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*Natural Classes and Causation*

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Menno Hulswit

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**Abstract:**

In this article, Peirce's conception of natural class is discussed. It is shown that Peirce's mature conception of natural class is intimately related to his conception of (final) causation. Peirce's originality in respect of natural classes concerns at least two insights: first, he made clear that all classification, be it natural or artificial, must be related to some purpose. Secondly, *natural* classifications do not primarily involve our purposes, but the final causes of the classified things themselves. According to Peirce, things belong to the same natural class on account of a metaphysical essence and a number of class characters. The metaphysical essence is a general principle by virtue of which the members of the class have a tendency to behave in a specific way; this is what Peirce meant by final cause. This finality may be expressed in some sort of microstructure. The class characters, which by themselves are neither necessary nor sufficient conditions for membership of a class, are nevertheless concomitant (in the case of a chair, the metaphysical essence is the purpose for which chairs are made, while its having chair-legs is a class character). Natural classes, though very real, do not exist; their reality is of the nature of possibility, not of actuality. The primary instances of natural classes are the objects of scientific taxonomy, such as elementary particles in physics, gold in chemistry, and species in biology, but also man-made objects and social classes.

**Keywords:** Natural Class, Causation, Final Cause, Pluralism, Scholastic Realism, Natural Classification

**Introduction**

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Though Peirce's theory of natural classes is often mentioned in contemporary philosophy of science and metaphysics (Ian Hacking, for example, gives Peirce a prominent place in the tradition of natural kinds<sup>2</sup>), it has not as yet been studied thoroughly. Accordingly, the presentation of Peirce's theory is often only partially correct, and sometimes even misleading. Perhaps the main reason for the absence of a thorough study is that Peirce's theory of natural classes is intimately related to his theory of final causation, - a concept which in contemporary philosophy is avoided for being a mystifying idea which neither agrees with the methods nor with the results of modern science. In another entry ['Teleology'] I have tried to show that this is a biased view, due to a number of false presuppositions that were clearly recognized by Peirce a century ago. Though there has been a complex evolution in Peirce's conception of

natural class,<sup>3</sup> in this article, I will restrict myself to a discussion of Peirce's mature theory of natural classes.

In the entry 'Teleology,' it was shown that Peirce held the view that in each act of causation there is an efficient and a final component: final causes are general types that tend to realize themselves by (teleologically) determining processes of efficient causation. They are not future individual events, but general potentialities. The efficient aspect of causation is that each event or fact is caused by a previous event or fact (the efficient cause); the teleological aspect is that each event or fact is part of a chain of events with a definite tendency. The tendency is determined by the final cause of the process. This entails that each act of causation is mediated by a final cause.

Indeed, Peirce held that the condition for causes and effects to be mediated by final causes is that they belong to a natural class. Thus, Peirce's theory of causation requires an elucidation of his concept of natural class. Conversely, since Peirce defined natural classes in terms of final causation, his concept of natural class must be considered within the perspective of his theory of final causation.

*Accordingly, the objective of this article is to reconstruct Peirce's mature theory of natural classes. The second objective is to examine Peirce's view of the relationship between natural classes and causation.*

Thus, the first section will provide a general sketch of some contemporary approaches to the problem of natural kinds. In the second section, some contemporary interpretations of Peircean natural kinds will be considered. These first two sections will raise a number of questions, which will serve as a point of departure for the subsequent sections. The third section will deal with Peirce's distinction between kinds and classes. Next, in the fourth section, the close relationship between the concepts of final causation and natural kind will be examined. In the fifth section, the question of demarcation criteria will be dealt with. Whereas the sixth section will deal with Peirce's reasons for believing in natural classes, the seventh section will give an account of Peirce's main examples of natural classes. Next, in the eighth section, I will consider Peirce's (assumed) pluralism. Finally, in the ninth section, I will summarize the obtained results and formulate a definition of Peircean natural classes that displays Peirce's view as fully as possible.

## **1. Natural Kinds and Causation in Contemporary Philosophy**

That there is a close relationship between causation and natural kinds is not as strange

as it may seem at first. On the contrary, in the contemporary philosophy of science and metaphysics it is widely believed that the concepts of causation, explanation, natural law, and natural kind are interrelated. For example, in an influential paper on natural kinds, W.V. Quine (1969, p.132) emphasizes that the concept of causation entails the concept of natural kind: "To say that one event caused another is to say that the two events are of *kinds* between which there is invariable succession." And, for example, D.M. Johnson (1990, p.63) defines a natural kind as "a spatiotemporally unrestricted or repeatable category ineliminatively presupposed by at least one true and explanatory law of nature."

In their glossary to their anthology "The Philosophy of Science," the editors Richard Boyd, Philip Gasper, and J.D. Trout give a very general definition of natural kind, which, it may be assumed, is supposed to cover most current theories. A natural kind is:

A type of property, process, state, event, or object studied by science, mentioned in scientific laws, and assumed to be a *causal feature of the world*. The primary instances of natural kinds are objects of scientific taxonomy, such as electrons in physics, zinc in chemistry, and species in biology. Natural kinds are contrasted with phenomena that are assigned no such systematic, organizing role, such as an event's occurring after I drop this pen, or an object's being located 34 miles west of the Liberty Bell. (1991, pp.778-779; italics mine)

According to this view, natural kinds, as opposed to other phenomena, play a systematic role in our explanations of the world; they are supposed to be something like the world's causal joints. The same idea is defended by J. Levinson (1991, p.65), according to whom the objects belonging to a natural kind "occupy the same causal role in nature." As it is not at all obvious, however, what it involves to be 'a causal feature of the world' or to 'occupy the same causal role in nature,' it would seem clearly that the concept of natural kind presupposes an elucidation of the concept of causation.

Bigelow et al (1992, p.373) stress that natural kinds are always associated with *essential properties*. "If something is of a natural kind, then there will be properties which this thing must have to be a thing of that kind, and which it could not cease to have without ceasing to be a thing of that kind." The idea that things belong to natural kinds seems to involve a commitment to *essentialism*: what makes a thing a member of a particular natural kind is that it possesses a certain essential property (or a cluster of essential properties), a property both *necessary and sufficient* for a thing to belong to that kind. The essential property is supposed to provide an objective feature that determines to what kind a thing belongs, independently of any context of inquiry. It is also supposed to play an important *explanatory role* in regard to other properties and relations.

The main examples of natural classes used by philosophers are the chemical elements and biological species. Especially the chemical elements are often taken to be paradigm cases of natural kinds. Consider Saul Kripke's famous example of gold: the fact that gold is defined by its atomic number, entails that a thing is made of gold precisely when it is composed of atoms that have atomic number 79. It is because "the essence of a natural kind must be *necessary, explanatory, and purely qualitative*" (Sober, 1995, p.345; italics mine), that the atomic number 79 is said to provide the essence of the natural kind of gold. Whereas it is an accident that some lump of gold has a specific shape, it is supposed to be a *necessary truth* that golden things have atomic number 79. Moreover, the atomic number *explains* many properties of golden things. Finally, specifying the essence of gold does not involve a reference to shape, place or time; the atomic number supplies this general *qualitative specification* (Sober, 1995, p.345).

The case of biological species is more complicated, for it is by no means clear that biological species have essences. The favored view is that species are *individuals*. According to this view species are said to be populations that have organisms as parts rather than as members (Hull, 1978). Organisms belong to the same species, not by virtue of their similarity, but because of their genealogical relatedness. Despite their common descent, they do not thereby form a natural kind (Sober, 1995, p.346).

Apart from a certain agreement regarding chemical elements, philosophers tend to heartily disagree when it comes to give clear examples of natural kinds. Thus Van Brakel (1992, pp.243-244) lists a number of different interpretations: while Putnam includes multiple sclerosis, gold, horses, and electricity, Kripke and Quine mention colors, Hacking suggests social kinds, and Churchland does not hesitate to include mass, length, duration, charge, color, energy and momentum. According to Van Brakel, this disagreement is not only due to different opinions regarding the distinction between natural kinds and artificial kinds, but to more fundamentally different views regarding induction, prototypes, universals, scientific realism, meaning and reference. Van Brakel might also have added the problems of causation, explanation and natural law.

Apparently there are a great many conflicting theories about natural kinds. To obtain some clarity in the problem, *a number of fundamental questions must be answered. Some of the most important are: (a) What are natural kinds?, (b) What argument is there for believing in their existence?, (c) What use has science for the notion of natural kind?, (d) What are the demarcation criteria by virtue of which one can decide to what natural kind an object belongs?, (e) Is there a uniquely correct grouping of objects into natural kinds, or are there countless legitimate, objectively grounded ways of classifying the*

*objects of the world?, (f) What is the precise relationship between causation, natural laws, and natural kinds?*

But before pursuing Peirce's views on these questions, I will first consider two recent interpretations of Peirce's theory of natural kinds. It will appear that they are rather meager, and in many respects contradictory. Their main value for our discussion consists in the questions they raise.

## **2. Two Contemporary Interpretations of Peircean Natural Kinds**

To obtain a first impression of Peirce's view of natural kinds, and of the problems it involves, I will briefly examine recent interpretations of, successively, Susan Haack and Sandra Rosenthal.

Susan Haack is a contemporary philosopher who stresses the importance Peirce's concept of natural kind. According to Haack in her "Extreme Scholastic Realism: Its Relevance to Philosophy of Science Today" (1992), Peirce's 'extreme scholastic realism' entails that there are real laws of nature and real kinds, which are independent of our characterization of the world. Haack defends Peirce's 'scholastic realism' as a necessary presupposition of science, but she realizes that "a full and detailed defense of this claim would require a better understanding of what makes a class natural" (Haack, 1992, p.42). As Haack understands it, it is Peirce's view that without real laws and real kinds, no genuine science is possible. Without them there can be neither explanation, nor can there be prediction or induction (Haack, 1992, p.28).

According to Haack, Peirce's realism entails that the particular facts and events we observe are the expression of an underlying pattern of natural kinds and laws. While particular facts and events are concrete, the underlying pattern consists of so called *generals*. This pattern is real inasmuch as it is independent of how any individual inquirer thinks about it. As science - which is by its very nature co-operative - proceeds, this real pattern will eventually emerge: "Which generals are real is a matter which would only be finally settled in a hypothetical completed science" (Haack, 1992, p.29). If science were to continue long enough, it would yield true classifications and true laws of nature, that is to say, classifications and laws "from which the local and idiosyncratic, the unreal, had been eliminated" (Haack, 1992, p.32).

Haack describes Peircean natural kinds as "generals that would figure in the laws," (1992, p.29) or as "the kinds of things in the world which really do behave in a lawlike way" (1992, p.25). As examples of Peircean natural kinds she mentions horses, men and

stones. Since there are no laws of nature that are specific to stones, the suggestion is that Peirce has a very broad idea of law. Haack observes, almost casually, that genuine Peircean laws are basically *habits* (1992, p.28). Thus, stones as well as fundamental particles are natural kinds because they are the kind of things in the world that behave in a habit-like manner. Moreover, the habitual aspect of natural kinds is illustrated by the fact that, for instance, stones that do not actually fall are nevertheless capable of falling. For laws (habits) sustain *subjunctive conditionals*; they tell "not just what does happen when ..., but what would happen if ..." (Haack, 1992, p.28). We expect that if someone *would* for instance drop the stone he has in his hand, it *would* fall to the ground<sup>4</sup>.

Sandra Rosenthal gives another interpretation: dividing things into classes *partly* reflects our interests and conventional decisions, and partly the way things really are. Consequently, there are many, but not infinitely many, equally legitimate ways of dividing the world into natural classes:

Knowledge is abstractive and selective. A world, though concrete, is nonetheless selective in the sense that a world, as the concrete content denoted by a system of meanings, is a way in which the concreteness of reality can be delineated or "fixed." A system, once chosen, limits the alternatives possible within it, but *alternative systems may be possible*. (Rosenthal, 1994, pp.7-8; italics mine)

While our abstractive and selective process of knowledge imposes "cuts" upon the world, the decision regarding where these "cuts" occur is at least partially ours:

As Peirce notes, "Truly natural classes may, and undoubtedly often do, merge into one another inextricably" (CP 1.209), and thus boundary lines must be imposed, although the classes are natural. The continuity is there; where the "cut" is imposed is, in part, our decision. (Rosenthal, 1994, p.8)

Thus, whereas Rosenthal grants that there is an arbitrary element in establishing boundary lines between natural classes, she agrees with Haack in insisting that there is an objective ground to our natural classifications. Yet Rosenthal fails to tell us what such arbitrariness or convention entails. Does the absence of clear boundary lines entail that natural classes are not clearly defined? Or does it only mean that there are no clear demarcation criteria by virtue of which it can always be decided to which natural class an object belongs.

The two foregoing interpretations raise a fundamental question concerning the nature of Peirce's genuine or assumed *pluralism*: What, according to Peirce, is the origin of our dividing the world into classes? Perhaps the best way to introduce Peirce's own

(mature) view is to consider his distinction between kinds and classes. This will be the subject of the next section.

### 3. Kinds and Classes

A *kind* is an entity that corresponds to a set, the elements of which do not exist; a class is an entity corresponding to a set of which at least one element does exist. Thus, Peirce pointed out for instance that, while at his time, black tulips were non-existent, nevertheless some people may very well have thought of the possibility of growing black tulips. While the kind 'black tulip' was real, there was no natural class of existing black tulips. For the 'existence' of a natural class requires the existence of at least one specimen of that kind:

For the class is that *ens rationis* whose existence consists in the actualization of a definite kind. The actualization in an existing singular is one requisite to a class, being requisite to its *existence*: the character which it is required that every member of the class should have, is a second requisite to the class, being requisite to its *entity*. The two together make up its *ousia*, its rational *essence*. (MS 200:00172; 1908)

This is an interesting definition for a number of reasons. The first thing that draws attention is that a class is called an *ens rationis* or "being of reason." Peirce applied this term, borrowed from Duns Scotus, to entities that owe their reality to an operation of the intellect which Peirce called 'hypostatic abstraction.' Contrary to a real being or *ens in re extra animam*, such as a concrete, individual horse, an *ens rationis* is a 'thing' that depends for its existence upon reason or thought. Whereas real beings exist independently of thought, beings of reason depend on thought. But there are two kinds of *entia rationis*: those with a foundation in reality and those without such foundation. Examples of the former are genera and species (for instance, animal and horse); examples of the latter are mythical figures.

Thus, according to Duns Scotus, some universals exist only by virtue of the operation of the intellect, but cannot in any sense be said to be mere 'figments' of the mind. We can form universal concepts only because there is an objective correlate of them in the objects themselves: the "common nature." *Horseness*, for example, is the common nature of all the things called horses. But *horseness* is neither a universal nor a particular. Horseness is simply horseness. Universals are concepts formed by the mind, but there is an objective basis to them in the "common nature" of the concrete, existing things.



Peirce had borrowed Duns Scotus's view to the extent that sometimes our abstractions reflect objectively real general principles: "that wonderful operation of hypostatic abstraction by which we seem to create *entia rationis* that are, nevertheless, sometimes real..." (CP 4.549; 1906). He also had borrowed Duns Scotus's idea that real generals have the reality of *possibility*, not of actuality, albeit with a different twist. Peircean real generals are not common natures or forms, but final causes or laws.

That generals are possibles entails that, though they may be real, they do not exist. It may be noted that Peirce was somewhat careless when he spoke of the *existence* of natural classes, for classes cannot strictly be said to exist. The members of a class exist, but the class itself does not. Classes are *entia rationis*, which are generals, and generals are real but do not exist; they are possibilities. Only individual things exist, that is, only things that occupy a definite space during a certain time. Individuals can be pointed at; generals cannot.

We now know that *a class must meet at least two criteria: it must have at least one existing member, and each member of the class must have both a defining or D-character and an indefinite number of (D-related<sup>6</sup>) class characters. A kind differs from a class on two counts: it does not contain an existing member, and therefore it has only a D-character, which constitutes its essence.*

Peirce made a distinction between the epistemological essence and the metaphysical essence of a class:

The essence of anything is that thought which renders the thing possible. The *epistemological essence* is that thought which renders it possible to conceive of the things. The *metaphysical essence* is that intellectual structure which renders the being of the thing possible. (MS 200:00145; 1908)

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In natural classifications, the epistemological essence coincides with the metaphysical essence. According to Peirce, it is usually quite easy to determine the metaphysical essence of an artifact. The metaphysical essence of a lamp, for example, is that it can give light. And that is the purpose that brings lamps about. And the metaphysical essence of a stove is "that it is intended to diffuse warmth" (CP 6.336; c. 1909). But the question regarding the metaphysical essence of a natural object is much tougher.

A possible objection to this view is related to the fact that the essence of anything is by nature immutable. But, contrary to Platonic or Aristotelian essences, and to Scotistic

"common natures," which are all immutable, static forms, Peircean essences are of the nature of habit; and habits are, at least in principle, subject to evolution. Consequently, one of the most persistent objections against natural classes, namely that they presuppose an immutable essence, does not hold for Peirce's position.

Yet another difficulty regards the intellectual structure of essences. Peirce, however, did not restrict 'idea' or 'thought' to something that a person has in mind, or to a psychical act of thinking: "by an idea [...] I mean a principle such as may be set before the mind in thought" (MS 1344:11; 1902). Thus, the statistical distribution of a large number of things, say the molecules of a gas, expresses a statistical law, which is the 'idea' of the distribution (MS 1344:11; NEM IV: 65-66). Moreover, ideas are not only (a) general principles; they are also (b) in a sense purposive or quasi-purposive (end directed). Thus, the statistical law is a general idea, which is the final cause explaining the tendency toward the end state of the gas. *Ideas, therefore, have a certain inherent tendency to realize themselves.* An idea without efficacy cannot be an idea at all:

Imagine such an idea if you can! If it was communicated to you viva voce from another person, it must have had efficiency enough to get the particles of air vibrating. If you read it in a newspaper, it has set a monstrous printing press in motion. If you thought it out yourself, it had caused something to happen in your brain. And again, how do you know that you did have the idea when this discussion began a few lines above, unless it had efficiency to make some record on the brain? (CP 1.231; 1902)

We have seen so far that *the essence of a natural class is of the nature of an idea, and that ideas are, basically, final causes.* The defining idea of a set of objects is its epistemological essence. In natural classes, however, the defining idea or epistemological essence reflects the metaphysical essence. Because the defining idea of a natural class is a final cause, it seems appropriate to further explore the purposive nature of ideas or essences. This will be done in the next section.

#### **4. Classification According to Final Causes**

In his note "On Classification" of his Carnegie Application (1902), Peirce mentioned that he had been a student of Agassiz (in 1861), and that his study over the years had convinced him that Agassiz's system of classification was basically correct. Peirce formulated Agassiz's central insight as follows: "*every classification whatsoever, be it merely arranging words in alphabetical order, has reference to some purpose, or some tendency to an end*" (NEM IV: 65; 1902; italics mine). Thus, classifications are teleological instruments, or a way of handling things for some particular purpose. Now,

arranging words in alphabetical order is an example in which it is just *our* purpose that determines the classification. That is why the classification is artificial. In natural classifications, however, it is not our purpose but the purpose or quasi-purpose of the class itself that is at stake:

Every unitary classification has a leading idea or purpose, and is a natural classification in so far as that same purpose is determinative in the production of the objects classified. (NEM IV: 15; 1902)

Similarly,

Every classification has reference to a tendency toward an end. If this tendency is the tendency which has determined the class characters of the objects, it is a natural classification. (NEM IV: 65; 1902)

Thus, the defining idea of a natural class teleologically determines the class characters of the objects belonging to the class. I will call the class characters from now on *TDE-characters* (teleologically determined empirical characters). Though Peirce sometimes used the term "essential characters" (for example in CP 1.204), for reasons yet to be explained, his term "class characters" is more appropriate.

In order to precisely understand the relationship between defining character and TDE-characters, we must consider what is perhaps Peirce's most important text on natural classes, "A Detailed Classification of the Sciences"<sup>7</sup> (CP 1.203-283; 1902), where he worked out his view that ideas may be said to be teleologically causal. Properly speaking, the text deals with the problem of finding a classification scheme in which all the sciences find their hierarchical place. But since his anti-nominalistic stance implied that such a scheme is based on natural or real classes, Peirce thought it necessary first to explain what he meant by a natural class. In his attempt to give an exact description of a natural class, he concluded that the final cause is its defining characteristic. Accordingly, a *natural or real class* is defined as a class "*of which all the members owe their existence to a common final cause*" (CP 1.204), or as "*a class the existence of whose members is due to a common and peculiar final cause*" (CP 1.211).

The final cause is described in this context as "a common cause by virtue of which those things that have the essential characters of the class are enabled to exist" (CP 1.204). Thus, the defining idea must clearly be understood as causally active in the teleological sense. For instance when Peirce wrote:

[e]very class has its definition, which is an idea; but it is not every class where the *existence*, that is, the occurrence in the universe of its members is due to the active causality of the defining idea of the class. That circumstance makes the epithet *natural* particularly appropriate to the class... (CP

1.214; 1902),

the expression 'active causality' must be taken in this teleological sense. In view of this, we must again return to the general characteristics of Peirce's conception of final causation.

According to Peirce, final causes are general types that tend to realize themselves by determining processes of mechanical causation. They are not future events, but general potentialities. Final causes are basically habits: they ('habitually') direct processes toward an end state. Like human habits, habits of nature (laws of nature) are final causes because they display tendencies toward an end state. Final causes stand to laws of nature as genus to species. Moreover, habits are not static entities, for they may evolve in the course of time. Peirce called the possible evolution of final causes "developmental teleology."

In view of this, what does it mean to say that a natural class owes its existence to a common defining idea or final cause?

Do I mean that the idea calls new matter into existence? Certainly not. That would be pure intellectualism, which denies that blind force is an element of experience distinct from rationality, or logical force. [...] What I mean by the idea's conferring existence upon the individual members of the class is that it confers upon them the power of working out results in this world, that it confers upon them, that is to say, organic existence, or, in a word, life. (CP 1.220; 1902)

Ideas cannot call new matter into existence; they can only work if there is matter to work upon. The action of ideas is typical of final causation; the action of matter is typical of efficient causation. Blind force (efficient causation) and rationality (final causation) are two undeniable elements of our experience; one requires the other. But all this does not as yet explain that "the idea [confers] existence upon the individual members of the class," and that it gives them "organic existence" or "life." The reason must be that, if matter were not governed by ideas or final causes, there would not be any regularity in its behavior, which means that it would not even *exist*:

... if [matter] were to be deprived of the governance of ideas, and thus were to have no regularity in its action, [...] throughout no fraction of a second could it steadily act in any general way. For matter would thus not only not actually exist, but it would not even have potential existence, since potentiality is an affair of ideas. It would be just downright nothing. (CP 1.218; 1902)

Two examples may illustrate Peirce's intention. The first is taken from the realm of social phenomena: the natural class of socialists. A member of the community of socialists can only be a socialist by virtue of the idea of socialism. In Peirce's view, it is

the idea of socialism that creates the socialist, not the other way round. Ideas are not just creations of a particular mind, but on the contrary, they have a capacity, a power, to create or to find their vehicles: "it is the idea which will create its defenders, and render them powerful" (CP 1.217). Of course, the idea of socialism does not create the *person* who is the socialist. But, given an existent person, the idea of socialism may turn him into a socialist. The idea of socialism confers existence upon the individual members of the natural class of socialists. It gives them "organic existence" or "life" as *socialists*, that is to say, it makes them behave, at least to a certain extent, as socialists are supposed to do.

The second example is related to what might be called Peirce's (metaphysical) holism. Final causation is seen as that general principle in virtue of which a whole is more than the sum of its parts. The final cause is the intellectual structure or thought that ties the parts together, and gives them "organic existence" or "life." In Peirce's words: "Efficient causation is that kind of causation whereby the parts compose the whole; final causation is that kind of causation whereby the whole calls out its parts" (CP 1.220; 1902). Thus, it is the final cause that confers "organic existence" or "life" upon the individual members of a natural class. To illustrate this idea, Peirce gave the example of a dissected corpse. No one would consider a man's organs lying separately on a stretcher as a human being. The dissection might give some insight into what parts are required to make the human body work, that is, it would at the most display efficient causation. But it cannot explain the fact *why* a human body works: "The final causation, which is what characterizes the *definitum*, it leaves out of account" (CP 1.220). The final cause is that principle whereby a person is something more than just a body; it gives the body "organic existence" or "life."

In the next section I will examine the question whether knowledge of the common final cause is sufficient to determine the class (or classes) to which an object belongs, or whether we need other demarcation criteria.

## 5. Criteria of Demarcation

Because natural classes must be understood in terms of final causes, it is necessary first to consider some further characteristics of final causes before the question of demarcation criteria can be addressed.

Final causes are general. This generality involves both *vagueness* and *longitude*. Final causes are *general* because: (1) they are not spatio-temporal; (2) they determine only *some* but not all qualities of a class of objects (or of a process). For example, the idea of

building a house only determines that the end product will be a house, but not the specific form of the house. This lack of specificity is also called the *vagueness* of the final cause. Finally (3), final causes are general because they are not exhausted by any finite number of instantiations.

Moreover, final causes have a certain *longitude*. "By this I mean that while a certain ideal end state of things might most perfectly satisfy a desire, yet a situation somewhat different from that will be far better than nothing; and in general, when a state is not too far from the ideal state, the nearer it approaches that state the better" (CP 1.207; 1902). If, for some reason, we do not succeed in realizing our plan to write a book on causation, the second best thing would be to write some articles on the subject. Though there was a definite tendency toward an end state - a book on causation - external or internal elements kept our purpose from being fully realized. But a partial realization is much better than no realization at all.

A third element, next to their longitude and vagueness, is important to the determining cause of a natural class: although a final cause is in itself rather general and simple, it necessarily tends to a greater definiteness and complexity in the course of its realization (MS 1343:15; 1902). Such process usually involves conditions that are specific to every step, as well as 'decisions' regarding the further realization of the general purpose. In the course of building a house, all kinds of decisions must be made about shape, size, material etcetera, and each of these functions as a subsidiary purpose.

As a result of (a) the vagueness and (b) the longitude of final causes, and as a result of (c) the action of subsidiary final causes, *the class characters of the objects of a natural class (that is, the qualities determined by its final cause) cluster around certain average values*. Peirce illustrates this by an example borrowed from human experience: if we are to produce artificial light as economically as we can, we must consider all kinds of additional subsidiary purposes:

... the situation of things most satisfactory to one desire is almost never the situation most satisfactory to another. A brighter lamp than that I use would perhaps be more agreeable to my eyes; but it would be less so to my pocket, to my lungs, and to my sense of heat. Accordingly, a compromise is struck; and since all desires are somewhat vague, the result is that the objects actually will cluster about certain middling qualities, some being removed this way, some that way, and at greater and greater removes fewer and fewer objects will be so determined. *Thus, clustering distributions will characterize purposive classes.* (CP 1.207; 1902; italics mine)

This consideration is relevant to the issue of demarcation criteria. Peirce illustrated this with an example taken from archeology:

... Prof. Petrie found in the town of Naucratis some hundred and eighty standard weights. The calculus of probabilities applied to their weight-values proves that they were intended to conform to five different quasi-prototypes; but many of the weights, owing to the imperfection of their manufacture, have intermediate values, so that, as far as their governing intended character goes, it would be impossible to say to which standard any one such intermediate weight was intended to conform. (MS 1343:14; 1902)

This example reveals that *closely related classes are not, in general, separated by sharp lines of demarcation*. Some forms may just as well belong to one natural class as to another. In such cases, further investigation will usually show that there are other, more or less accidental characters, which may help in directing the forms to their true classes. Such characters, which are not specific to the class, may help us in ascertaining whether a given individual belongs to one class rather than the other: "unless we have some supplementary information we cannot tell which ones had one purpose and which the other" (CP 1.208). In the case of Petrie's example, further information might concern the shapes or the material of the stones, or some other "inessential" character (MS 1343:13-14).

The example of the weights also reveals that, though natural classes are characterized by a defining idea, which makes up their metaphysical essence, *there are no essential qualities that are both necessary and sufficient for belonging to a specific natural class*:

[We may want to] enumerate characters which are absolutely decisive as to whether a given individual does or does not belong to the class. But it may be, as our [example of the weights] shows, that this is altogether out of question; and the fact that two classes merge is no proof that they are not truly distinct classes. (CP 1.224; 1902)

Though there are no essential qualities by virtue of which it can unambiguously be ascertained to which natural class the weights with intermediate values belong, they nevertheless were intended to conform to one definite prototype. Each of these weights therefore belongs to one specific natural class. *Thus, things belong to the same natural class, not because of some essential qualities (which are Firsts according Peirce's categorial system), but because of a metaphysical essence, which is an idea or final cause (which is a Third). Class qualities therefore are not essential qualities.*

In the next section I will (a) consider Peirce's reasons for believing in the reality of natural classes, and (b) see what use science has for the notion of natural class.

## 6. Why Believe in Natural Classes?

It is a well-known fact that Peirce was greatly interested in medieval logic, especially in the works of the nominalist William of Ockham and the realist Duns Scotus. He thought that nominalism was the greatest source of the mistakes of modern philosophy (CP 6.348; c. 1909; CP 5.61; 1903). On the other hand, he thought the philosophy of Duns Scotus offered a good basis for a philosophy "which is best to harmonize with physical science" (CP 1.6; c. 1897). Whereas Ockham held that only individuals exist in the real world and that universals are mere names, Scotus insisted that the real world contains real universals or generals.

Peirce thought the nominalistic outlook of most modern philosophers was disastrous for the understanding of science. Nominalistic theories cannot explain that scientific theories are excellent tools for predicting future events. If we say, with Ockham, that all generalizations are subjective because they are based on the mind's capacity to form generalizations on the basis of perceived similarities, then our predictions miss any rational ground.

Peirce claimed to have proven the falsity of nominalism by a simple thought experiment (CP 5.93-101; 1903). In a Harvard classroom he held up a stone, and asked his audience whether they could predict that it would fall if he were to drop it. Of course, everyone said he could. Peirce argued that this entails that there are real laws of nature. For if laws were merely generalizations of past happenings, there would be no ground for our *expectation* that the stone would fall to the ground. Hence, he drew the "irrefragable" conclusion that "*general principles are really operative in nature*" (CP 5.101). Without general principles, which are final causes (laws), prediction, induction and explanation would be impossible (CP 5.100-101; also Haack 1992, 25-29). This view has the immediate implication that science must discover the true laws of nature, and therefore it must establish the kinds of things that are connected by those laws. In other words, science must point out natural classes.

Having obtained some understanding of Peircean natural classes and why they are necessary for our understanding of the world, I will now consider some important examples.

## 7. Examples of Natural Classes

First I will examine social classes and man-made objects, then the chemical elements, and finally the biological species.



## 7.1 EXAMPLES FROM THE REALM OF HUMAN EXPERIENCE: SOCIAL CLASSES AND MAN-MADE OBJECTS

The examples taken from the realm of human experience are usually easiest to classify, for in this domain it is often easy to discover by what purpose the objects of a class are determined. *Social classes* are examples of natural classes. Peirce mentions artists, practical men (business men), and scientists (CP 1.43; c. 1896). Each of these groups owes its identity to a specific purpose.

*The sciences* provide a second category of examples of Peircean natural classes that are closely related to the realm of human action. Indeed, Peirce developed most of his ideas about natural classes while working out a classification scheme of the sciences. All science is divided into three major branches, each of which has a different purpose. Within each branch, every science is classified according to its specific purpose or object. The classifications are hierarchical; the more general the object, the higher is its place in the hierarchy (CP 7.54; c.1902).<sup>8</sup>

The *man-made objects* are the third category of examples from the domain of human culture. A natural classification of man-made objects is a classification according to the purpose for which they were made. Accordingly, it can be said that stoves are different from lamps because they serve a different aim. Often man-made objects may also be classified according to subsidiary purposes.

To illustrate the precedence of form over matter in natural classifications, Peirce also gave an example from the domain of art: "... who would classify Rafael's paintings according to their predominant tinges instead of according to the nature of the composition, or the stages of Rafael's development?" (NEM IV: 322; c.1906) Only the form or structure of the compositions "renders the composition of the entire classified object rationally intelligible," not their matter. Apparently, knowledge of this structure provides insight into the purposes of the painter.

In the next two sections, we will see that there is an important similarity between classifications of works of art and classifications of chemical substances and biological classes; in all of these the final cause is displayed in some kind of structure.

## 7.2 THE CHEMICAL ELEMENTS

According to Peirce, the chemical elements differ in an important respect from all other natural classes: they are grouped not hierarchically, but periodically. Indeed, it was Peirce's view that there are two different kinds of systematic relationships between

different natural kinds. Whereas classes are normally grouped according to the Aristotelian hierarchical model, chemistry groups the elements periodically.

Dmitri Mendeleef had been the first person to arrange the elements according to their periodic similarities (1869). He found that if the elements are arranged approximately according to their increasing atomic weight, elements with similar physical and chemical properties occur at periodic intervals. His table proved to be a good guide to predicting chemical behavior, because it enabled us to determine what elements should be chemically similar to others. Not only do similar elements act alike, but their compounds may also act alike. For instance, NaCl has properties that are similar to those of both KCl and RbCl, because Na, K, and Rb are chemically alike.

Peirce, however, thought that the chemical elements owe their classification first and foremost to their valency. Indeed, natural classification is classification according to structure. But indecomposable chemical elements have no parts, and therefore no internal structure. Thus only their *external structure* must be taken into account. The *external structure* of an element was defined by Peirce as "the structure of its possible compounds" (CP 1.289; c.1908). In chemical elements, the basis of all external structure is valency:

In classification generally, it may fairly be said to be established, if it ever was doubted, that Form, in the sense of structure, is of far higher significance than Material. Valency is the basis of all external structure; and where indecomposability precludes internal structure [...] valency ought to be made the first consideration. (MS 292:34; 1906)

The view that elements are indecomposable has been refuted by 20th century physics. But in a way, the idea that elements do have an internal structure which determines their valency and behavior only confirms the consistency of Peirce's view that (a) natural classification is classification according to the final cause of the objects classified, and that (b) natural classification is classification according to structure. An external structure can hardly be a final cause of the objects classified, because it depends itself upon the existence of those objects. I will try to show that the internal structure can be such a final cause. First, however, I will show that internal structures can never be efficient causes.

That the internal structure cannot be an efficient cause appears from three facts: (a) whereas efficient causes are always concrete events or facts, internal structures are always *general*, for they are displayed in a multitude of events. Moreover, (b) because efficient causation is not directed toward an end in any way, it cannot explain that

atomic structures are responsible for the atom's *tendency* to behave in a regular way. Finally (c), whereas efficient causes only induce one or more lines of mechanical causation at one singular moment, the atomic structure continually induces events to conform to a definite pattern.

Because Peirce recognized only two types of causation - efficient causation and final causation - one is forced to conclude that inasmuch as the internal structure has some kind of causal influence, it must necessarily be teleological causation. Indeed, the internal structure has all the characteristics of final causation: (a) it is *general*, (b) it explains a *tendency* to behave in a regular way, and (c) it *continuously* induces processes of causation to conform to a definite pattern.

Thus, there is no reason for believing that Peirce would not have agreed with the insights of contemporary physics, according to which the external structure (or valency) of the chemical elements is determined by their internal structure. Therefore, according to my (21st century) interpretation of Peirce, it would be correct to say that the chemical elements are classified according to their internal or atomic structure.

Whereas the chemical elements are classified according to their atomic structure, the chemical *compounds* are classified according to their molecular structure. The classification of compounds is related to the fact that "... all samples of the same molecular structure react chemically in exactly the same way..." (CP 4.530; 1906)<sup>9</sup>. Analogous behavior of two compounds may indicate that the molecular structures are similar: "to take a simple example, chlorates KClO<sub>3</sub>, manganates KMnO<sub>3</sub>, bromates KBrO<sub>3</sub>, rutheniates KRuO<sub>3</sub>, iodates KIO<sub>3</sub>, behave chemically in strikingly analogous ways" (CP 1.223; 1902). Similarity of behavior indicates that there is a similarity of *molecular structure*, and a certain degree of similarity of molecular structure is a good reason for believing that we are dealing with the same natural class.<sup>10</sup>

To *summarize*: the chemical elements and the chemical compounds are classified, respectively, according to their atomic and their molecular structures. Because Peirce defined natural classifications as those that were made according to the final cause to which the members of the class owe their existence, it may be concluded that he thought the final cause of the atom or the molecule to be expressed in their internal structure. Inasmuch as these structures are expressed in individual entities, they are neither universal nor particular. But *qua* structures, they are universal. According to Peirce, chemical structures are final causes, because (a) they are general (and therefore possibilities, not actualities), and because (b) they explain the tendencies to behave according to definite patterns.

In the next subsection, we will see that in biological species the defining cause is also a chemical structure.

### 7.3 THE BIOLOGICAL SPECIES

Peirce tried to apply his findings about chemical classes to the biological classes. Thus he sought the metaphysical essence (final cause) of biological species in their internal structure, which he identified with the chemical constitution of their protoplasm. He felt confident that future research would show that the chemical constitution of the protoplasm is "*the sole determining cause of the forms of all animals and plants*" (CP 1.262; italics mine). This leads us to believe that if Peirce had known modern molecular biology, he would not have hesitated to consider the chemical structure of DNA as the metaphysical essence of biological species. DNA is precisely that part of the protoplasm that determines the essential morphological and functional characters of the biological species. Moreover, DNA is related to heredity. Thus, the cause of heredity is the chemical structure of DNA. And thus heredity must be related to final causality:

Heredity [...] is not a force but a law, although, like other laws, it doubtless avails itself of forces. But it is essentially that the offspring shall have a general resemblance to the parent, not that this general resemblance happens to result from this or that blind and particular action. No doubt, there is some blind efficient causation, but it is not that which constitutes the heredity, but, on the contrary, the general resemblance. (CP 1.215; 1902)

Thus, whereas classification is always classification according to form, in biological species, the form is the expression of the internal structure of DNA. Because DNA is the final cause of the biological class, it may also be said that classification in biological species is classification according to their final cause.

Peirce's approach was broadly Aristotelian inasmuch as natural classification always concerns the form of things (which is that by virtue of which things are what they are) and not their matter. This entails that Peirce *borrowed Aristotle's idea that the form is identical to the intrinsic final cause*. Therefore it was obvious that natural classification concerns the final causes of the things. From the natural sciences, Peirce had learned that the forms of chemical substances and biological species are the expression of a particular internal structure. He recognized that it was precisely this internal structure that was the final cause by virtue of which the members of the natural class exist.

To summarize: *whereas natural classes are not defined in terms of essential qualities, but in terms of a final cause (and therefore in terms of possible behavior), the final*

*cause may yet be expressed in some empirical internal structure. The chemical substances, the biological species, and art objects are Peirce's main examples of such natural classes. In these cases, similarity of internal structure indicates that objects belong to the same natural class.*

In the next section I will discuss Peirce's alleged pluralism regarding natural classes.

## **8. Was Peirce a Pluralist Regarding Natural Classes?**

I started my investigation by giving a survey of the interpretations of Peircean natural kinds that were given by, respectively, Haack (1992) and Rosenthal (1994). One of the most important questions raised by them, was: how pluralistic is Peirce's conception of natural class?

Before tackling this question, it may be helpful to distinguish two meanings of pluralism, which I borrow from John Dupré. *Pluralism* (1), as opposed to reductionism or eliminativism, refers to "the insistence on the equal reality and causal efficacy of objects both large and small" (Dupré 1993, p.7). This pluralism rejects *in principle* the reduction of macro-objects to subatomic particles. Eliminativism, in its most extreme form, would lead to the conclusion that there is only one natural class: the fundamental particles or processes of physics; micro-reductionism wants us to believe that causes at our normal, common sense level of awareness, are not real. I will call the pluralism that rejects eliminativism and micro-reductionism *causal pluralism*.

*Pluralism* (2), as opposed to classical essentialism, is "the claim that there are many equally legitimate ways of dividing the world into kinds." Our classifications are partly determined by our interests or purposes, and partly by "the recalcitrance of nature." This pluralism rejects classical essentialism because it denies the idea that things possess essential properties (which are both necessary and sufficient for a thing to belong to a natural class), independently of any context of inquiry. But it maintains that our activity is constrained by events beyond our control. Questions like, To which natural kind does this object belong? are always relative to a context, that is to say, "such questions can be answered only in relation to some specification of the goal underlying the intent to classify the object" (Dupré, 1993, pp.5-6). For this type I borrow Dupré's terms *promiscuous realism or radical ontological pluralism* (Dupré, 1993, pp.5-18).

From my description in section II, it appears that Rosenthal considers Peirce to be a promiscuous radical ontological pluralist, while Haack sees him as a causal pluralist. I

will briefly discuss these interpretations successively.

That Peirce was not a pluralist in the promiscuous sense (pluralism 2) appears clearly from the following statement in which he explicitly denies the possibility of more than one system of natural classification: "*there are artificial classifications in profusion, but [there is] only one natural classification*" (CP 1.275; 1902; italics mine). Though natural classes may partially overlap, there is but one natural system of classification. In this sense Peirce was a monist, not a pluralist.

The idea that objects belong to unambiguously discoverable natural classes, is intimately connected with Peirce's specific essentialism: what makes an object belong to a particular natural class is that it be teleologically caused by the D-character. The D-character unambiguously determines to what natural class an object belongs, *independently of any context of inquiry*. This interpretation is opposed to Rosenthal's, according to which the concept of a Peircean natural class is intimately related to a context of inquiry.

But, whereas Peirce was not a 'radical ontological pluralist', he most certainly defended a *causal pluralism*. There are many different levels of natural classes (physical entities, chemical entities, biological entities, sociological entities, artifacts, etcetera), and therefore also many different levels of causation. *Each class is characterized by a distinctive final cause, and the objects belonging to a natural class do so by virtue of their ability to exert a type of real causal influence.* Thus, it is the task of science to determine exactly what natural classes there are.

The idea that Peirce was a causal pluralist agrees with Haack's interpretation of Peircean natural kinds. As we have seen, Haack correctly pointed out that Peircean natural kinds are "the kinds of things in the world that really do behave in a lawlike way." She clearly acknowledged that Peirce thoroughly rejected any kind of micro-reductionism. Not only the fundamental processes of physics can have a real causal influence, but so can men, horses, and all kinds of other macro-objects.

In the next and last section, I will summarize the results obtained so far, and make an attempt to formulate a definition of Peircean natural classes that displays Peirce's mature position as fully as possible.

## 9. Conclusion

The problem of natural classes is important because it is inextricably linked to several philosophical notions, such as induction, universals, scientific realism, explanation,

causation, and natural law. In this paper, it was established that Peirce's mature discussion of natural classes was intimately related to his theory of causation.

Peirce's originality concerns at least two insights: first, he made clear that all classification, be it natural or artificial, must be related to some purpose. Secondly, *natural* classifications do not primarily involve our purposes, but the final causes of the classified things themselves.

Peirce adopted Duns Scotus's view of classes as *entia rationis*, owing their reality to an operation of the intellect. *Natural* classes are abstractions corresponding to objectively real general principles. They are, however, not pure abstractions (or 'Firsts'), but generals ('Thirds') embodied in concrete existing things ('Seconds'). Because these real generals are *possibilities*, not actualities, natural classes cannot strictly be said to exist, but are nevertheless real.

The reason why there must be natural classes is that without them, we would miss any rational ground for predicting future events. Science must discover the true laws of nature and the kinds of things that are connected by those laws.

Peirce defined a natural class as "a class the existence of whose members is due to a common and peculiar final cause" (CP 1.204) by virtue of which the members of the class behave in a regular way that is characteristic for that particular class. By thus defining natural classes in terms of final causation, the defining character comes to display the "metaphysical essence" of the class.

As a result of (a) the vagueness and (b) the longitude of final causes, and (c) the action of subsidiary final causes, the class qualities of the objects of a natural class (the qualities determined by its final cause) cluster around certain average values. Accordingly, closely related classes are not, in general, separated by sharp lines of demarcation.

Things do not belong to the same natural class because of some common essential qualities (Firstness), but on account of a similarity in behavior; they conform to the same final cause or law. The locus of universality is final causation, habit, or law (Thirdness). The final cause may be expressed in some empirical internal structure. The chemical substances, the biological species, and art objects are Peirce's main examples of such natural classes. In these cases, similarity of internal structure indicates that objects belong to the same natural class.

On the basis of this reconstruction I propose to give the following characterization of Peircean natural classes: *Things belong to the same natural class, not because of certain*

*essential qualities (Firsts), but on account of a metaphysical essence which is a final cause (or Third). Thus, Peircean natural classes are characterized by (a) a defining character, which is a final cause and (b) a number of class characters or teleologically determined empirical characters (TDE-characters); moreover, (c) the TDE-characters of the objects of a natural class cluster around certain average values; (d) the TDE-characters are not essential characters because they are neither necessary nor sufficient conditions for making something to be a member of the class; (e) there are no clear boundary lines between closely related natural classes; (f) natural classes, though very real, are not existing entities; their reality is of the nature of possibility, not of actuality.*

In respect of the contemporary discussion, Peirce's view involves a rejection of micro-reductionism and eliminativism as viable theories of natural classes; Peirce's theory, which I have labeled a *causal pluralism* (because it insists on the equal reality and causal efficacy of both micro- and macro-objects), does not reduce our common sense, daily experience in favor of some abstract, physical principles. Though the scientific method may yield knowledge of natural classes, there are many obvious examples that are derived from common, human experience.

## References

- Dupré, J. (1993). *The Disorder of Things. Metaphysical Foundations of The Disunity of Science*. Cambridge, Mass. and London: Harvard University Press.
- Engel-Tiercelin, C. (1992). Vagueness and the Unity of C.S. Peirce's Realism. *Transactions of The Charles S. Peirce Society* 28(1), 51-82.
- Haack, S. (1992). Extreme Scholastic Realism: Its relevance to Philosophy of Science Today. *Transactions of The Charles S. Peirce Society* 28(1), 19-50.
- Hull, D. (1978). A Matter of Individuality. *Philosophy of Science* 45, 335-60.
- Hulswit, M. (1996). Teleology: A Peircean Critique of Ernst Mayr's Theory. *Transactions of The Charles S. Peirce Society* 32(2), 182-214.
- Hulswit, M. (1997). Peirce's Teleological Approach to Natural Classes. *Transactions of The Charles S. Peirce Society* 33(3), 722-772.
- Hulswit, M. (2000). C.S. Peirce on Causality and Causation. In this encyclopedia.
- Hulswit, M. (2001). Teleology. In this encyclopedia.
- Hulswit, M. & Sowa, J. F. (Forthcoming). *Causality and Causation in Philosophy*,



*Physics and Artificial Intelligence.*

- Johnson, D.M. (1990). Can Abstractions be Causes?. *Biology and Philosophy* 5, 63-77.
- Kent, B. (1987). *Charles S. Peirce. Logic and the Classification of the Sciences*. Kingston and Montreal: McGill-Queen's University Press.
- Levinson, J. (1991). Attribute. In Burkhardt, H. & Smith, B. (Eds), *Handbook of Metaphysics and Ontology* (pp.65-70). München: Philosophia.
- Pape, H. (1993). Final Causality in Peirce's Semiotics and his Classification of the Sciences. *Transactions of The Charles S. Peirce Society* 29, 581-607.
- Quine, W. (1969). *Natural Kinds*. In *his Ontological relativity and Other Essays*. New York: Columbia University Press.
- Rosenthal, S. (1994). *Charles Peirce's Pragmatic Pluralism*. Albany: State University of New York Press.
- Sober, E. (1995). Natural Kinds. In Kim, J. & Sosa, E. (Eds.), *A Companion to Metaphysics*. Oxford and Cambridge, Mass.: Blackwell. 345-46.
- Van Brakel, J. (1992). Natural Kinds and Manifest Forms of Life. *Dialectica* 46, 243-261.

**Endnotes**

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1. This article is an excerpt of my 1997 article on natural classes. ↵
  2. Hacking 1991. ↵
  3. For an extensive discussion of the evolution of Peirce's conception of natural class, see Hulswit (1997). ↵
  4. I think, however, that Haack makes a mistake by mentioning stones as examples of Peircean natural kinds. For, there are no final causes or laws that are specific to stones. The law of gravity is a final cause that makes all things of a certain density approach the center of the earth, not just stones. ↵
  5. The relationship of the class characters to the defining character will be explained in the next section. ↵
  6. For Peirce's Century Dictionary Definition of 'essence,' see W5: 417; 1886. ↵
  7. The most important part of this text was also published in EP II, section 9 (pp. 115-132), entitled "On Science and Natural Classes." ↵

8. For explanations of Peirce's Natural Classifications of the Sciences, see Kent (1987) and Pape (1989, 1993). Pape explicitly deals with the relationship between final causation and natural classifications. ←
9. This point is further explained in Hulswit (1997, 756-7). ←
10. The question regarding the criteria of 'sufficient similarity' is empirical in nature; it has to be answered by chemistry. In contemporary chemistry, analogous behavior points to analogous molecular structure even when there is no similarity in molecular formulas. In those cases, the chemist will try to rewrite the formulas in an analogous form. For example, the molecular formulas  $\text{CH}_4\text{O}$  (methanol) and  $\text{C}_2\text{H}_6\text{O}$  (ethanol) are rewritten as the structure formulas  $\text{CH}_3\text{OH}$  and  $\text{C}_2\text{H}_5\text{OH}$ . ←