledge are not characterized as entirely unsystematic. For instance, in order to determine the number of people in a room, everybody uses a systematic procedure from everyday life, namely counting. The thesis is fundamentally comparative, granting scientific knowledge a higher degree of systematicity, but not denying any systematicity from other forms of knowledge.

Third, the thesis asserts a higher degree of systematicity of scientific knowledge only relative to other knowledge about the same subject matter, not to any arbitrarily chosen area of knowledge. For instance, we have everyday techniques of getting to know people, and there are scientific procedures to find out personality traits. The assertion of the thesis is that in cases like this, scientific knowledge is more systematic than, for instance, everyday knowledge. If one compares unrelated pieces of scientific knowledge with knowledge of other origins, then scientific knowledge is not necessarily more systematic. For instance, knowledge gained by police forces in suspected serial criminal cases is much more systematic than knowledge in loosely structured scientific fields.

Fourth, due to its comparative nature, the thesis does to directly apply to fields which are scientific but which lack any counterparts in other forms of knowledge. For instance, theories about black holes or about the folding of proteins to their tertiary structure have no counterparts in other domains of knowledge. For cases like these, the thesis has to be understood with a grain of salt. Historically, these areas have developed from earlier states where there was a contrast between scientific knowledge and other forms of knowledge regarding systematicity. The further development of scientific knowledge then even increased its systematicity, but at the same time pushed it into domains not occupied by other forms of knowledge.

Clarifications of the Thesis

The central term of the thesis, 'systematicity,' is vague and therefore in need of more precision and concretization. With respect to more precision, it is useful to look at some contrasting terms. If something is systematic, it is not

- purely random or accidental
- arbitrary

- unmethodical
- unplanned
- unordered.

It must be admitted that the degree of precision gained by these contrast terms is not very high. In the abstract, however, apparently no more can be achieved. In order to positively determine the meaning of 'systematicity,' some context must be given in which the term can then be made more concrete.

In the following section, I will sketch eight contexts in which 'systematicity' will become a more concrete, richer concept. The connection of these contexts with the main thesis is this. Although the main thesis seems to be a single statement, it covers eight different dimensions (or areas, or contexts) in which scientific knowledge is claimed to be more systematic than other kinds of knowledge. It is in these dimensions that the meaning of 'systematicity' can be made more concrete. These eight dimensions are

- descriptions
- explanations
- predictions
- the defense of knowledge claims
- epistemic connectedness
- an ideal of completeness
- knowledge generation
- the representation of knowledge.

The result will be eight concretizations of the abstract concept of systematicity. These different concepts of systematicity, as they are generated by concretization in the eight different dimensions mentioned, are connected to each other by family resemblance only, and not by a set of necessary and sufficient conditions. Thus, what counts as a more systematic description may be more or less uninformative about what counts as a more systematic explanation, or what is a more systematic defense of some knowledge claim, etc. Thus, the abstract concept of systematicity functions as an umbrella covering a set of more concrete systematicity concepts, connected to each other by family resemblance relations.

Furthermore, a closer look reveals that even within one specific dimension, e.g., descriptions, many different systematicity concepts exist each of which is again more concrete than the more abstract term 'systematicity of descriptions.' This time, the difference among these concepts is generated by different disciplinary (and sub-disciplinary) contexts. For instance, the systematicity of a mathematical description is different from the systematicity of a historical description, which in turn differs from the systematicity of the description of a work of art, etc. Again, the connection between these different concepts of 'systematicity of descriptions' is one of family resemblance.

As a consequence of the aforesaid, the unity of the sciences that is (implicitly) claimed in my main thesis is an extremely weak one. The different branches of learning are, so it is claimed, indeed all more systematic than other corresponding forms of knowledge. But the relevant concept of systematicity is split up into eight different concepts, depending on which aspect of science is in focus, and the concept co-varies further with different disciplines and sub-disciplines. Thus, the unity of science consists in family resemblances that hold between different branches of science, resulting in a very loose network represented by the abstract concept of systematicity.

A systematic justification of the main thesis should show that *all* the different sciences, in the wide sense of the term as it is used here, display in *all* eight dimensions a higher degree of systematicity then other forms of knowledge, especially everyday knowledge. This Herculean task cannot be performed. Instead, in the following I shall only refer to some examples, hoping that the intended generality will become at least plausible.

The Systematicity of Science

I shall now develop the claimed higher degree of systematicity of science, in comparison with other forms of knowledge, regarding the eight dimensions mentioned before. Of course, I can only give a few examples out of a plethora of others to illustrate my point.

Descriptions

In the (classical) formal sciences like logic or number theory, an apparently unsurpassable high degree of systematicity is reached in the basic descriptions of their objects of study. These objects are characterized by a system of axioms that are complete (as far as possible) and logically independent from each other.

In many empirical sciences, for descriptive purposes the wealth and diversity of individual items to be considered is dealt with by classification, and by iterating classifications, by taxonomy, and by a fitting nomenclature. All sorts of things are classified: physical things like plants, animals, viruses, genes, chemical elements, chemical compounds, enzymes, and minerals, or physical conditions like diseases or nursing diagnoses, or abstract entities like mathematical objects, languages, literary genres, economical or political systems, or structures of societies. The historical variant of classification is periodization. Processes are divided into different phases thus breaking historical continuity. Periodization is not only used in historical sciences, but also in disciplines that deal with recurrent processes, for instance in developmental psychology or economics. Of course, we also classify phenomena in everyday knowledge and make periodizations, for instance regarding our own life. Obviously, here the degree of systematicity is much lower than in the sciences where much effort and reflection goes into classifications in order to make them defensible. Furthermore, the number of objects to be classified in science is sometimes enormously larger than the number of items we deal with in everyday life. For instance, there are about 10 million organic compounds classified and described in the respective data base.

In the historical natural sciences like cosmology or paleontology, or in the historical humanities like political or art history, descriptions of individual events and processes are predominant. These descriptions take on the form of narratives in which a particular sequence of events or processes is told. Also in our everyday practice, we tell stories that have principally the same form as the stories told by the historical sciences. However, the latter stories are typically much more systematic. For instance, the principle of historical continuity is often violated in our everyday stories, or the principles of historical relevance which govern the selection of the elements of a story are applied in a rather loose or even inconsistent way. Stories told by professional historians differ from this looseness by a much higher degree of systematicity.

In the generalizing empirical sciences like physics or chemistry, scientists are not interested in particular events or processes, but in classes of them. They aim at generalized descriptions, as opposed to the individualized descriptions of the historical disciplines. These generalizations describe the regularities holding in the respective domain, be they just empirical regularities or even (natural) laws. They presuppose appropriate classifications of the respective phenomena. Of course, a generalized description of a set of phenomena is more systematic that the set of the individual descriptions.

Finally, there is a tendency towards quantification in all areas of research. This tendency serves various purposes. With respect to descriptions, a (successfully) quantified description is more systematic than a purely qualitative (verbal) one, and a more precise quantified description is more systematic then a less precise one. The reason for this is that the latter allow distinguishing and ordering more possible cases than the former.

In sum, all the procedures mentioned in this section have the effect to increase the systematicity of descriptions, in comparison with descriptions used in other kinds of knowledge.

Explanations

In the historical disciplines, explanations typically consist of narratives that explain why certain events or processes occurred (these narrative may also contain theoretical or law-like elements but this is not my concern here). Again, the structure of these explanations resembles the structure of our everyday explanatory stories, but, in various respects, they are more systematic. For instance, historians are typically more careful to exclude possible alternative explanations than we are in our everyday explanatory narrative practice.

In the generalizing empirical sciences the generalized descriptions mentioned above already have some explanatory power. In addition, theories that perform various tasks are articulated in these disciplines. It is obvious that the invention and use of theories immensely increases the systematicity of science because of their potential to provide unified explanations (in addition to their predictive power, see below). Of course, in everyday knowledge we also have various theories that are put to the same service as in science. But it is obvious that these informal theories are by far less systematic than the explicit theories articulated and discussed in science.

In various branches of the social sciences and the humanities, actions are explained by recourse to beliefs and desires of the actors. Again, the structure of these explanations is the same as in our everyday explanatory practice, but in science they are typically more systematic in various respects.

A particularly successful explanatory strategy that is used in very different disciplines is the use of reductionist explanations. They make use of the fact that, very often, the behavior of a particular system can be explained with reference to its constituent parts together with the regularities governing their interactions. Again, this explanatory strategy is also used by laypersons, for instance, when the breakdown of some machine is to be explained. But in many sciences such as solid state physics, quantum chemistry, molecular biology, or economics, this explanatory strategy is systematically exploited (of course, I am not making any statement here how far this strategy may ultimately lead).

Predictions

I should note first that not all sciences predict. Neither the historical natural sciences typically predict nor the historical humanities nor the formal sciences as such. So the following only applies to those disciplines that indeed predict. Several procedures of prediction can roughly be distinguished. The simplest (and oldest) case concerns predictions that are based on regularities of the empirical data in question. A simple and paradigmatic case is the expectation that the sun will raise tomorrow. Scientific examples comprise the prediction of eclipses based on the Saros cycle, or economic predictions based on analogues of the pig-cycle. Many of our every day predictions are based on this procedure. When used in science, it is usually much more elaborated in various respects, especially with respect to the data on which the prediction is based.

Another way to predict the values of some variable(s) $p(t)$ is based on their correlation with other variable(s) $c(t)$. In the simplest case, p is a function of c and c can be predicted. An example is the theory of the economist William Stanley Jevons (1835–1882) that the sunspot cycle is (causally) correlated with the business cycle. A somewhat more sophisticated case is given by a correlation of $p(t)$ with $c(t)$ in which $c(t)$ cannot be predicted, but $c(t)$ anticipates (in some sense) changes of $p(t)$. A by now everyday case is the anticipation of weather changes by barometric pressure changes. Scientific cases abound, for instance, in economics where economic development is predicted on the basis of the behavior of so-called “leading indicators” that signify future changes. In comparison to similar everyday techniques, the predicting sciences are much more systematic in the identification of leading indicators and the evaluation of their predictive potential. This observation is immune against the indubitable fact that the sciences are not always successful in their forecasts.

Probably the most spectacular predictions have been made in the natural sciences the basis of theories. The discovery of the planet Neptune on the basis of Newtonian Theory and the prediction of the bending of light by gravitation on the basis of the General Theory of Relativity are paradigmatic examples. These dramatic predictions concerned yet unknown objects or phenomena. Much less spectacular are the by now routine predictions of precise sunrise or sunset times, or of eclipses, also based on Newton’s theory. Of course, exploiting a theory’s predictive potential by mathematical derivations is an enterprise much more systematic than its analogues in everyday thinking. There, theories are much vaguer entities, and correspondingly, their predictions are much less systematic.

Since the advent of computers, however, the dominant type of scientific predictions has been model based. Models are used for systems that are too complex to be straightforwardly treated by laws or theories. For instance, the global climate system involves a large number of variables interacting in various and complicated ways such that it is impossible to set up a set of equations from fundamental physics describing the system. Similarly, an economic system should be described in terms of in principle measurable variables like prices, costs, incomes, savings, employment, etc. The relationships among them derive from complex behavior and interaction of millions of households, millions of firms, and thousands of governmental units, producing and exchanging millions of products. Such systems cannot be treated rigorously. Roughly speaking, models in the relevant sense are a set of simplifications of such systems leading to sets of equations that are designed both to capture some of the properties of the original system and to be computationally treatable. On the basis of such sets of equations, predictions can be produced. In our everyday production of predictions, we may use faint equivalents of such models by making all sorts of simplifying assumption, but whatever they are in detail, they are surely less systematic than their scientific counterparts.

Finally, there is a procedure to make predictions by asking people who are more knowledgeable than oneself. In its scientific form, it is called the Delphi method. Roughly, the recipe is this: Ask a number of experts about their predictions, feed the answers back to the whole group, and repeat the query in the hope that some convergence of the answers occurs. Of course, this is a more systematic form of what we may do in our everyday life when we ask A about some future event, then ask B and tell her A's answer.

The Defense of Knowledge Claims

The higher degree of systematicity of science in its defense of knowledge claims, when compared to other kinds of knowledge, is probably the most popular of the eight dimensions discussed. The central insight, which science takes extremely seriously, is that human knowledge is constantly threatened by error. Error may arise as the result of mistakes, false assumptions, entrenched traditions, belief in authorities, superstition, wishful thinking, prejudice, bias, and even fraud. Of course, we all know of these possibilities also in everyday thinking, but science is typically much more careful and successful in detecting and eliminating these sources of error. It is not that it is invariably successful, but it appears to be the most systematic human enterprise in its attempt to eliminate error in the search for knowledge. As it is to be expected, in different areas of science the particular ways to defend knowledge claims differ.

First, in the formal sciences, the most rigorous way to eliminate error has been practiced since antiquity, namely to provide a proof for any statement that is not an axiom or a definition. This was the leading idea for all of science in the first phase discussed (see Historical Preliminaries section), but it turned out in the course of the 19th century that it can only be upheld for the formal sciences. Of course, this way of error elimination displays an unsurpassed degree of systematicity.

Second, in the empirical sciences, empirical data play a preeminent role in the defense of knowledge claims. The way in which these data are generated, evaluated and handled differs significantly in the different areas. In the historical sciences, remnants of all kinds are the raw data that, after diverse kinds of processing, enter as sources into historical reconstructions. Observational and experimental data that are often systematically generated are the primary basis for justification and testing of hypotheses and theories of different degrees of generality. Especially experimental data play a preeminent role in modern natural science because they allow a much more rigorous testing of theories that, by there very nature, are otherwise highly speculative.

Third, wherever a discipline has managed to successfully quantify its descriptions or theories, an enormous spectrum of statistical and other mathematical testing procedures can be used that may make testing more subtle and rigorous.

Epistemic Connectedness

As in the case of the concept of systematicity, the concept of epistemic connectedness cannot be substantially clarified on an abstract level. On this level, it only means the existence of connections of scientific knowledge to other pieces of knowledge, but the nature of those connections is left unspecified. They comprise all sorts of logical relations like logical equivalence, implication, dependence, consistency, or independence; or specifically epistemic relations like confirmation, disconfirmation, falsification, generalization, specialization, or reduction. The basic idea of the dimension of epistemic connectedness is that scientific knowledge has more articulate connections to other pieces of knowledge than, especially, everyday knowledge that is more loosely structured. In addition, there are transitory areas between scientific research and related activities that are more tuned toward practical purposes. In these areas, a (necessarily rough and vague) distinction between the two poles should be drawn. For instance, there is a transitional area between technological research and technological development, between economic research into markets and market research as performed by companies regarding their actual or potential products, or between contemporary history and (good) political journalism. In the context of the present project, the problem is that in these areas the scientific and the non-scientific side may not differ regarding their degree of systematicity with respect to the other dimensions of systematicity.

One way of characterizing the differences between the scientific and the non-scientific in these transitory areas *in a general way* is to point out the higher degree of epistemic connectedness of the scientific side. However, this may mean very different things in different contexts. For instance, the activities of automobile manufacturers regarding the improvement of fuel efficiency are typically tuned towards particular engines that are already on the market or should hit the market soon. By contrast, the analogous activities in engineering departments of research universities typically have a wider intended range of applications, or they may even have no particular application in sight at all by aiming at new design principles. The difference may be described as a higher degree of epistemic connectedness, at least potentially, of the science side due to its higher degree of generality. However, this particular form of a higher degree of epistemic connectedness is not applicable in some other areas, for instance regarding the difference between political journalism and contemporary history. Here the subject matter may be identical, e.g., the political development in some country during the last month. Although the basic messages of the respective articles in a historical journal and a (serious) newspaper may be identical, their difference will concern the number of explicit connections to other pieces of knowledge. In contrast to the newspaper article, the scientific paper will have many footnotes in which the connections to various other pieces of knowledge will be explicitly noted.

It is obvious that a higher degree of epistemic connectedness implies a higher degree of systematicity in a specific sense. Knowledge that has more (explicit) connections to other pieces of knowledge is to a higher degree part of a system of knowledge.

An Ideal of Completeness

One of the most astonishing facts about science, especially about modern natural science, is its remarkable growth, both in scope and in precision. Science is a dynamic enterprise through and through. This feature probably best distinguishes science from all other knowledge systems, past and present. Of course, the growth of science depends on the availability of the appropriate material and intellectual resources, but the mere availability of these resources does not explain why science strives toward, and succeeds in, improving and expanding its knowledge. First, why does science constantly attempt to expand its knowledge and second, how does it manage to succeed so consistently?

With respect to the first question it has to be noted that science is driven by the ideal of systematically completing its knowledge. Science is never satisfied with some scattered facts about a certain domain. Ideally, any discipline wants to know "everything" about its subject matter, given its particular focus. Mathematicians seek axiom systems that are complete (as possible), physicists want to fully describe all fundamental interactions of matter, chemists have sought a complete system of elements, biologists want an overview over all biological species, linguists want to systematically classify all languages, political scientists want to systematically classify systems of political order, etc. The contrast to our everyday knowledge is as tremendous as it is obvious.

With respect to the second question, how does science manage to succeed so consistently in expanding its knowledge, a new section is in order because this brings in another aspect of science's systematicity.

Knowledge Generation

Science is not only systematic in having a goal of complete knowledge; it is also more systematic in pursuing this goal then our everyday practice. First, with respect to data that play such a pre-eminent role (see The Defense of Knowledge Claims section), science is constantly on the move to systematically improve existing data and to gain new ones. The ways different fields of research go about this goal may be extremely different. Procedures vary from systematically searching archives to performing systematically observations in some domain to systematically changing parameters in some experiment, and so on.

Second, scientific disciplines systematically exploit other bodies of knowledge for their own purposes, mainly knowledge of neighbouring and auxiliary disciplines, and technological knowledge. With respect to the latter, today literally all disciplines use information technology in one way or another, and some disciplines have even been fundamentally revolutionized in the process. All natural sciences make extensive use of technology in their building of observational and experimental equipment. But also in many humanities, especially the historical sciences, cutting edge technologies are put to various purposes, e.g., for dating and other analyses of materials.

Third, the existence of chance discoveries is a well-known phenomenon from the history of science. However, science has even managed to somehow systematically force chance in order to improve its knowledge. One way to force chance consists in so-called brute force approaches, where a vast number of cases are systematically searched, one by one, until an interesting case arises. Another way to force chance is explorative experimentation. Bringing a comparatively unknown system into different experimental conditions may bring its unknown properties to the fore. Finally, even the experimental test of a hypothesis contains this element of forced chance. Any deviation of the experimental result from what is predicted by the hypothesis may be clearly due to a failure of the hypothesis. But it is also possible that some auxiliary hypothesis which was tacitly used and taken for granted in the experimental set-up is at fault. As there is a virtually unlimited number of such auxiliary hypotheses that are operative in any experiment, the set of those background assumptions is constantly, that is to some degree systematically though not intentionally, challenged by the experimental activity of science.

Fourth, on a more abstract level, a key element of science's astonishing ability to generate new knowledge is the fact that the stock of already existing knowledge is systematically used in order to create new knowledge. This holds across all disciplines. Every piece of newly gained knowledge provides additional resources for potentially expanding knowledge further. In a word, science is a self-amplifying (or auto-catalytic) process. Consequently, science follows, given sufficient resources, an exponential growth pattern that has indeed been observed over several centuries.

However, given these systematic approaches it should not be overlooked that very often also a chaotic element plays a prominent role in scientific knowledge generation. The process of creating a new idea is often beyond the systematic planning and control of the creator. This is no contradiction to our main thesis that only states that scientific knowledge is *more* systematic than other kinds of knowledge.

The Representation of Knowledge

Scientific knowledge is not just an unordered aggregate, but due to its intrinsic epistemic connectedness it is structured, and an adequate representation of knowledge must take this internal structure into account. The first and prime example is mathematics in which the axiomatic representation of knowledge exhibits an extremely high degree of systematicity.

Second, in the empirical sciences, a host of distinctions and rules governs knowledge representation: The general has to be distinguished from the particular, the well-established from the merely hypothetical, the descriptive from the theoretical, the logically dependent from the logically independent, etc. In addition, many rules have to be followed in the outline and other representational aspects of books and articles.

It should be noted that the systematicity of knowledge representation is not just an aim in itself. Rather, it serves important functions for science. The systematic representation supports the efficient screening and reception of knowledge, and it helps detecting errors and gaps that might otherwise go unnoticed. Thus, this aspect of systematicity supports other aspects of systematicity.

Comparison with Other Positions

In this section, I want to compare in an extremely schematic way the position outlined above with alternative positions given in the history of philosophy. My leading assumption is that these positions will probably not be just wrong, but they will be one-sided by overemphasizing, or even pushing to the absolute, one or the other aspect of systematicity. This is quite obvious with regard to the first two historical phases of the answers to the question 'What is science?' mentioned in Historical Preliminaries section. In these phases, where the specificity of scientific knowledge was seen in its absolute certainty, the fourth aspect of systematicity, the defense of knowledge claims, was pushed to the extreme. In the third historical phase, where the scientific method was stressed, the aspect of order was overemphasized. 'Systematicity' is a weaker concept than 'methodicity,' and it covers more than just rules of generation or justification of knowledge.

With respect to individual authors, Aristotle, of course, is a good starting point. In the *Posterior Analytics*, he proposed a categorical–deductive ideal for scientific knowledge, as it was apparently realized in Euclidean geometry. This ideal sets the standards for the defense of knowledge claims extremely high, together with a particularly rigorous form of systematicity with respect to the epistemic connectedness and the representation of knowledge. Even in mathematics this extreme ideal could not be upheld, as the discovery of non-Euclidean geometries had severe implications for the status of mathematical axioms.

Descartes is usually and rightly seen as the champion of method. His four rules of method in his *Discours de la Méthode* concern the recognition of truth by evidence, the resolution of problems into sub-problems, the rule to think in the right order, and an attempt at completeness. Both the first rule that concerns a specific way to defend knowledge claims, and the fourth rule that concerns completeness in the sense of a goal and of the means of attainment, fit well to the corresponding categories of systematicity. The second and the third rules, by contrast, belong to a rational heuristic which is of dubious value from today's perspective.

Kant seems to be a key witness for systematicity, as he states that it is systematic unity that transforms common knowledge to scientific knowledge (*Critique of Pure Reason*, A832/B860). However, Kant's understanding of 'systematicity' is much narrower and more rigorous than the one espoused here, as, for him, systematicity roughly equals axiomatization.

In logical empiricism and in critical rationalism, the dominant themes were protocol or basic sentences, the questions of inductive or deductive justification of hypotheses, and scientific explanation and prediction. Thus, stress was laid upon the systematic defense of knowledge claims, and the explication of scientific explanation and prediction, properly called "scientific systematizations" by Hempel.

In Kuhn, for the phase of normal science emphasis is laid upon the systematic generation and the increase of precision of knowledge. For the theory choice situation, the (comparative) defense of knowledge claims is stressed.

Feyerabend voices a position that seems to be in straight contradiction to the one developed here. His slogans "Against Method" and "Anything goes" as well as the following two citations seem to be opposed to any idea of method or systematicity: "*[T]he events, procedures and results that constitute the sciences have no common structure*, there are no elements that occur in every scientific investigation but are missing elsewhere" (*Against Method*, 3rd ed. 1993, p. 1) and "Science … is a collage, not a system" (*Killing Time*, 1995, p. 143). However, as the second part in the passage from *Against Method* indicates, Feyerabend denies science a common structure in terms of necessary and sufficient conditions whereas, here, the kinship of the sciences is founded in nets of family resemblances (see Clarifications of the Thesis section).

Consequences for the Demarcation Problem

On the basis of the given characterization of the nature of science, a new attempt at the notorious demarcation problem can be launched. The central problem of the demarcation of science from pseudo-science (and, perhaps, metaphysics) appears to be the extreme inner diversity of the sciences, especially when viewed in a historical perspective. It looks hopeless to find a uniform criterion that delineates just this domain in opposition to areas that are, in some particular historical period, seen as pseudo-scientific.

Given this fact, a more dynamic view appears more promising. Even if scientific and pseudo-scientific areas do not show enough uniform contrast when looked upon synchronically, diachronically they may display different developmental patterns on the basis of which they may be discerned.

Following what has been said in What is Science? and The Systematicity of Science sections, the dynamics of a scientific field can, in the most abstract way, plausibly be characterized by the tendency to increase its degree of systematicity, in whatever dimension it is possible. As there are several dimensions competing, different scientists will choose different directions, depending on their interests, abilities, resources, anticipated feasibility and expected importance of the results. For example, some scientists will try to increase the systematicity of descriptions by improving the accuracy of measurement apparatus, or the consideration of additional historical sources, and so on. Other scientists will increase the systematicity of explanations by expanding the scope or accuracy of theories, by refinement of some particular narrative explanation and stricter exclusion of competing ones, and so on. Still other scientists will improve the rigor of the defense of knowledge claims, or attack certain hypotheses, and so on and so forth. But the overall direction of what the scientific community does is clear: It is the direction of increased systematicity.

The dynamics of typical pseudo-scientific areas, however, looks very different. First, in many cases there is no real dynamics whatsoever; it is always the same cases to which the putative knowledge is applied, without any further development of its cognitive basis. Very rarely does it happen that the scope of intended applications is extended, or that the claimed accuracy of some prediction or explanation is improved.

Second, there is typically no autonomous development of self-critical tests of the basic assumptions of the field. For instance, in many fields that are predominantly seen as pseudo-scientific, statistical approaches could be developed in order to test basic assumptions. But usually this is not done; if it happens at all, then it is typically done by outside scientists who try to challenge the respective field.

Third, most of the dynamics of pseudo-scientific fields, as far as it exists, is defensive. It is directed against attacks by the established sciences who challenge the legitimacy of the respective field. The protective belt of auxiliary hypotheses is strengthened.

In this view, pseudo-science that poses as science by mimicking science may be comparatively successful with its self-presentation when viewed at a particular time. But when observed over time, it typically lacks the central characteristic of the dynamics of the real sciences, namely the increase of the degree of systematicity in all dimensions where it is feasible.

Conclusion

There is a famous quote by Albert Einstein: "The whole of science is nothing more than a refinement of everyday thinking." Reflecting upon the possible meaning of "refinement" and having the content of this paper in mind, I am tempted to rephrase Einstein's dictum as: The whole of science is nothing more than a *systematisation* of everyday thinking.