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Who were Cartesians in Science? A Philosophical and Historical Consideration

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Who were Cartesians in science? This historical question presupposes a general philosophical problem of science: what is an X-ian school or X-ism in science? This paper answers the general philosophical question by taking Cartesian science as an example. My argument goes along the following line. First, I examine three possible answers from the notions of "paradigm", "research programme", and "research tradition" that were proposed by history-oriented philosophers Kuhn, Lakatos, and Laudan. Next, I argue that each of the three answers faced theoretic difficulties and failed to offer an adequate account of the Cartesian school case; and **the notion of theory family** better answer the philosophical and historical question than do other examined notions. Finally, I propose a **dynamic model of theory families**, providing a theoretical account of the identification of *a* **theory family** and giving an outline of the formation of Cartesian school. I particularly address some controversial cases in Cartesian school, focusing on Huygens and Leibniz.

[Keyword] Cartesian, paradigm, research programme, research tradition, theory family, Descartes, Huygens, Leibniz

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1. Introduction

Who were Cartesians in Science? Said otherwise, who was adequately qualified as a Cartesian scientist in the history of science? This question implies a notion of Cartesian science. Historians of science and philosophy frequently use "Cartesian science" to refer to scientific ideas that are associated with René Descartes to some extent. Sometimes they use "Cartesian school" to refer to those scientists who should or might be viewed as Cartesians; and the system of scientific beliefs held by members of Cartesian school is Cartesian science. So far these sentences sound tautological at all. However, all sentences jointly presuppose a particular question: what conditions admit a scientist to be viewed as a Cartesian? This question casts a generally philosophical question about what X-ian science, X-ian school, or X-ism in science is. It also rises to an identity problem of members in such a historical entity (say, an X-ian school or a school of X-ism), because it involves the problem about how to identify its members. The identity problem can be formulated as "what conditions admit a scientist to be viewed as an X-ian?"

This paper aims to answer the general philosophical question, which, however, cannot be satisfactorily responded without considering any historical case. A particular historical case offers a support or a negation to a philosophical answer. This interactive relation between the philosophy of science and the history of science has been expressed well by Lakatos's dictum, "philosophy of science without history of science is empty; history of science without philosophy of science is blind." Thus, I take Cartesian science as a particular case and answer the historical question about who might be adequately qualified as a Cartesian scientist. Nicolas Malebranche, Jacques Rohault, Pierre S. Régis, Christian Huygens, Gottfried W.

Leibniz, Jacob Bernoulli, and Johann Bernoulli are candidates mentioned in the literature; and among them Huygens and Leibniz are more controversial than others. The case of the relation among Descartes', Huygens', and Leibniz's sciences is too complicated to give an easy account. If one can provide a satisfactory account of such a complicated relation, then one may offer a strong justification for her philosophical answer.

Why is the relation among Huygens', Leibniz's, and Descartes' sciences crucial? Huygens and Leibniz ever stood at the position of Cartesian camp against Newton's celestial dynamics, but their "theories" were quite different from Descartes'. They both criticized Newtonian attraction as being "action in a distance" and devalue it as being "magical" and "unscientific," although they also oppose to Descartes as well as Newton on the notion and measurement of force.[1] Huygens and Leibniz think that forces should be measured by "the product of mass and speed square (mv^2)" while Descartes and Newton by "the product of mass and speed (mv)".[2] **Given these facts, may they be viewed as Cartesian in science?**

In the case of Huygens, many philosophers and historians of science gave an affirmative but divergent answer (Aiton 1972; Dijksterhuis 1986; Elzinga 1992; Koyré 1965; Lakatos 1978b; Laudan 1977).[3] Leibniz's being a Cartesian was more controversial than was

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1) Koyré (1965), pp. 115-148.

2) Ibid., p. 65; Garber (1995), pp. 284-293.

3) Dijksterhuis writes: "The first thoroughgoing Cartesian who also did full justice to that other meaning of mathematical treatment was Christiaan Huygens." (Dijksterhuis 1986, p. 414) Aiton's work focuses on the development of the vortex theory in cosmology, of which Huygens' vortex theory is an important component. Elzinga carefully says, "Huygens' relationship to Cartesianism is complicated. Elsewhere I have shown that Huygens certainly was a Cartesian, as far as his ontology is

Huygens. Some philosophers and historians of science view Leibniz largely as a Cartesian (Duhem 1980; Koyré 1965; Lakatos 1978b; Laudan 1977),[4] but many historians of philosophy, in particular specialists on Leibniz, seem unwillingly to assign such a title to Leibniz (Woolhouse 1994). They have jointly presented that there are many differences between Leibniz's and Descartes' philosophy (metaphysics, epistemology, and methodology) and science in terms of textual analyses in details.[5] In their view, Leibniz should not be a Cartesian. Given the fact that there is a huge difference between the

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concerned. But he departs from René Descartes in regard to epistemology and method." (Elzinga 1992, p. 282) Hall has a similar thought to Elzinga, as he says: "His general metaphysics of nature was very close to that of Descartes, certainly he was a 'mechanical philosopher' even to the extent that he seems to have been privately unable to acknowledge the existence of a God… In his methodology, however, Huygens was neither a Cartesian nor a rationalist of any sort,…" (Hall 1992, p. 47) Koyré's attitude is more ambiguous. In a footnote, Koyré writes: "Even those who, like Huygens and Leibniz, rejected some of the fundamental theses of Descartes, such as the identification of extension and matter and the conservation of momentum, and who therefore considered themselves as non-Cartesians (Huygens) or anti-Cartesian (Leibniz), were very deeply influenced by Descartes and accepted his ideal of a purely mechanical science;…" (Koyré 1965, p. 54)

4) It is interesting that Duhem views Leibniz as a Cartesian as he says that Leibniz and Malebranche continue to keep a physics as close as possible to Cartesian physics (Duhem 1980, p. 10). However, Duhem divides mechanics into Cartesian mechanics, atomistic mechanics, and Newtonian mechanics and treats Huygens as a member of atomistic mechanics. This seems to mean that Huygens is a non-Cartesian (Duhem 1980, pp. 5-15).

5) It is noteworthy that Garber (1994) points out the young Leibniz had ever been a Cartesian. See the first section of his paper, "The Cartesian Period: 1668-1670".

two giants' thoughts, what conditions allow us (as a historian and philosopher of science) to view Leibniz as a Cartesian? Or, is the answer that there are simply no such conditions?

Before moving to the next stage, it is important to ask whether or not a satisfactory answer to the historical-philosophical question has been provided. In the literature of history and philosophy of science, three history-oriented philosophers of science have provided important proposals respectively. They are Thomas Kuhn, Imre Lakatos, and Larry Laudan, who suggested the notions of "a paradigm," "a research programme," and "a research tradition" that could be used to define a scientific school. Every notion refers to some certain historical unit that has a specific structure and lasting through a period of scientific development. However, I argue that each of the three notions faces some problems that are difficult to overcome. They also fail to provide an adequate account of the Descartes-Huygens-Leibniz case. I argue that the notion of **theory family** or **family of theory versions** (Chen 2000) provide a better answer to those problems than do the notions of **paradigm**, **research programme**, or **research tradition**. This notion views that every **theory** in a "family" is an independent entity; and in this sense, this family is **a theory family**.[6] Every **theory** in a family is also a **version of a prototypical** theory that is usually the **original ancestor** and used to represent the family; and in this sense, this family is **a family of theory versions.** Therefore, I use the two terms of **theory family** and **family of theory versions** interchangeably.

Based on the two notions, I propose a meta-theory or a

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[6] See Ruse (1995), chapter 5. Ruse envisages the notion of theory family by using the history of evolutionary theory to argue that "scientific change is a family affair." However, Ruse does not deal with the problem of competition among theory families.

philosophical theory of history of science. According to this philosophical theory, we should view Cartesian school as a theory family in which all members share **a family resemblance** in conceptual structure. Moreover, this theory can be applied to the history of scientific development, providing a dynamic account of the formation of Cartesian school. I will call this **the dynamic model of theory families**. It can also provide a better account of the relation between Descartes' and Huygens' science and that between Descartes' and Leibniz's science than other rivals can. Due to the limited space of this paper, however, I will not involve many historical details of Cartesian science.

2. Criteria from a paradigm, a research programme, and a research tradition

Historians of science and philosophy usually define, characterize, or describe "Cartesian" in a variety of ways, ranging from narrower senses to wider ones. Who is or was a Cartesian? The answer to this question may be those who have scientific claims are directly derived from Descartes' own science, or those who do scientific researches based on Descartes' metaphysical, epistemological, and methodological principles, or those who inquire science and philosophy with a Cartesian style, or those whose fundamental views on science and philosophy are similar to Descartes' theory or influenced by Descartes. There seems to be no explicit definition or clear consensus among the senses of "Cartesian" and "Cartesian school" used by historians and philosophers. However, many scholars still want to explore whether "Cartesian" can be exactly defined or not.

To answer the foregoing question, one might find sources from history-oriented philosophers of science. For example, one could define "Cartesian school in science" by the notions of "paradigm" (Kuhn 1970a), "research programme" (Lakatos 1978a), or "research tradition" (Laudan 1977). "Cartesian school" thus refers to the group of scientists who worked under Cartesian paradigm, Cartesian research programme, or Cartesian research tradition. However, each of those notions needs further interpretations.

The concept of **paradigm** in **The Structure of Scientific Revolution** is notorious about its vagueness (Shapere 1980[1964]; Masgrave 1970). In order to respond to such criticisms, Kuhn articulates and redefines a paradigm as a **disciplinary matrix**, which consists of shared exemplars, symbolic generalizations, models, metaphysical beliefs, and shared values (Kuhn 1970a, 1970b, 1977a). In Kuhn's own words, a paradigm or a disciplinary matrix is the constellation of group commitments that all members of a scientific community share. Exemplars, accepted as standards by a scientific community, are concrete solutions to special problems. Symbolic generalizations such as Newton's laws of motion are those universal statements representing principles and laws of nature; and they can be usually formalized by mathematical languages. Models are preferred analogies by the group whose members work under a specific ontology or a set of metaphysical beliefs. Shared values such as accuracy, consistency, scope, simplicity, and fruitfulness are those criteria that are used to make choice among competing theories (Kuhn 1977b).

There are at least two problems in the model of Kuhn's paradigm for an X-ian school. First, what element of a disciplinary matrix can be used to identify a paradigm *per se* and distinguish the paradigm from other theories? Is the element the exemplars, the models, the generalizations, the metaphysical beliefs, or the methodological

values? Is there any element of a disciplinary matrix keeping unchangeable through the "living" span of the paradigm? Can a paradigm still keep the same one during its living period if there is no such an element? Kuhn had not ever considered these questions.

Second, applying Kuhn's view to the case of Cartesian school, one may say that Descartes provides scientific exemplars, generalizations, models, metaphysical beliefs, and methodological values for scientists in Cartesian school. Reversely, Cartesian scientists apply the matric elements of Descartes' paradigm to their research. However, Shapere puts the boundary between a paradigm and their applications into question:

> ···where do we draw the line between different paradigms and different articulations of the same paradigm? It is natural and common to say that Newton, d'Alembert, Lagrange, Hertz, Hamilton, Mach, and others formulated different versions of classical mechanics; yet certainly some of these formulations involved different 'commitments' – for example, some to forces, other to energy, some to vectorial, others to variational principles.[7)]

If Shapere's question to Kuhn's notion of paradigm is plausible, one naturally wants to ask the following related questions: Had Cartesian scientists their own "theories" with different commitments from Descartes'? Did they share all Descartes' metaphysical beliefs and methodological values? If Cartesian scientists' "theories" are not only articulations of Descartes' generalizations and models, and if they had different beliefs and values from Descartes', then Kuhn's notion of disciplinary matrix (paradigm) encounters a severe trouble. Moreover, regarding the problem of Huygens and Leibniz, Kuhn might simply exclude them from Cartesian paradigm. In doing so,

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7) Shapere (1964 [1980]), p. 32.

however, he would not be able to explain the role that Huygens and Leibniz played in the competition between Cartesian and Newtonian schools, given the fact that they ever stood at the position of Cartesian metaphysics of mechanism and vortex theory against Newton's celestial dynamics.

Being a descriptive and evaluated unit for the history of science and the methodology of science, Lakatos' "research programme" is similar **in function** to but different **in structure** from Kuhn's paradigm. A research programme refers to the common structure of a series of theories in succession. It consists of three interrelated elements: a common and invariable hard core, a changeable and evolutionary protective belt, and a set of heuristics that guides successive researches and modifications. Different hard cores define and delimit different research programmes, for example, Newton's three laws of motion and law of gravity define Newtonian mechanics as a particular research programme. Hard cores are irrefutable in the sense that the proponents of a programme would not falsify it when they intended to test the programme by experiments. If a piece of empirical evidence is in conflict to the prediction out of the tested theory, then it should not be regarded as counterinstance to the hard core. Scientists should modify the protective belt which consists of many auxiliary hypotheses, observation hypotheses, and initial conditions – they gather around the hard core as a belt to prevent it from being falsified. Heuristics are a set of methodological rules. Negative heuristic tells scientists what paths of research to avoid and positive heuristic what paths to pursue. In Lakatos's own sentences,

> the negative heuristic specifies the 'hard core' of the programme which is 'irrefutable' by the methodological decision of its proponents; the positive heuristic consists of a partially articulated set of suggestions or hints on how to change, develop

> the 'refutable variants' of the research-programme, how to modify, sophisticate, the 'refutable' protective belt.[8)]

Lakatos' notion of research programme can be applied to Cartesian school without suffering the identification problem of a programme *per se*, because he suppose that every programme has its own hard core and negative heuristics that can be used to identify itself.[9)] However, this notion still faces the same problem as Kuhn's paradigm does when it is applied to the actual history. One may wonder whether or not all Cartesians share a common hard core and common negative heuristics. Many identified Cartesian, especially Huygens and Leibniz, did not explicitly share a common hard core and negative heuristics with Descartes. Although Lakatos might simply exclude Huygens and Leibniz from Cartesian school as Kuhn might do, he would not provide a reasonable account of their important role in the competition between Cartesian and Newtonian schools. This case seemly constitutes an anomaly to Lakatos' notion of research programme.

In his **Progress and Its Problem**, Larry Laudan developed the notion of "research tradition" and gave it a working definition: "a

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8) Lakaos (1978a), p. 50.

9) Lakatos himself provides a rough description of Cartesian programme as follows. "Cartesian metaphysics, that is, the mechanistic theory of the universe – according to which the universe is a huge clockwork (and system of vortices) with push as the only cause of motion – functioned as a powerful heuristic principle. It discouraged work on scientific theories – like (the 'essentialist' version of) Newton's theory of action at a distance – which were inconsistent with it (negative heuristic). On the other hand, it encouraged work on auxiliary hypotheses which might have saved it from apparent counterevidence – like Keplerian ellipses (positive heuristic)." (Lakatos 1978a, pp. 47-48)

research tradition is a set of general assumptions about the appropriate methods to be used for investigating the problems and constructing the theories in that domain."[10] It can be said that a research tradition is a great theory in general. This general theory is associated with a series of specific theories, committing to a set of metaphysical beliefs and methodological rules and generally lasting a significant period of time. For Laudan, the nature of science is problem-solving; scientists always endeavor to construct specific theories to solve a variety of empirical and conceptual problems. Therefore, the most important mode of interaction between research tradition and its constituent theories defines the roles of research tradition. A research tradition has the capability to determine its problems, to constrain the types of theories that can be developed within the domain, to provide heuristics for the construction of special theories, to rationalize or justify theories. So far it echoes the tones of Kuhn's paradigm or Lakatos' research programme, but it appears a significant difference from the latter two. Laudan claims that a research tradition may change or evolve through a long time, as he said metaphorically,

> Research traditions, as we have seen, are historical creatures. They are created and articulated within a particular intellectual milieu, they aid in the generation of specific theories – and like other historical institutions – the wax and wane.[11]

He identified two types of changes in a research tradition: one was modification of some of its subordinate, specific theories; the other was change of some of its most basic core elements. The admittance brings a severe challenge to Laudan's theory of scientific changes:

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10) Laudan (1977), p. 81.

11) Ibid., p. 95.

How can a research tradition undergo certain deep-level transformations and still remain the "same" tradition in some sense? The answer depends on identifying out the irrefutable elements of a research tradition and indicating a continuous and gradual modification of those elements. Laudan partially agrees with Kuhn and Lakatos, admitting that there existed irrefutable parts in a research tradition, but he insists that "the set of elements falling in this (unrejectable) class changes through time."[12] Nevertheless, the question of what elements of a research tradition are to be treated as being irrefutable still leaves unanswered. Laudan confessed that he could not give a fully satisfactory answer but he suggested the conceptual well-foundedness as being a rational one.

Based on the view of changing traditions, Laudan points out two major errors in Kuhn's notion of paradigm and Lakatos' notion of research programme: (a) Paradigms and programmes have a rigid structure which precludes their core elements from evolving in the course of time; (b) Kuhn fails to give an adequate account of the relationships between a paradigm and its constituent theories and Lakatos mistakes in permitting that a special theory within a programme must be entailed by its successor.[13]

Which of Kuhn's paradigm, Lakatos' programme, or Laudan's tradition can best define Cartesian school? Which can give an adequate account of the relation between Descartes' and Huygens' science and that between Descartes' and Leibniz's science? In fact, the relation among Descartes', Huygens', and Leibniz's sciences constitutes a severe challenge to all of the three notions. This

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12) Ibid., p. 99.

13) Laudan makes five points of criticism on Kuhn's theory of paradigm and six points on Lakatos' theory of research programme respectively (Laudan 1977, pp. 74-78). There is no need for me to reiterate them here.

challenge is represented by the following questions: Can a paradigm, a research programme, or a research tradition keep unchangeable through a period of time? How can we clearly delineate the boundaries between a paradigm, a programme, or a tradition and their constituent, subordinate theories? Should we classify a scientist's work into some certain and special paradigm, research programme, or research tradition, if her work is both similar and dissimilar to the theory as the paradigm, research programme, or research tradition? In next two sections, I argue that the notions of **theory version and family of theory versions** can provide a satisfactory answer to the challenge.

3. The nature of theories in a series

As the previous section has shown, neither Kuhn's nor Lakatos's notion can provide satisfactory answers for the case of Cartesian school, because they imply rigid, unchangeable, and common elements that cannot be found in theories in this school. Laudan is right in claiming that all elements in a tradition may evolve through time, but wrong in thinking that Huygens's science was a subordinate constituent theory belonging to Cartesian tradition. He asks "Does Huygens become a non-Cartesian because he admits the possibility of void spaces?" and gives a negative answer.[14] However, why might Huygens be viewed as a Cartesian if he rejected Descartes's argument for the impossibility of void space? Laudan views Huygens and Leibniz as Cartesians for the reason that they committed to an ontology of pushes and pulls.[15] Again, why is the ontology of

14) Ibid., p. 97.
15) Ibid., p. 89.

pushes and pulls the adequate criterion by which one may reasonably view Huygens and Leibniz as Cartesians? In fact, their theories of motion are quite different from Descartes's mechanics, because Descartes's notion of force is defined by "momentum" (mv) while Huygens's and Leibniz's notion of force is defined by "energy" (mv^2).[16] Given the big difference along with many others, why do they still belong to Cartesian tradition? Laudan, as he confessed, explicitly failed to give a satisfactory account for the challenge: How can a research tradition undergo certain deep-level transformations and still remain the "same" tradition in some sense?

A paradigm, a research programme, or a research tradition always includes a series of theories in succession. As Laudan has seen, it is wrong to suppose that there an unchangeable exemplar (of a paradigm) or a hard core (of a research programme) over and through a series of theories. Laudan is right in supposing that there are no rigid and unchangeable elements through a research tradition. However, it may be wrong to imagine that there is an identifiable, well-defined general, superordinate **theory** dominating over other constituent, subordinate **theories**. The object we can identify is a **prototypical** or a **paradigmatic** (in the sense of model) theory in a series of successive theories rather than a superordinate paradigm, programme, or tradition over and through the theory series. Theories in the series should be interpreted as followers to the prototypical theory, which is in turn the very **model** for its followers to imitate and learn. Every follower is rather an individualistic, independent, and integral theory than a constituent and subordinate part of the prototypical theory. In other words, the relation between the prototypical theory and other following theories is not hierarchical **in structure** but successive **in time** and equal **in level**.

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16) Garber (1995), pp. 284-293.

To explain scientific development and change, in my view, we are not to identify a superordinate theory overarching over subordinate theories, nor to find some common element across a series of theories. Rather, we should regard every one of a theory series as being equal and examine similarities and differences among those theories. If we want to analyze the development of a theory series, then we need identify what theories should be included in the series. One may assume that we can do this by identifying some certain common and irrefutable elements as being a prior **criterion** by which the members of the series can be determined. However, before detecting whether there are any common and irrefutable elements or not, we have to decide what members should be included in the same series of theories. Only after classifying some theories into the same series or tradition, it would be possible for us to search for irrefutable elements. However, there may or may not be irrefutable elements common in all members of the series. In effect, **family resemblance** among theories may be the simple **outcome** when we have identified a theory series successfully. This implies that all following theories have a similar constitutive structure as the prototypical theory has. This also implies a parallelism rather than a hierarchy **in structure** between the prototypical theory and its followers. These claims will be elaborated in next sections.

The **family resemblance** among the theories in a series allows us to call the series **a theory family**. In many historical cases including Cartesian school and Newtonian school, we may find **family diversity** among the members of a family. This notion implies that members (theories) that are included in one and the same family may be quite different from one another. Moreover, the difference between a pair of theories may be different from that between another pair; and differences do not prevent those diverse theories from belonging to

one and the same family. However, this notion brings a new problem: what conditions allow we to include diverse theories to one and the same family? One should note that **family resemblance** is not a **criterion** for identifying a theory family; instead, it is an outcome out of identifying a theory family.

As far there seem to be good reasons for us to define an X-ian school in terms of the notion of **a theory family**. However, theories in Newtonian school share a family resemblance in the mechanics of collision to Huygens's theory that belongs to Cartesian theory family. Even Newton's own theory is similar to Descartes's for their common insistence on the concepts of inertia and momentum.[17] Why was Newton not a Cartesian? Why was Newton the beginner of Newtonian school while Descartes the father of Cartesian school? Are there "genes of an X-ian school" and "unchangeable and rigid elements of an X-ian school" for us to determine whether a theory should belong to a theory family or not? Even if we take the notion of **theory family**, these considerations still make a big trouble with the endeavor to understand an X-ian school in terms of this notion. That means that we have still to solve the identification problem of a

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17) Koyré points out that "neither Kepler nor even Galileo dared to attribute such forces (centrifugal forces) to the motion of celestial bodies, and accordingly, did not need centripetal forces to counteract them." He further says, "That is not a mean merit. Voltaire could ignore it; Newton, however, could not. Yet he did not mention it, as he did not mention the Cartesian origin of the concept *quantity of motion* (*mv*), which he stubbornly maintained as a measure of force against the Huygenian and Leibnizian *vis viva* (mv^2), even while he rejected the Cartesian assertion of the conservation of motion in our world. Nor did he mention that it was Descartes's formulation of the principle of inertia, which placed motion and rest on the same ontological level, that inspired his own." (Koyré 1965: 65)

theory family and its members.

4. The identification of a theory family

Theories belonging to different families may be similar to one another, and theories in an identical family may be diverse. This fact raises several related questions: How does a theory family be identified? What is the criterion according to which we select a theory to be the original "ancestor" of some new theory family from a scientific field or the grand tradition of the whole science? Why is a new theory family qualified as *new*, given that the original ancestor has its own conceptual or theoretical "ancestor"? In order to answer these questions, the notion of **family resemblance** simply has no help and **family diversity** even makes bigger troubles, because the original theory of a new family is similar **in conceptual content** to its parent theories that necessarily belong to another old family. The big trouble can be solved, I suggest, by looking into both internal and external (or contextual) conditions in which a theory family are gradually forming.

In order to answer those questions, we should divide the identification problem of a theory family into two levels: (1) How should we identify the original ancestor of a family? (2) What member theories does the family have? Or, what theories should be included in the family? Only if both of the two questions have answered, we can identify a theory family. As I have suggested, we should find the criteria respectively for the identification of an original theory and for the inclusion of family members by finding externally contextual conditions as well as internally conceptual conditions.

How does a theory become a founder of a theory family, given every theory has its conceptual parents and ancestors? Usually people identify a theory as the original ancestor of a theory family only if the theory attained an **unprecedented achievement** and ever inspired other scientists to construct newer theories by extending it to other problems and domains. Herein we can apply Kuhn's first characterization of scientific paradigm to "define" a potential ancestor.[18] We reformulate the characterization as the three necessary conditions:

(I1) The **conceptual novelty** condition means that a potentially original theory possesses novel conceptual components.

(I2) The *great achievement* condition means that a potentially original theory attained an unprecedented achievement that enabled it to define the legitimate problems and methods.

(I3) The **conceptual inspiration** condition means that a potentially original theory can attract followers who use its conceptual components to solve new problems and develop newer versions.

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[18] In his first characterization of paradigm, Kuhn said, "Aristotle's *Physica*, Ptolemy's *Almagest*, Newton's *Principia* and *Opticks*, Franklin's *Electricity*, Lavoisier's *Chemistry*, and Lyell's *Geology* – these and any other works served for a time implicitly to define the legitimate problems and methods of a research field for succeeding generations of practitioners. They were able to do so because they shared two essential characteristics. Their achievement was sufficiently unprecedented to attract an enduring group of adherents away from competing modes of scientific activity. Simultaneously, it was sufficiently open-ended to leave all sorts of problems for the redefined group of practitioners to resolve." (Kuhn 1970a, p. 10) This paragraph may well re-interpret as a definition of "a prototypical version."

These are not jointly sufficient, however, because there may be such a theory which is not original. Since no theory was born from vacuum, a theory would be identified as an original ancestor only if it shows a **competitive attitude** to an established family on some received important problems or issues. The attitude motivates its proponents to take specific actions against that established family's solutions, extensions, and proliferations. Let me call this kind of situation "**competitive context**". A **competitive context** can be specified by the following conditions.

(Ca) **The opposing condition** means that two competing theories derive incompatible judgments or predictions on a common problem. The condition is satisfied if a theory, on received important issues, derives assertions and predictions that are incompatible to those assertions and predictions from some important theories in an established family.

(Cb) **The criticizing condition** means detecting errors in a theory based on other theories. The condition is satisfied if a scientist who constructs a new theory publicly criticizes some important members in an established family on received important issues. The action of criticizing makes a new theory opposed to an established family. Making a theory public helps attract new comers to accept it as a prototype and then produce **descendants** by applying and extending the prototypical theory to new problems or fields. However, this condition is not sufficient, because a theorist may criticize other theories in the same family.

(Cc) **The extending condition** means that the advocates of a prototypical theory positively extend the range of the theory to new problems and fields. The condition is satisfied if

there are similar but diverse theories are constructed by applying the conceptual, theoretical, or methodological sources from the ancestral theory or other parent theories inspired by the ancestor.

To summarize the six conditions, one simply concludes that if a novel and inspiring theory attains an unprecedented achievement and enters into a competitive context with an established family, then it would likely become an original ancestor of a new theory family. However, those conditions can not be used to decide the members of a family, given that any member is allowed to criticize and refute other members of the same family or even the original ancestor on some issues. Thus, other conditions for deciding family members are necessary. I suggest the following three:

(Ma) **The inheriting** condition means a scientist takes a theoretic framework whose conceptual components majorly come from members of some theory family. This is an internal condition.

(Mb) **The defending** condition means that a scientist takes a position on some issue and provides reasons for the position against criticisms from other families. If the builder of a theory C defends for an original theory A against the other family of theories on received important issues, then C may be regarded as a member of A's family in spite of its giant difference from A. But this is not sufficient, because a scientist belonging to some family may defend for another family on some issue.

(Mc) **The relative position in a competitive context** is a context-dependent criterion. To decide a theory to be

> assigned to which family in the case that two or more families compete with one another, we have to consider the position of the theory relative to all competing theories and families. There is no general standard can be drawn out; the membership of a theory may be decided case by case. Thus, this condition is to be explicated more clearly by a real case.

The first two conditions help decide members of a theory family and thus identify the family. However, this does not imply that a new family can be identified *a priori* so that we can decide what members to be included in it. On the contrary, a new family would form *a posteriori* only when some theories were constructed and their relative positions to the old families emerged in such a competitive context. Moreover, the genesis of all theory families needs a long time. From a dynamic perspective, these conditions also suggest a generative process of a theory family.

The generative or formative process of a theory family can be largely outlined as follows. In any time, there is or was at least one family or tradition or school which has or had been established. A scientist who is constructing a new theory version takes a position opposing to the paradigmatic or some other important theory of the established family. He criticizes his rival on some received important issue. Some scientists were inspired to take the new position against the old family by applying the new version to old and new problems. In order to solve those problems, they would inevitably modify some (formulating, conceptual, modeling, or methodological) elements of the original theory and construct their own new versions. In the due process, they sometimes defend for the original theory on some important issue in spite of the difference between their theories and the original theory. A new theory family is thus gradually forming.

For example, Cartesian family of theories was forming against Aristotelian family which dominated the kingdom of natural philosophy from the middle age to the seventeenth century.

When a new theory family is developing, some more remote and divergent theories might be constructed. Everyone has the potentiality to become the original ancestor of another family. Usually, only very few theories may establish new families. Some remote versions that are quite different from its ancestor turn out to be seen as a member of the family due to some special historical and contextual conditions. Let us imagine a complicated situation in which two new theories Ca and Ne were proposed against an established old family Ar. Both were founding their own families. However, Ca's family opposes to Ne's family on some important issue. Some remote version Hu had been constructed. However, Hu shared a similarity with and had a giant difference from Ca so that Hu might give birth of a new family. But Hu also opposed to Ne which was extending its family. In the due process, the builder of Hu defended for Ca against Ne while the proponents of Ne criticized Ca on some important issue. In consequence, Hu should be seen as a member of the family Ca, because its conditions satisfied the criteria of family members.

Ar, Ca, Ne, and Hu can adequately represent schools, families, and theories in the seventeenth century – say, Ar represents Aristotelians, Ca Cartesians, Ne Newtonians, and Hu Huygens's or Leibniz's theory. According to the foregoing analysis, Huygens's and Leibniz's theories may be viewed as Cartesian in spite of their giant difference from Descartes's theory, because they oppose to Newton's on the issue of gravity in celestial mechanics and cosmology. They both criticized Newton's notion of attraction and devalue it as being "magical" and "unscientific," although Huygens and Leibniz also oppose to Descartes as well as Newton on the notion and

measurement of force. In consequence, the reasons for Huygens and Leibniz may finally belong to Cartesian school are: (1) Huygens and Leibniz solved the gravity problem by **defending** Descartes's vortex theory. (2) The problem of gravity was regarded as more important than that of force measurement by the turn of the century. (3) In the issue of force, Huygens and Leibniz also opposed to Newton.

It is not difficult to see that the dynamic model of theory families is able to solve the problems in Kuhn's, Lakatos', and Laudan's metatheories. Moreover, this model can absorb and assimilate the notions of paradigm, research programme, and research tradition. Kuhn's "paradigm" can be reinterpreted as the paradigmatic (or the prototypical or the originally ancestral) theory of a family, because it plays a "role model" for other following theories. When the paradigmatic theory inspires the construction of other theories, it functions as a research programme which can offer formulating, conceptual, modeling, and methodological heuristics. An established family of theories can be also referred as a research tradition. However, the meanings of "paradigm", "research programme," and "research tradition" in this frame are not any longer the same as those in Kuhn's, Lakatos', and Laudan's theories. Now we may claim that **the dynamic model of theory families** does give a better account of the relation between Descartes' and Huygen's theories and that between Descartes' and Leibniz's theories than do Kuhn's, Lakatos', and Laudan's theories. The claim will be further illustrated by a historical examination in next section.

5. The formation of Cartesian science

The competition between Cartesian school and Newtonian school is

an important historical episode. Any historical philosophy of science or historiographical theory of science should be required to give a plausible account of this case, in particular, the special relations among Descartes, Huygens, Leibniz, and Newton. A plausible account implies a reconstruction of the developmental process of Cartesian school. For the purpose of this paper, a complete exposition in the intricate case is unnecessary.[19] My goal is only to show that there is a good fit between **the dynamic model of theory families** and the historical case, focusing on discovering the external conditions of the formation of Cartesian school. In consequence, "Cartesian school" will be finally characterized as **Cartesian theory family**.

5.1 Descartes against Aristotelism and Scholasticism on natural philosophy

Descartes became the originator of a new Cartesian school, due to his "complete programme", which holds an extreme opposition to Aristotelism and Scholasticism on almost every issue of the whole natural philosophy (Ariew 1992; Des Chene 2000). *Principles of Philosophy* published in 1644 well summarizes Descartes' great architecture of thought. However, the architecture needs a starting point and a foundation both for the developmental process of his thought and for his own epistemology. It's well known that Descartes began his philosophical progamme by methodological reflections on the problem of knowledge in his several writings, *Discourses on*

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19) To my knowledge, there are many historical and philosophical studies in the relations between Descartes and Newton (Koyré 1965; Herivel 1965; Lakatos 1978b), Descartes and Leibniz (Meyer 1952; Garber 1995, 2001; Woolhouse 1994 [ed.]), and Newton and Leibniz (Hall 1980). There is yet a relatively little body of literature in English on the relations between Huygens and others (Elzinga 1992; Hall 1992).

Method, *Mediations on the First Philosophy*, and *Rules for the Direction of Mind*. He put the old system of knowledge, Aristotelian and Scholastic, into dubiousness and searched an entirely new foundation. They are the celebrated "skeptical thinking" and "ego's existence".[20] The skeptical thinking is not only a skeptical attitude but also a systematical method for pursuing certain and indubitable knowledge and truths in terms of clear and distinct ideas. "I think, therefore I am", from which an edifice of knowledge can be built, was the first indubitable truth which Descartes found.

By the beginning of the 17th century, an academic atmosphere against Scholastic cosmology and philosophy of nature and for a new and alternative system of world had been emerging. Copernican revolution was silently advancing by Galileo and Kepler. A new, single, heliocentric system of celestial world had been announced. By contrast, many physical and metaphysical programmes about the terrestrial world had also been suggested. The question "Is a programme unifying the celestial and the terrestrial world possible?" was emerging in most scientists' minds in the dawn of the great Scientific Revolution. Descartes was the first natural philosopher/scientist who dared to propose a unified theory. As Koyré praised, in Cartesian physics "we find there the first consistent, though of course unsuccessful, attempt at a rational cosmology, an identification of celestial and terrestrial physics…".[21] The point is

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[20] In a frequently quoted paragraph, Descartes writes, "Some years ago now I observed the multitude of errors that I had accepted as true in my earliest years, and the dubiousness of the whole superstructure I had since then reared on them; and the consequent need of making a clean sweep for once in my life, and beginning again from the very foundations, if I would establish some secure and lasting result in science." (Descartes 1971, p. 61)

that Descartes had paved a well-firmed methodological and epistemological ground for his new system of the world. The fullness of his theory inspired many scientists to construct new versions against scholastic philosophy of nature by applying the formulations, models, theoretic concepts, metaphysical beliefs, and methodological implications of his theory (Rogers 1992; Jolly 1992; Verbeek 2000; Harrison 2000; McClaughlin 2000; Garber 2001b). A Cartesian family of theory versions was forming and growing. Another Descartes' kernel achievement is the theoretic and metaphysical system of mechanism. This metaphysics insists that all actions must be produced by contacts, collisions, pulls, and pushes. It sets strong methodological and metaphysical constrains on next generations of scientists including anti-Cartesians, for example, Newton (Lakatos 1978b).

5.2 Newton against Descartes on vortex theory

Some historians of science and philosophy have shown that Newton was deeply influenced by Descartes as well as Galileo (Koyré 1965; Herivel 1965). However, Newton should not be viewed as a Cartesian because he took an opposition to Descartes on the structure of the cosmos and the existence of heavenly vortices. He criticized Descartes' vortex theory in his *Mathematical Principles of Natural Philosophy* by refuting the lasting motion of heavenly vortices. He argued,

> Therefore, in order to continue a vortex in the same state of motion, some active principle is required from which the globe may receive continually the same quantity of motion which it is always communicating to the matter of the vortex.[22)]

21) Koyré (1965), pp. 64-65.

Newton did not mean that we can keep a vortex in the same quantity of motion by introduce **some active principle**. In his view, there was no vortex in the heaven at all. Therefore, Newton concluded,

> ···the hypothesis of vortices is utterly irreconcilable with astronomical phenomena, and rather serves to perplex than explain the heavenly motions. How these motions are performed in free spaces without vortices, may be understand by the first Book···[23]

This was a diametrical opposition to Cartesian school. In the case that the problem about the structure of the world and the cause of celestial motions was the most important topic in the 17th century, Newton thus became a **genuine** anti-Cartesian. Furthermore, Newton became *the original ancestor* of a new school or family because of his **unprecedented achievement**: the mathematical excellence of his theory and the completeness of his models for the system of world. In such a competitive context of Newton versus Cartesian family of theories, Huygens and Leibniz who have quite different versions from Descartes' theory turn out to be viewed as Cartesians.

5.3 Huygens and Leibniz as Cartesians

We have indicated that there is a controversial on the membership of Huygens and Leibniz as Cartesians. I will not contend with those historians of philosophy who view Leibniz as the founder of Leibnizian school. Certainly, it is a simple fact that Leibniz's thought is quite different from Descartes'. Despite this fact, I view Leibniz, as well as Huygens, as a Cartesian based on the following reasons.

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22) Newton (1962), p. 390.
23) Ibid., p. 396.

First, **family diversity** is an elementary characteristic of all **scientific** families of theory versions. Even a typical version of Cartesian science, say Malebranche's, is quite different from Descartes'. Consequently, **family diversity** does not prevent disparate versions from being included in the same family. Second, a family may be identified according to the external conditions and historical context to which its members encounter. Leibniz, as well as Huygens, had been situated in a context which satisfied all conditions of a **competitive context of Cartesian versus Newtonian theory families**. Third, the relative position in such a competitive context offers a good reason for us to view Leibniz and Huygens as Cartesians. Moreover, Leibniz didn't found a **scientific** school like Cartesian school which could persuade historians of science to identify it as a new school. By contrast, Huygens didn't found a Huygensian school either, because he didn't have a full work on metaphysics and methodology.[24)]

Why were Huygens and Leibniz situated in such a competitive context?

At the turn from 17th century to 18th century, Copernican Revolution was coming to the end. The belief, "the moving Earth," became a new consensus in astronomy and cosmology. Thus, "Why can the Earth move through the 'empty' space?" became the most important problem after a new system of world had been established. Newton employed the notion of universal attraction to interpret "the centripetal force" in his mathematical models. However, he could not give an account of the "mechanism" of universal attraction and even he allowed universal attraction to be an **action in a distance**.

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24) Why both Huygens and Leibniz finally failed to be the *original ancestor* of new scientific schools? This is a question worthy of a deep investigation. I leave it for the future.

Constrained by the metaphysics and methodology of Cartesian mechanism, Huygens and Leibniz could not allow the notion of **action at a distance** to be scientific. They publicly and strongly criticized Newton's notion of attraction[25] and their criticisms showed that they committed to Cartesian notion of mechanisms. Moreover, they tried to solve the "moving Earth" problem by **defending** and modifying Descartes' vortex models (Aiton 1972). In such a historical context, they might be reasonably qualified as Cartesians, admitting that they are the remote members of this theory family. As many historians of science have shown, Huygens' and Leibniz's criticisms on Newtonian theory lent Cartesian school a strong power to counterattack Newtonians' attack and resist against the extension of Newtonian school in the turn of the century.

It is very plausible to view Huygens as a "non-Cartesian" and Leibniz as an "anti-Cartesian" according to some important **internal** criterion (i.e., some conceptual similarities). It is also reasonable to view both of them as Cartesians on the ground of other conceptual similarities. As we have seen, in fact, different philosophers and historians had diverse opinions about the **membership** of Huygens and Leibniz according to different conceptual similarities. The fact shows that it is hard to solve the **membership** problem only by appealing to internal conditions.

It is plausible to interpret that Leibniz founded a **philosophical Leibnizian** school different from Cartesian philosophy in the modern sense of philosophy (Wilson 1995). This interpretation can be justified by the two reasons: one is the giant conceptual difference between the two giants and the other is to separate philosophy from science. However, the two reasons are internal. According to the external conditions developed in this paper, the two internal reasons

25) Koyré (1965), pp. 115-148.

may be suspended or overridden. The external conditions allow us to view Leibniz as a Cartesian in **a competitive context of Descartes versus Newton** in spite of the giant difference between Leibniz's and Descartes' theories. The externally historical interpretation highlights the **relative position** among Descartes', Leibniz's, and Newton's theories. In order to locate Leibniz's theory adequately in that relative context, it is very reasonable and even necessary to view Leibniz as a Cartesian. Moreover, in the light of the notion of theory version, Huygens' and Leibniz's theory are independent of Descartes' theory, but they both are Cartesians as well.

6. Concluding remarks

Cartesian school could be established only if there were Cartesian scientists. Every Cartesian scientist built a theory version of Cartesian science. Cartesian science is thus Cartesian **family of theory versions**. However, there are no common elements but only **family resemblance** and **family diversity** within a theory family. One may reasonably and successfully identify a scientist with Cartesian by combining a set of internal (Ia, Ib, Ic, and Ma) and a set of external (Ca, Cb, Cc, Mb, and Mc) conditions among theory families. So I conclude that the pair of notions of theory version and theory family best reveals both the independency of a theory version and the communality of a theory family.

Admittedly, it is completely plausible to disuse the notion of theory family and thus to avoid falling in the identification problems of a theory family and its members. There are only individual, independent, and isolate theories without theory families. In consequence, we would not talk of the communality of a series of

theories. If the communality of some theories is historically important, then we should suggest a notion to account. As we have argued, each of Kuhn's paradigm, Lakatos' research programme, and Laudan's research tradition encounters unsolvable difficulties. The notion of theory family can solve those difficulties and show its advantages: it grasps the commonality of a series of theories without losing the independency of every theory within the family. In this sense, using the notion of theory family is not unbeneficial.

Take a final note. Families of theory versions are not natural but artificial. They are not "historical creatures" as that Laudan used to characterize "research traditions". They are invented to put plural and intricate theories in order, giving the intelligibility to the development of theories. A family is identified according to its conceptual, traditional, historical, and contextual conditions. Those internal and external conditions can be discerned only with hindsight, but this does not imply that the identification of a theory family is subjective and arbitrary. All internal conditions (conceptual novelty and inheritance) and external conditions (competing, opposing, criticizing, extending, defending, and relatively positioning) are objective and factual in history.

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과학에서 데카르트주의자들은 누구인가?

첸 류엘린

과학에서 데카르트주의자들은 누구인가? 이 역사적 질문은, 과학 영역에서 “~주의자” 혹은 “~주의”가 무엇인가에 대한, 과학에 대한 일반적인 철학적 문제를 전제하고 있다. 이 논문은 데카르트주의 과학의 예를 들어 이 일반적인 철학적 질문에 답한다. 답변 과정은 다음과 같다. 먼저, 나는 역사적 과학철학 전통의 철학자 쿤, 라카토스, 라우든에 의해 각각 제안된 “패러다임”, “연구 프로그램”, “연구 전통”이란 개념에 근거한 세 가지 답변을 검토할 것이다. 다음, 나는 이 세 답변이 각각 이론적 문제점에 직면해있으며, 데카르트주의 학파를 정확하게 설명하지 못한다는 점을 보인 후, 이론 가족(theory family) 개념과 이론 가족들에 대한 역학 모형이 앞서 검토한 개념들보다 철학적, 역사적 질문에 더 나은 답변을 제공한다는 것을 논증한다. 마지막으로, 나는 이론 가족의 판별을 위한 이론적 설명을 제안하고, 데카르트주의 학파의 형성에 대한 윤곽을 제시한다. 나는 특히 데카르트, 하위헌스, 라이프니츠에 주목하여 데카르트주의 학파의 몇몇 논쟁적인 사례를 다룬다.

주요어: 데카르트주의, 패러다임, 연구 프로그램, 연구 전통, 이론 가족, 데카르트, 하위헌스, 라이프니츠