

Ms. February 2001. Partee, Barbara H. Montague grammar. To appear in Neil J. Smelser and Paul B. Baltes, eds. *International Encyclopedia of the Social and Behavioral Sciences*. Oxford: Pergamon/ Elsevier Science.

### 3.9.19 Montague Grammar

Montague grammar is a theory of semantics, and of the relation of semantics to syntax, originally developed by the logician Richard Montague (1930-1971) and subsequently modified and extended by linguists, philosophers, and logicians. Classical Montague grammar had its roots in logic and the philosophy of language; it quickly became influential in linguistics, and linguists have played a large role in its evolution into contemporary formal semantics. The most constant features of the theory over time have been the focus on truth-conditional aspects of meaning, a model-theoretic conception of semantics, and the methodological centrality of the Principle of Compositionality: “The meaning of a whole is a function of the meanings of its parts and their mode of syntactic combination.” This article presents a brief outline of the origins of Montague grammar, summarizes the basic principles of the classical form of the theory, and sketches some more recent developments and interesting controversies.

#### 1. Montague grammar in historical context.

Richard Montague was a logician and philosopher of language whose seminal works (Montague 1970a; 1970b; 1973) founded the theory known after his death as Montague grammar. Montague had been a student of Alfred Tarski, one of the pioneers, with Frege and Carnap, in the model-theoretic semantics of logic. As a logician, Montague built on that tradition and developed an intensional logic with a rich type theory and a possible-worlds model-theoretic semantics, incorporating certain aspects of pragmatics, including the treatment of “indexical” words and morphemes like “I, you” and the present tense. In the late 1960’s, Montague turned to the project of “universal grammar”, which for him meant a theory of syntax and semantics encompassing both formal and natural languages.

Montague’s idea that a natural language like English could be formally described using logicians’ techniques was a radical one at the time. Most logicians believed that natural languages were not amenable to precise formalization, while most linguists doubted the appropriateness of logicians’ approaches to the domain of natural language semantics.

At the time of Montague’s work, Chomskian generative syntax was well established, and linguists were developing and debating approaches to semantics to fit into the enterprise of generative grammar, and questions of the relation of semantics to syntax had become central. The “linguistic wars” between generative semantics (Lakoff, Ross, McCawley, Postal) and interpretive semantics (Jackendoff, with the support of Chomsky) were in full swing. In the earliest introductions of Montague’s work to linguists, including (Partee 1973; 1975) and Thomason’s extended introduction to (Montague 1974), it was argued that Montague’s work offered the potential to accommodate some of the best aspects of both of the warring approaches, with some added advantages of its own.

Early attempts to integrate Montague grammar with transformational grammar (Partee 1975) faced two kinds of obstacles. On the one hand, Montague’s own syntax was in quite unconstrained and in practice combined some systematic use of categorial grammar with some *ad hoc* extensions; it clearly needed overhaul for serious linguistic work. On the other hand, transformational grammars of the period could not be directly coupled with Montague’s semantics because many of the posited transformations did not have uniform semantic effects,

as Montague's theory required. Much of the subsequent diversity in approaches to formal semantics that incorporate features of Montague's theory reflect different responses to those problems.

Montague's work, and related work by the philosophers Michael Bennett, M.J. Cresswell, David Lewis, Terence Parsons, Robert Stalnaker, Richmond Thomason, and others, and by linguists such as Emmon Bach, Robin Cooper, David Dowty, E.L. Keenan, Lauri Karttunen, Barbara H. Partee, gained influence during the 1970's. Formal semantics became one mainstream approach to semantics within linguistics by the 1980's; major textbooks include (Chierchia and McConnell-Ginet 1990; Dowty et al. 1981; Gamut 1991; Heim and Kratzer 1998); a good "lay introduction" is (Bach 1989). See also (Lewis 1970; Partee 1976; Partee 1997).

## **2. The theory and the substance of Montague grammar. Central principles.**

The paper of Montague's that had the most impact on linguists and on the subsequent development of formal semantics was "PTQ" (Montague 1973): short, but densely packed. "Montague Grammar" has often meant what Montague did in the fragment in PTQ and the extensions of PTQ by linguists and philosophers in the 1970's and 80's with greater or lesser innovations. But it is the broader algebraic framework of "UG" ("Universal Grammar", Montague 1970b) that constitutes Montague's theory of grammar. This section therefore begins with the basic principles laid out in UG, concentrating on the principle of compositionality, then continues with model-theoretic interpretation, type theory, and the "method of fragments", including some of the key features of the fragment in PTQ.

### *2.1. Universal Grammar: Syntax and Semantics as algebras, compositionality as homomorphism*

Montague's "Universal Grammar" (Montague 1970b) contains the most general statement of Montague's formal framework for the description of language. The central idea is that a grammar should be able to be cast in the following form: the syntax is an algebra, the semantics is an algebra, and there is a homomorphism mapping elements of the syntactic algebra onto elements of the semantic algebra. This very general definition leaves a great deal of freedom as to nature of these algebras. In a logical language, the elements of the syntactic algebra can be the well-formed expressions. But for a natural language, ambiguity makes that impossible, since the homomorphism requirement means that each element of the syntactic algebra must be mapped onto a unique element of the semantic algebra. So for a natural language, the elements of the syntactic algebra are usually taken to be expressions together with disambiguating structural descriptions, typically trees of some sort.

The nature of the elements of the semantic algebra is also open to variation. They may be model-theoretic constructs, as in Montague's own work, Heim's "file change potentials", the extensional domains of first-order logic, hypothesized concepts, expressions in a "language of thought", or anything else. What is constrained is not the "substance" of the semantics but properties of its structure and its relation to syntax.

It is the homomorphism requirement, which formalizes the compositionality requirement, that provides one of the most important constraints on UG in Montague's sense. The compositionality requirement, stated in the introductory paragraph, is almost uncontroversial when stated informally. But formalizing it requires an explicit theory of syntax (to specify what is meant by *parts* and *syntactic combination*), an explicit theory of semantics (*meanings*), and an explicit theory of the mapping from one to the other (*is a function of*).

Logicians typically specify the syntax of a formal language as a recursive definition; in that case the requirement of compositionality as homomorphism can be satisfied by giving the semantics in the form of a parallel recursive definition. The “derivation trees” that correspond to the steps in applying a recursive definition become the elements of the syntactic and semantic algebras, and the homomorphism requirement says that each syntactic derivation must be mapped onto a unique semantic derivation.

The simplest linguistic examples take the elements of the syntactic algebra to be (sub)trees generated by a context-free grammar, and semantic interpretation to specify how the interpretation of a given subtree is computed from the interpretations of its immediate “daughter” subtrees. Formal semanticists often work either with a “monostratal grammar”, i.e. a grammar with a single level of syntax and no transformations (GPSG, HPSG, Categorical Grammar), or with a specified level of syntactic representation such as “LF” in Chomskyan syntax.

### 2.2. *Model theory; direct and indirect interpretation*

Montague’s “Universal Grammar” presents formal frameworks for both “direct” and “indirect” semantic interpretation. The fragment of (Montague 1970a) illustrates the direct model-theoretic interpretation of natural language syntactic rules; direct model-theoretic interpretation of natural language is also found in some of the work of Cresswell, von Stechow, and Kratzer. “Indirect” interpretation, illustrated in UG and PTQ and in the works of many others, proceeds via translation into an intermediate language, such as Montague’s Intensional Logic. The translation process must then itself be compositional, and the intermediate language is in principle dispensable. Montague viewed the intermediate language as offering increased perspicuity in presentation; linguists tend to want evidence for the psychological reality of some level of “semantic representation”, but strong evidence for or against such levels is still lacking

### 2.3. *Type theory and intensionality*

Linguists before Montague had tried unsuccessfully to give a compositional semantics to natural language syntax, but their efforts were stymied in part by the mismatch between natural language syntax and first-order logic. The richness of Montague’s logic, with several crucial features previously unfamiliar to linguists, was a crucial factor in the possibility of giving a compositional semantic interpretation to independently motivated syntactic structure.

Montague’s use of a richly typed logic with lambda-abstraction made it possible for the first time to interpret noun phrases (NPs) like *every man, the man, a man* uniformly as semantic constituents, something impossible with the tools of first-order logic. More generally, Montague’s type theory represents an instantiation of Frege’s strategy of taking function-argument application as the basic “semantic glue” by which meanings are combined. This view, unknown in linguistics at the beginning of the 1970’s, is now widely viewed as standard.

Intensionality is a key notion in the analysis of referential opacity. The construction exemplified in “Jones is seeking \_\_\_\_” is *referentially opaque*, since the substitution of one coreferential expression for another in that context does not always preserve the truth-value of the whole. It may be true that Jones is seeking the president and false that Jones is seeking Mary’s father even though the president is Mary’s father. Montague’s intensional logic develops Frege’s distinction between sense and reference and Carnap’s distinction between intension and extension, to treat the phenomenon of referential opacity, pervasive in belief-sentences and other propositional attitude constructions.

Montague analyzed intensions as functions from possible worlds to corresponding extensions: propositions as functions from possible worlds to truth values, individual concepts as functions from possible worlds to individuals, properties as functions from possible worlds to sets. Montague proposed that not only propositional attitude verbs like *believe* create opaque contexts, but also transitive verbs like *seek* and *need*, modifiers like *former* and *alleged*, and prepositions like *about*. Montague's possible-worlds analysis of intensionality opened up new avenues of research as well as leading to interesting controversies and discussions of possible alternative ontological foundations for semantic theory.

#### 2.4. The method of fragments; the PTQ fragment

Each of Montague's three "grammar" papers (Montague 1970a; 1970b; 1973) contains a "fragment". The term was introduced in EFL, which begins:

In the present paper I shall accordingly present a precise treatment, culminating in a theory of truth, of a formal language that I believe may be reasonably regarded as a fragment of ordinary English. (Montague 1974, p.188)

The "method of fragments", a methodological feature of Montague's work, is the writing of a complete syntax and semantics for a specified subset ("fragment") of a language, rather than writing rules for the a single construction while making implicit assumptions about the rest of the grammar.

The fragment of PTQ, the best known of Montague's works, had a number of noteworthy features. One was the systematic correspondence between syntactic categories and semantic types, an appreciation of which led to a revival of interest in categorial grammar, where such a correspondence is built into the system of categories.

Another innovation was Montague's bottom-up syntax, combining concatenation and transformation operations in single recursive grammatical rules (modeled on the recursive rules of logicians' syntax), thus building well-formed expressions of all sorts of categories directly, rather than building an entire "deep structure" top-down and then applying transformations bottom-up.

Montague's PTQ contained many other ideas that were new to linguists, some of which had antecedents in the work of other logicians and philosophers. We mention only a few here. The fragment illustrated the use of lambda-abstraction to generate phrasal conjunction directly, without the need for the semantically problematic syntactic transformation of "Conjunction Reduction". Montague introduced a version of Quine's treatment of relative clauses as "sentential adjective phrases" derived from open sentences by lambda-abstraction, without any kind of "deletion under identity". He introduced the binding of bound-variable pronouns by lambda-operators rather than directly by quantifiers or by their antecedents, a move which has had major consequences for theories of anaphora. Montague used meaning postulates to distinguish entailments due to individual lexical items from entailments due to the semantics of a grammatical construction, and laid the foundations for the strong "lexicalist" tradition in formal semantics led by Dowty (1979). Details of Montague's analyses have in many cases been superceded, but in overall impact, PTQ was as profound for semantics as Chomsky's *Syntactic Structures* was for syntax. Emmon Bach (Bach 1989) summed up their cumulative innovations thus: Chomsky's Thesis was that English can be described as a formal system; Montague's Thesis was that English can be described as an *interpreted* formal system.

### 3. Further developments and controversies

#### 3.1. *The impact of Montague's work on linguistics*

Before Montague, linguists took as the task of semantics the explication of ambiguity, semantic anomaly, and synonymy: the key questions were how many readings a sentence has, and which sentences share readings. But the individuation of "readings" had always been problematic, so there was often crucial disagreement about data. The introduction of truth-conditions as the basic semantic property of a sentence that a semantic theory should capture profoundly affected the adequacy criteria for semantics, and led to a great expansion of semantic research.

Montague had a very abstract theory of syntax (as an algebra), and some specific syntactic ideas; but in general his semantics was far more influential than his syntax. There have been many proposals for different ways to link Montague's semantics, or some variant of it, to different sorts of syntactic theories [see *Syntax-semantics interface*]. In general, the richness of Montague's semantics eliminates some of the motivation for transformations and some other kinds of richness in syntactic theories, and lends itself to a monstratal syntax with a rich lexical component. Theories which have included a semantics influenced by Montague grammar include Extended Categorical Grammar, GPSG (Generalized Phrase Structure Grammar), HPSG (Head-Driven Phrase Structure Grammar), Heim's File Change Semantics, Dynamic Montague Grammar, and to some extent Discourse Representation Theory [see *Discourse Representation Theory*].

Montague's method of "fragments" is no longer widely followed except in computational linguistics, where completeness is a necessity. Many aspects of Montague grammar have found fruitful application in computational semantics, and many innovations (such as methods for working with underspecified representations rather than with large sets of meanings of ambiguous expressions) have in turn come from the computational semantics community.

#### 3.2. *Resistance, skepticism, ongoing debate*

Some aspects of Montague's approach met with resistance or skepticism in the linguistics community, and some aspects were controversial among philosophers. We mention three foundational issues that distinguish Montague grammar, and formal semantics in general, from other approaches to semantics.

Many linguists have resisted the relevance of truth conditions and entailment relations to natural language semantics, and some still do. Some of the objections to truth conditions are countered by arguing that part of human semantic competence is the matching of sentences with their truth conditions relative to possible worlds (including fictional worlds), with no necessary reference to the 'actual world'. Entailment (Sentence A *entails* sentence B if sentence B is true in every possible state of affairs in which sentence A is true) is a central semantic concern in logic, and remains so in formal semantics. Cognitive semanticists replace concern with logical entailment by concern with human inference; formal semanticists see the relation of entailment to actual human inference as indirect. But many semanticists agree about the importance of revising the formal logics invented by logicians to model the "natural logic(s)" implicit in the semantics of natural languages.

Many linguists think of semantics in terms of a "level of representation" of expressions analogous to a syntactic or phonological level. A representational view of semantics is quite congenial to the popular computational theory of mind. The contrasting model-theoretic view sees semantic interpretation relating expressions to elements of models (possibly mental models) defined in terms of constituents such as possible situations, entities, properties, truth-

values, etc.

The non-psychologistic tradition of "objective" (though abstract) meanings (Frege, Tarski, Carnap, Montague) contrasts with the psychologistic view of meanings "in the head" (Fodor, Lakoff, Jackendoff, and all psychologists). Do expressions refer to objects or to concepts? Is semantics a branch of mathematics, or is it (as on the Chomskyan view of all of linguistics) a branch of psychology? Classical formal semanticists, who take the first disjunct in these choices, follow David Lewis in distinguishing semantics from knowledge of semantics, making semantic competence interestingly different from syntactic competence. Many today seek an integration of cognitive and formal perspectives by studying mind-internal intuitions of mind-external relations such as reference and truth-conditions.

### 3.3. *Typology and natural language metaphysics*

The issue of "Natural Language Metaphysics" (Bach) is an important foundational area that connects cognitive issues with formal semantics and linguistic typology. What presuppositions concerning the constitution and structure of the world as humans conceive it are built into human languages, and how, and which are universal? These questions may concern both semantic structure and semantic content, from the semantic difference between nouns and verbs to the content of color terms or whether time is discrete or continuous. Their investigation may challenge the lines between semantic knowledge and other kinds of knowledge. Formal semantics, following the logical tradition, initially employed relatively "austere" model structures; recent investigations, particularly into lexical semantics, invite richer models. Typological issues have included the distribution of nominal vs. adverbial quantification, the semantics of languages that lack a determiner category, and the range of tense and aspect systems.

### 3.4. *The naturalization of formal semantics*

As formal semantics has developed from Montague grammar since the beginning of the 1970's, it has increasingly become a core part of mainstream theoretical linguistics, with continuing important contributions from logicians and philosophers. Areas of early research success tended to be in the "logical" parts of language: quantification, anaphora, conjunction, tense and aspect. Later work expanded the domains covered and the range of languages treated. An important development of the 1980's was the work of Kamp and Heim on Discourse Representation Theory (see *Discourse Representation Theory*) and File Change Semantics. Their work led to changes in theories of indefinite noun phrases, quantification, and anaphora, and more generally led to the replacement of truth conditions by "context change potential" as the core semantic property of sentences. Later work by them and others extended this "dynamic" perspective on the interaction of meaning and context, in some cases involving associated innovations in logic. Formal theories of topic-focus structure have been developed.

The basic model theory has been enriched by additional structure on the domain of entities, to model mass nouns and "plural entities" (Link 1998), and by widespread acceptance of events as basic entities. Kratzer and other have argued for a "situation semantics" as a more fine-grained model structure, taking situations as parts of worlds. There is increasing attention to details of lexical semantics, and to interfaces of semantics with syntax on one hand and pragmatics on the other.

Of the key journals for the field, one, *Linguistics and Philosophy*, first published in 1977, maintains the collaborative links between those fields that marked the beginnings of Montague grammar. One, *Natural Language Semantics*, first published in 1993, is more nearly centered

within linguistics and includes greater concern with the syntax-semantics interface. A third, *The Journal of Logic, Language, and Information*, first published in 1992, reflects the split found in some European universities, where Chomskyan syntax is located in linguistics departments and formal semantics within philosophy or logic departments. While this article has emphasized Montague grammar and formal semantics within linguistics, fruitful cross-fertilizations continue to strengthen and enrich the field now as they did at its beginnings.

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