Formal Ontology: Lecture One

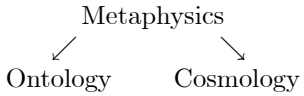
Prof. Nino B. Cocchiarella

Formal Ontology

1. Introduction

Formal ontology is a discipline in which the formal methods of mathematical logic are combined with the intuitive, philosophical analyses and principles of ontology. Formal ontology brings together the clarity, precision and methodology of logical analysis on the one hand with the philosophical significance of ontological analysis on the other. Father I.M. Bochenski, for example, has said of ontology that it is a "sort of prolegomenon to logic" in that whereas ontology is an intuitive, informal inquiry into the categorial aspects of reality in general, "logic is the systematic formal, axiomatic elaboration of this material predigested by ontology."

Ontology, which is the study of being *qua* being (Aristotle, Meta. 1031a), has been a principal part of metaphysics since ancient times. Metaphysics itself has usually been divided into ontology and cosmology:



where

- ontology = the study of being as such, and
- cosmology = the study of the physical universe at large; i.e., space, time, nature and causality.

Implicit in this division is a distinction between methodologies. In particular,

(1) the methodology of cosmology is based on:

   (a) the analysis of such categories as space, time, matter, and causality, and where

   (b) the goal is to discover by observation and experiment the laws connecting these categories and their constituents with one another, including in particular the natural kinds of things (beings) in nature.

(2) The methodology of ontology, on the other hand, is based on:

   (a) the analysis of ontological categories, i.e., categories of being, where
   (b) the goal is to discover the laws connecting these categories and the entities in them with one another.

The particular sciences that are part of cosmology and that are concerned with particular natural kinds of beings may be prior to ontology in the order of discovery — and even in the order of conception. But as an analysis of ontological categories, ontology is a science that contains the ontological forms, if not the specific content, of the ideas and principles of the different natural sciences, and in that sense it is a science that is prior to all of the others.

Similarly, logic contains the logical forms, but not the specific material content, of the different scientific theories that make up the content of our knowledge of nature, and in that sense logic is a science prior to all others.

Thus, when the logico-grammatical forms and principles of logic are formulated with the idea of representing the different categories of being and the laws connecting them, i.e., when ontological and logical categories are combined in a unified framework, then the result, which is what we mean by formal ontology, is a comprehensive deductive science that is prior to all others in both logical and ontological structure.

2. Formal Ontology as a Characteristica Universalis

A system of logic can be constructed under two quite different aspects.

On the one hand, it can be developed as a formal calculus and studied independently of whatever content it might be used to represent. Such a formal system in that case is only a *calculus ratiocinator*.

On the other hand, a system of logic can be constructed somewhat along the lines of what Leibniz called a *characteristica universalis*.

Note: A *characteristica universalis* was to serve three main purposes.

1. The first was that of an international auxiliary language that would enable the people of different countries to speak and communicate with one another. Apparently, because Latin was no longer a "living" language and new trade routes were opening up to lands with many different local languages, the possibility of such an international auxiliary language was widely considered and discussed in the 17th and 18th centuries. There were in fact a number of proposals and partial constructions of such a language during that period, but none of them succeeded in being used by more than a handful of people.

Esperanto was constructed at the end of the 19th century and came to be used by as many as eight million people. At present, the question of whether even Esperanto will succeed in fulfilling that purpose is very much in doubt.

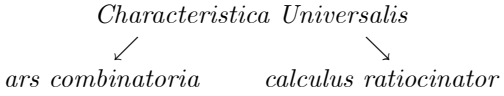
Ido is another such language, which was constructed in 1907 by a committee of linguists, but it has not been used since about 1930. Notwithstanding its visionary goal, the idea of an international auxiliary language is not the purpose of a formal ontology.

The second and third purposes Leibniz set for his *characteristica universalis* are what distinguish it from its precursors and give his program its formal or logistic methodology.

2. The second purpose is that the universal character is to be based upon an *ars combinatoria*, i.e., an ideography or system of symbolization, that would enable us to provide a logical analysis of all of the actual and possible concepts that might arise in science.

An *ars combinatoria* would contain both a theory of logical form, i.e., a theory of all the possible forms that a meaningful expression might have in such a language, and a theory of definitions, i.e., a theory of the operations whereby one could construct new concepts on the basis of already given concepts.

3. The third purpose was that the universal character must contain a *calculus ratiocinator*, and in particular a complete system of deduction and valid argument forms, by which, through a study of the consequences, or implications, of what was already known, it could serve as an instrument of knowledge. These two purposes are central to the notion of a formal ontology.



With a universal character that could serve these purposes, Leibniz thought that a unified encyclopedia of science could be developed about the world, and that, by its means, the universal character would then also amount to a *characteristica realis*, i.e., a representational system that would enable us to see into the inner nature of things and guide our reasoning about reality like an Ariadne's thread.

In other words, in Leibniz's program for a *characteristica universalis* we have an attempt to encompass the relationships between

language and reality,
language and thought, and
language and knowledge,

especially as represented in terms of scientific theories. In two fundamental parts of the program, namely, the construction of an *ars combinatoria* and a *calculus ratiocinator*, we also have critical components that are necessary for a formal ontology.

The idea of a *characteristica realis*, i.e., a unified encyclopedia of science, is also important for a formal ontology. A formal ontology must be such that in principle every scientific theory can be formulated within it. This will be possible only by adding to the general framework of a formal ontology nonlogical constants, axioms, and meaning postulates that represent the basic concepts and principles of a given science.

In addition, though this is not required from a strictly scientific point of view, a formal ontology should be sufficiently structured so that with the addition of suitable nonlogical constants and meaning postulates a logical analysis of every meaningful declarative sentence of natural language can be given within

it. A formal ontology should be able to contain a semantics for natural language that captures the ontology of our commonsense framework. In that case such a logistic system can be taken not only as a characteristica realis, but also as a *lingua philosophica*.

Of course, prior to the introduction of such constants and postulates, whether for science or natural language, a formal ontology is essentially just a shell containing the logico-ontological categorial forms and principles of science and of our commonsense understanding of the world.

3. Commonsense Versus Scientific Understanding

Our commonsense understanding of the world is sometimes said to be in conflict with our scientific understanding, which, on this view, is taken as providing the only proper criteria for truth.

It is also claimed that the construction of a logistic system as the basis of a unified encyclopedia of science can represent only our scientific understanding, because by its very nature such a system can operate only with concepts and principles that have sharp and exact boundaries, such as the concepts and principles we strive to formulate in our scientific theories.

The same cannot be said of the concepts and principles of our commonsense understanding. The concepts underlying our use of natural language do not have sharp boundaries, and do not require the kind of precision of thought that is the goal of scientific knowledge, which alone can provide an adequate criterion of truth.

Many of the words and phrases of natural language by which we express our commonsense understanding are vague or ambiguous, and as such are unsuitable, some would say, for the kind of logical representation involved in our methodology. Gottlob Frege expressed this view in comparing the difference between his logical system and ordinary language with that between a microscope and the human eye. Even though the eye is superior to the microscope, Frege observed, "because of the range of its possible uses and the versatility with which it can adapt to the most diverse circumstances," nevertheless, "as soon as scientific goals demand great sharpness of resolution, the eye proves to be insufficient".

Now it is true that only our scientific understanding can provide an adequate criterion of truth about the natural world, but that does not mean that our commonsense understanding gives a false picture of the world, or a picture that, for the purposes of knowledge, ought to be eliminated.

No doubt, many of our commonsense beliefs and concepts about the natural world have been revised and corrected over the millennia, and probably many will be revised or corrected in times to come. The concept *water*, for example, has been replaced by the concept H_2O in the scientific context of the atomic theory of matter, where the concept H_2O is systematically related to the concept H for hydrogen and the concept O for oxygen. This does not mean that the concept *water* is somehow misleading and that the role it plays in our commonsense framework is to be eliminated. Indeed, not only has the concept continued to be functionally useful in everyday contexts, but it also continues to serve in scientific contexts as well.

It is not just our commonsense concepts that are important for an understanding of the world, however, but also how we structure our thought in our commonsense framework as well. How we reason and argue in this framework are preconditions of scientific knowledge and theorizing.

Scientific understanding depends, in other words, both conceptually and pragmatically upon our commonsense understanding, including the way the world is categorially structured, and the way we reason in terms of that structure. In this regard, the representation of our scientific knowledge involves more

than the representation of a large number of facts or beliefs about the objects in a given domain of scientific inquiry, regardless of whether those facts or beliefs are in conflict with what is believed by common sense. In particular, it involves the criteria for valid reasoning that we bring to bear on our commonsense arguments, and the way those arguments are structured in terms of the categorial structure of our commonsense understanding.

It is precisely the formal representation of the categorial structure of our commonsense framework, as well as the criteria for valid reasoning within that framework that is one of the goals of formal ontology.

The arguments that we find in natural language can be evaluated as valid or invalid only with respect to a logical theory, and in particular one that provides an adequate formal representation of the basic categories of natural language and our commonsense framework. The adequacy of such a logical theory is judged on the basis of how well it agrees with our commonsense intuition of which arguments are valid and which invalid.

We are not claiming that the ontology of our commonsense framework, based as it is on perceptible objects and their qualitative features, is also fundamental to science. Our commonsense framework is prior in the order of conception, but it is not necessarily prior in the order of being. That is an issue that, among other things, involves the mind-body problem and the way consciousness and the mind are described in terms of a formal ontology as both a *characteristica realis* and an intensional logic.

In such a formal ontology, the mind-body problem divides into at least two different sub-problems:

> (a) the study of the relations between physiological states and certain states of consciousness, and
> (b) the study of the emergence of consciousness, meaning, and the self and its relation to its body.

The first problem, the study of the relations between physiological states and certain states of consciousness, is a problem that is studied by experts in neuropsychology and other neurosciences, and as such it is a proper part of a characteristica realis.

The second problem, i.e., the problem of the emergence of consciousness, meaning and the self can be solved, on the other hand, only by taking natural language, intentionality, and our commonsense framework into account, which means the inclusion within formal ontology of an intensional logic.

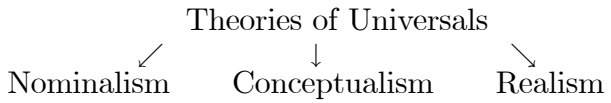
Such an intensional logic must be able to represent our commonsense understanding and the contents of our beliefs and theories, including the fables and stories that are part of our culture and of our individual mental spaces. It must also provide an account of the ontology of fictional objects in terms of the contents of our concepts, and it should contain a logic of our various cognitive modalities, including a logic of knowledge and belief.

4. The Nexus of Predication

Leibniz's own ideography for his *characteristica universalis* was algebraic and it did not deal with the central feature of either a conceptual or ontological theory of logical form—namely, the nexus of predication.

How predication is represented in a formal ontology depends on different theories of universals, where by a universal we mean that which can be predicated of things (Aristotle, *De Int.* 17a39).

Traditionally, there have been three main theories of universals: nominalism, conceptualism, and realism.



The difference between these three types of theories depends on what each takes to be predicable of things. In this regard, we will distinguish between:

- predication in language (nominalism),
- predication in thought (conceptualism), and
- predication in reality (realism).

All three types of theories agree that there is predication in language, in particular that predicates can be predicated of things in the sense of being true or false of them.

Nominalism goes further in maintaining that only predicates can be predicated of things, that is, that there are no universals other than the predicate expressions of some language or other.

> *Nominalism:* only predicates are true or false of things; there are no universals that predicates stand for.

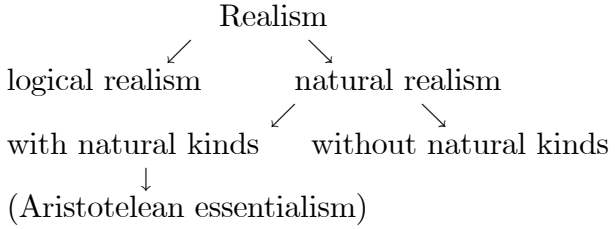
Conceptualism opposes nominalism and maintains that predicates can be true or false of things only because they stand for concepts, where predicable concepts are the cognitive capacities—intelligible universals—that underlie predication in thought and our rule-following abilities in the use of the predicate expressions of natural language.

> *Conceptualism:* predication in thought underlies predication in language; predicable concepts are rule-following cognitive capacities regarding the use of predicate expressions.

Realism also opposes nominalism in maintaining that there are real universals, namely, properties and relations, that are the basis of predication in reality.

Realism: there are real properties and relations that are the basis of predication in reality.

There are two distinct types of realism that should be distinguished; namely, various forms of logical realism as modern forms of Platonism, and various forms of natural realism, with at least one being a modern form of Aristotle's theory of natural kinds.



Both forms of realism are compatible with conceptualism, but natural realism, especially Aristotle's theory of natural kinds, is closely connected with the kind of conceptualism we will describe in later lectures.

As a formal ontology, natural realism presupposes some form of conceptualism in order even to be articulated; and the kind of conceptualism that we will defend depends in turn on some form of natural realism as its causal basis. How conceptualism is compatible with logical realism, and how natural realism and a certain modern form of conceptualism are intimately connected are issues we will take up later in our discussion of what we call conceptual realism.

Corresponding to these different theories of universals, there are different formal ontologies containing different formal theories of predication, each representing some variant of one of these theories of universals. That means that there will be different comprehensive systems of formal ontology.

Each formal ontology will view itself internally as the final arbiter of all logical and ontological distinctions. But different formal ontologies can be compared and studied in a framework such as set theory.

The study of the consistency, adequacy, and relative strength of different formal ontologies, as well as the subtheories they might contain, is a subject I call *comparative formal ontology*.

A comprehensive system of formal ontology will in general have different branches or subsystems within which different ontological tasks can be carried out. One such branch, for example, might be a theory of parts and wholes, which would include a relation of foundation regarding how some parts are founded or dependent upon other parts or wholes. There might also be a theory of extensive and intensive magnitudes, i.e., a measurement theory, and a theory of continuants and of the existence of the latter in space and time.

5. Univocal Versus Multiple Senses of Being

One important distinction between different systems of formal ontology is whether *being* is taken as univocal or as having different senses.

A formal ontology will have different senses when different types or categories of expressions are understood as representing different categories of being, in which case there will also be different types of variables bound by quantifiers having the entities of those different categories as their values. Such is the case in both conceptualism and some variants of realism.

Where being is univocal, on the other hand, i.e., where there is just one ontological category of being (being *simpliciter*), only one type of quantifiable variable will have semantic significance. This does not mean that there are no different "kinds", or sorts, of being, but only that in such a framework being is a genus, and that the different kinds of being all fall within that genus.

In a formal ontology for *nominalism*, for example, there will be no ontological category corresponding to any grammatical category other than that of singular terms (logical subjects).

In particular, in nominalism, there will be no ontological category or mode of being corresponding to the grammatical category of predicate expressions. Only objectual variables, i.e., the category of variables having singular terms as their substituents, will have semantic-ontological significance in such a formal ontology. Predicate variables, and quantifiers binding such, if admitted at all, must then be given only a substitutional and not a semantical interpretation, which means that certain constraints must be imposed on the logic of the predicate quantifiers in such a formal ontology.

Most nominalists in fact eschew even such a substitutional interpretation of predicate quantifiers and describe their ontology only in terms of first-order logic where there is but one type of bindable variable, i.e., where, as in Willard Quine's phrase,

to be = to be the value of a bound objectual variable.

Some contemporary nominalists, e.g., Nelson Goodman, take abstract objects, e.g., qualia, as well as concrete objects to fall under their univocal sense of being. This means that although there is but one ontological category of being in such an ontology, there may still be different "kinds" of being. In such a system being is a genus, which is not the same as there being multiple senses of being.

Nominalism: being is univocal; i.e., being is a genus.

Being is also univocal in some forms of realism. This was the case, for example, in the ultra-realism of certain early scholastic philosophers such as John Scottus Eriugena and Remigius of Auxerre for whom the realm of being is the realm only of universals.

Being is also univocal in certain contemporary forms of *logical realism*, where properties, relations, concrete objects, and perhaps states of affairs as well, are different "kinds," as opposed to, different categories of being.

A formal ontology for such realists is developed today much as it is in nominalism, namely, as an axiomatic first-order logic with primitive predicates standing for certain basic ontological notions. Indeed, except perhaps for the distinction between an intensional and an extensional logic, there is little to distinguish realists who take being to be univocal from such nominalists as Goodman who include abstract objects as values of their objectual variables and who describe such objects axiomatically (e.g., in terms of a mereological relation of *overlap*, or of *part-to-whole*).

This is particularly true of those realists who, in effect, replace the extensional membership relation of an axiomatic set theory by an intensional relation of *exemplification*, and, dropping the axiom of extensionality, call the result a theory of properties.

Logical realism: being is univocal (i.e., being is a genus) if predication is based on a relation of:

(a) membership (set theory), or

(b) exemplification (in first-order logic), or

(c) part-to-whole (mereology).

Formal ontology, in other words, for both the nominalist and those realists who take being to be univocal and who have abstract as well as concrete objects as values of objectual variables, i.e., for whom being is a genus, is really no different from an applied theory of first-order logic. That is, it is no different from a first-order logic to which primitive "nonlogical" (descriptive?) constants and axioms are added and taken as describing certain basic ontological notions.

The dividing line in such a formal ontology between the logical and the nonlogical, or between pure formal ontology and its applications, has become somewhat blurred, if not entirely arbitrary.