

- Kelso, J. A. S. (1995). *Dynamic Patterns: The Self-Organization of Brain and Behavior*. Cambridge, MA: MIT Press/Bradford Books.
- Maturana, J., and F. Varela. (1980). *Autopoiesis and Cognition: The Realization of the Living*. Dordrecht, Reidel.
- Morowitz, H. J., B. Heinz, and D. W. Deamer. (1988). The chemical logic of a minimum protocell. *Origins of Life and Evolution of the Biosphere* 18: 281–287.
- Oyama, S. (1985). *The Ontogeny of Information*. Cambridge: Cambridge University Press.
- Port, R., and T. van Gelder. (1995). *Mind as Motion: Explorations of the Dynamics of Cognition*. Cambridge, MA: MIT Press.
- Prigogine, I. (1973). Irreversibility as a symmetry breaking factor. *Nature* 248: 67–71.
- Prigogine, I., and I. Stengers. (1984). *Order Out of Chaos: Man's New Dialogue with Nature*. New York: Bantam.
- Salthe, S. N. (1993). *Development in Evolution: Complexity and Change in Biology*. Cambridge, MA: MIT Press.
- Simon, H. A. (1962). The architecture of complexity. *Proceedings of the American Philosophical Society* 106: 467–482.
- Smith, L. B., and E. Thelen. (1993). *A Dynamic Systems Approach to Development*. Cambridge, MA: MIT Press/Bradford Books.
- Turing, A. M. (1952). The chemical basis of morphogenesis. *Philosophical Transactions of the Royal Society London. Series B. Biological Sciences* 237: 37–72.
- Weber, B. H., and D. J. Depew. (1996). Natural selection and self-organization: Dynamical models as clues to a new evolutionary synthesis. *Biology and Philosophy* 11: 33–65.
- Wicken, J. (1987). *Evolution, Information and Thermodynamics: Extending the Darwinian Program*. New York: Oxford University Press.

Further Readings

- Bechtel, W., and R. C. Richardson. (1993). *Discovering Complexity: Decomposition and Localization as Strategies in Scientific Research*. Princeton, NJ: Princeton University Press.
- Depew, D. J., and Weber, B. H. (1995). *Darwinism Evolving: Systems Dynamics and the Genealogy of Natural Selection*. Cambridge, MA: MIT Press/Bradford Books.
- Godfrey-Smith, P. (1996). *Complexity and the Function of Mind in Nature*. Cambridge: Cambridge University Press.
- Harrison, L. G. (1993). *Kinetic Theory of Living Pattern*. Cambridge: Cambridge University Press.
- Juarrero, A. (Forthcoming). *Dynamics in Action: Intentional Behavior as a Complex System*. Cambridge, MA: MIT Press/Bradford Books.
- Langton, C. G., Ed. (1995). *Artificial Life: An Overview*. Cambridge, MA: MIT Press/Bradford Books.
- Mittenthal, J. E., and A. R. Baskin, Eds. (1992). *The Principles of Organization in Organisms*. Reading, MA: Addison-Wesley.
- Morowitz, H. J., and J. L. Singer, Eds. (1995). *The Mind, The Brain, and Complex Adaptive Systems*. Reading, MA: Addison-Wesley.
- Swenson, R., and M. T. Turvey. (1991). Thermodynamic reasons for perception-action cycles. *Ecological Psychology* 3: 317–348.
- Stein, W., and F. J. Varela, Eds. (1993). *Thinking about Biology*. Reading, MA: Addison-Wesley.
- Thelen, E., and B. D. Ulrich. (1991). Hidden skills: A dynamic systems analysis of treadmill stepping during the first year. *Monographs of the Society for Research in Child Development*, serial no. 223, 56 (1).
- Ulanowicz, R. E. (1997). *Ecology: The Ascendent Perspective*. New York: Columbia University Press.

Semantic Memory

See EPISODIC VS. SEMANTIC MEMORY

Semantic Networks

See FRAME-BASED SYSTEMS; SCHEMATA

Semantics

Semantics is the study of MEANING. It is not surprising that “semantics” can “mean” different things to different researchers within cognitive science. Notions relating to meaning have had long (and often contentious) histories within the disciplines that contribute to cognitive science, and there have been very diverse views concerning what questions are important, and for what purposes, and how they should be approached. And there are some deep foundational and methodological differences within and across disciplines that affect approaches to semantics. These have partly impeded but also stimulated cooperative discussion and fruitful cross-fertilization of ideas, and there has been great substantive progress in semantics, in the sister field of PRAGMATICS and at the SYNTAX-SEMANTICS INTERFACE in recent decades.

The logico-philosophical tradition divides semiotics (the study of signs, applicable to both natural and constructed languages) into syntax, semantics, and pragmatics (Morris 1938). On this view, SYNTAX concerns properties of expressions, such as well-formedness; semantics concerns relations between expressions and what they are “about” (typically “the world” or some model), such as reference; and pragmatics concerns relations between expressions and their uses in context, such as IMPLICATURE. Some approaches reject the characterization of semantics as dealing with relations between language and something external to language, especially between language and “the world” (see (1) and (2) below). And many approaches have challenged, in different ways, the autonomy of semantics from pragmatics implied by the traditional trichotomy. We return to some of these foundational issues below.

One of the basic issues that any theory of semantics must deal with is how we can understand the meanings of novel sentences. Syntax describes the recursive part-whole structure of sentences; semantics must account for how the meanings of smaller parts are combined to form the meanings of larger wholes (see COMPOSITIONALITY and LOGICAL FORM). There are many controversial issues surrounding the principle of compositionality, which contains several crucially theory-dependent terms: *The meaning of an expression is a function of the meanings of its parts and of how they are syntactically combined*. But most explicit semantic theories, especially formal semantics, accept it as a basic working principle. The extension of compositional semantics beyond the level of the sentence, to the interpretation of DISCOURSE, has been of increasing importance.

Another basic issue for semantic theory is the nature of the meanings of the smallest meaningful units of language,

words or morphemes (or even smaller units if some morphemes are viewed as decomposable into submorphemic “features”). Lexical semantics has an even longer history than compositional semantics and is connected with the most fundamental problems in the philosophy of language and the psychology of CONCEPTS (see REFERENCE, THEORIES OF and LEXICON).

Crucial *interfaces* include the syntax-semantics interface and the interfaces of semantics with pragmatics, with encyclopedic and common-sense knowledge, and perhaps directly with PHONOLOGY (e.g., with respect to the semantic/pragmatic interpretation of PROSODY AND INTONATION). Other important areas of research concern acquisition, human semantic processing, and computational semantics.

Among the most important semantic properties of linguistic expressions that need to be accounted for, most semanticists would include the following:

Ambiguity: Having more than one meaning. Strongly compositional theories require all semantic ambiguity to reflect either *lexical* or *structural* (syntactic) AMBIGUITY.

Vagueness: A challenge for some theories of the nature of word meanings as well as to classical theories of concepts. Drawing the distinction between ambiguity and VAGUENESS is a classic problem (Quine 1960; Zwicky and Sadock 1975).

Anomaly: Some expressions, like the famous *Colorless green ideas sleep furiously* (Chomsky 1957), are judged to be *semantically anomalous* although syntactically well-formed. The lines between semantic and other sorts of anomaly are crucially theory-dependent and often debated.

Entailment: Sentence A *entails* sentence B if sentence B is true in every possible state of affairs in which sentence A is true. Entailment has always been a central semantic concern in LOGIC and the philosophy of language, and remains so in POSSIBLE WORLDS 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 most semanticists are concerned with some notion of entailment or inference, and many agree about the importance of revising (incrementally or radically) the formal logics invented by logicians to model the “natural logic(s)” implicit in the semantics of natural languages.

Presupposition: A precondition for the felicity or truth-valuedness of an expression in a context. PRESUPPOSITION research has been important in theorizing about the relation between (or possible integration of) semantics and pragmatics.

Context: Expressions are interpreted in the (linguistic) context of other expressions, and in the (nonlinguistic) context of an utterance situation in which the participants have various beliefs and intentions. Any approach to semantics has to take a stand on the relation of “semantics proper” to various aspects of context, including the treatment of INDEXICALS AND DEMONSTRATIVES (Kaplan 1977). One important trend in formal semantics has been the shift from “meanings as

truth conditions” to “meanings as functions from contexts to contexts” (with truth conditions as a corollary; Heim 1982); see CONTEXT AND POINT OF VIEW, SITUATEDNESS/EMBEDDEDNESS, DYNAMIC SEMANTICS.

Referential opacity: The construction exemplified in “Jones is seeking—” is *referentially opaque*, because 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. Frege’s distinction between SENSE AND REFERENCE, Carnap’s distinction between intension and extension, and Montague’s intensional logic all treat the phenomenon of referential opacity, pervasive in PROPOSITIONAL ATTITUDE constructions.

Other issues important to semantics include ANAPHORA, negation and QUANTIFIERS, TENSE AND ASPECT, and modality; other issues important for semantics and pragmatics together include topic-FOCUS structure and the interpretation of questions, imperatives, and other speech acts.

Many foundational issues of semantics are relevant to cognitive science; some are particularly linguistic, others overlap heavily with issues in the philosophy of language and philosophy of mind. We mention a few central issues that divide different approaches to semantics.

1. The nonpsychologist tradition of “objective” (though abstract) meanings (Frege 1892; Carnap 1956; Montague 1973) versus the psychologist view of meanings “in the head” (Fodor 1975; Lakoff 1987; Jackendoff 1983; 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, distinguish semantics from knowledge of semantics (Lewis 1975), making semantic competence interestingly different from syntactic competence. Jackendoff (1996), following Chomsky (1986) on “I-language” and “E-language,” distinguishes “I-semantics” (internalized semantics, semantic competence) from “E-semantics” (an abstract relation external to language users), and characterizes his own Conceptual Semantics as well as COGNITIVE LINGUISTICS (Lakoff 1987) as studying the former whereas formal semantics studies the latter. Many today seek an integration of these two perspectives by studying mind-internal intuitions of mind-external relations such as reference and truth-conditions. See Putnam 1975 for an influential philosophical perspective.

2. Model-theoretic versus representational approaches. Many linguists think of semantics in terms of a “level of representation” of expressions analogous to a syntactic or phonological level. Psychologists generally think of semantics as relating expressions to concepts, regarding concepts as something like elements of a LANGUAGE OF THOUGHT. In AI, semantic interpretation is sometimes expressed in a language of KNOWLEDGE REPRESENTATION. A representational view of semantics is quite congenial to the popular COMPUTATIONAL THEORY OF MIND (Jackendoff 1983). 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, and so on. Intensional objects may be modeled, for instance, as functions from possible worlds or situations to extensions (see POSSIBLE WORLDS SEMANTICS). The question of the mental representation of such model-theoretic constructs is open (see Johnson-Laird 1983); the inclusion of Marrian “2½-D sketches” in Conceptual Structure in Jackendoff 1995 suggests the possibility of mixed approaches.

3. The issue of Natural Language Metaphysics (Bach 1986) or the “naive picture of the world” (Apresjan 1974) and its role in semantics. 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? (See LINGUISTIC RELATIVITY HYPOTHESIS, NAIVE PHYSICS, FOLK BIOLOGY.) These questions may concern both semantic structure and semantic content, from the semantic difference between nouns and verbs to the content of color terms. Their investigation may challenge the lines between semantic knowledge and commonsense, encyclopedic, or other kinds of knowledge. Formal semantics, following the logical tradition, has employed relatively “austere” model structures; recent investigations, particularly into lexical semantics, tend to invite richer models.

4. The semantic atomism question: Are all meanings decomposable into combinations of “semantic atoms,” “semantic primitives,” or “atomic concepts” drawn from some fixed, universal, and presumably innate set? The affirmative view goes back at least to Leibniz (Kretzmann 1967), and is popular in cognitive science in spite of little progress on identification of a suitable set of primitives (see Wierzbicka’s work, e.g., Wierzbicka 1985, for the most sustained attempt). A “yes” answer implies that lexical semantics will take the form of semantic decomposition; a “no” answer is compatible with various approaches to word meaning including the use of meaning postulates or a FUNCTIONAL ROLE SEMANTICS approach to word meaning.

5. The relation between meaning and use. The distinction between “sentence meaning,” the literal meaning of a sentence abstracted away from any particular context, and “speaker’s meaning,” the intended interpretation of a particular utterance of a given sentence, presupposes a boundary between semantics and pragmatics, sometimes disputed. One traditionally influential approach (Austin 1962) is based on the identification of meaning and use.

See also SEMANTICS, ACQUISITION OF; WORD MEANING, ACQUISITION OF

—Barbara H. Partee

References

- Apresjan, J. D. (1974). *Leksicheskaia Semantika* (Lexical semantics, 1992). Moscow: Nauka and Ann Arbor, MI: Karoma.
- Austin, J. L. (1962). *How to Do Things with Words*. London: Oxford University Press.
- Bach, E. (1986). Natural language metaphysics. In R. B. Marcus, G. J. W. Dorn, and P. Weingartner, Eds., *Logic, Methodology,*

and Philosophy of Science 7. Amsterdam: Elsevier, pp. 573–595.

- Carnap, R. (1956). *Meaning and Necessity*. 2nd ed. with supplements. Chicago: University of Chicago Press.
- Chomsky, N. (1957). *Syntactic Structures*. The Hague: Mouton.
- Chomsky, N. (1986). *Knowledge of Language: Its Nature, Origin, and Use*. New York: Praeger.
- Fodor, J. A. (1975). *The Language of Thought*. New York: Thomas Y. Crowell.
- Frege, G. (1892). *Über Sinn und Bedeutung* (On sense and reference). *Zeitschrift für Philosophie und philosophische Kritik* 100: 25–50. Reprinted in P. T. Geach and M. Black, Eds., *Translations from the Philosophical Writings of Gottlob Frege* (1952). Oxford: Blackwell, pp. 56–78.
- Heim, I. (1982). *The Semantics of Definite and Indefinite NPs*. Ph.D. diss., University of Massachusetts, Amherst.
- Jackendoff, R. (1983). *Semantics and Cognition*. Cambridge, MA: MIT Press.
- Jackendoff, R. (1995). *Semantic Structures*. Cambridge, MA: MIT Press.
- Jackendoff, R. (1996). Semantics and cognition. In S. Lappin, Ed., *The Handbook of Contemporary Semantic Theory*. Oxford: Blackwell, pp. 539–559.
- Johnson-Laird, P. N. (1983). *Mental Models: Towards a Cognitive Science of Language, Inference, and Consciousness*. Cambridge, MA: Harvard University Press.
- Kaplan, D. (1977). The logic of demonstratives. *Journal of Philosophical Logic* 8: 81–98.
- Kretzmann, N. (1967). Semantics, history of. In P. Edwards, Ed. in chief, *The Encyclopedia of Philosophy*, vol. 7. New York: Macmillan, pp. 358–406.
- Lakoff, G. (1987). *Women, Fire, and Dangerous Things*. Chicago: University of Chicago Press.
- Lewis, D. (1975). Languages and language. In K. Gunderson, Ed., *Language, Mind, and Knowledge*. Minneapolis: University of Minnesota Press, pp. 3–35.
- Montague, R. (1973). The proper treatment of quantification in ordinary English. In K. J. J. Hintikka, J. M. E. Moravcsik, and P. Suppes, Eds., *Approaches to Natural Language*. Dordrecht: Reidel, pp. 221–242. Reprinted in R. Montague, (1974). *Formal Philosophy: Selected Papers of Richard Montague*, R. Thomason, Ed. New Haven, CT: Yale University Press, pp. 247–270.
- Morris, C. W. (1938). Foundation of the theory of signs. In O. Neurath, R. Carnap, and C. Morris, Eds., *International Encyclopaedia of Unified Science* 1, no. 2. Chicago: University of Chicago Press, pp. 1–59.
- Putnam, H. (1975). The meaning of meaning. In K. Gunderson, Ed., *Language, Mind, and Knowledge*. Minnesota Studies in the Philosophy of Science. Minneapolis: University of Minnesota Press, pp. 131–193. Reprinted in H. Putnam, (1975). *Mind, language, and reality. Mind, language, and reality: Philosophical Papers*, vol. 2. Cambridge, MA: MIT Press, pp. 215–271.
- Quine, W. V. O. (1960). *Word and Object*. Cambridge, MA: MIT Press.
- Wierzbicka, A. (1985). *Lexicography and Conceptual Analysis*. Ann Arbor, MI: Karoma.
- Zwicky, A., and J. M. Sadock. (1975). Ambiguity tests and how to fail them. In J. P. Kimball, Ed., *Syntax and Semantics* 4. New York: Academic Press, pp. 1–36.

Further Readings

- Bach, E. (1989). *Informal Lectures on Formal Semantics*. Albany: SUNY Press.

- Chierchia, G., and S. McConnell-Ginet. (1990). *Meaning and Grammar: An Introduction to Semantics*. Cambridge, MA: MIT Press.
- Cresswell, M. J. (1978). Semantic competence. In M. Guenther-Reutter and F. Guenther, Eds., *Meaning and Translation: Philosophical and Linguistic Approaches*. London: Duckworth.
- Davidson, D. (1970). Semantics for natural languages. In B. Visentini et al., Eds., *Linguaggi nella Società e nella Tecnica*. Milan: Edizioni di Comunità.
- Dowty, D. (1979). *Word Meaning and Montague Grammar*. Dordrecht: Reidel.
- Dowty, D., R. Wall, and S. Peters. (1981). *Introduction to Montague Semantics*. Dordrecht: Reidel.
- Fillmore, C. J. (1982). Frame semantics. In The Linguistic Society of Korea, Ed., *Linguistics in the Morning Calm*. Seoul: Hanshin Pub. Co., pp. 111–137.
- Fodor, J. A. (1987). *Psychosemantics: The Problem of Meaning in the Philosophy of Mind*. Cambridge, MA: MIT Press.
- Gamut, L. T. F. (1991). *Logic, Language, and Meaning*. Vol. 2: *Intensional Logic and Logical Grammar*. Chicago: University of Chicago Press.
- Heim, I., and A. Kratzer. (1997). *Semantics in Generative Grammar*. Oxford: Blackwell.
- Kamp, H. (1981). A theory of truth and semantic representation. In J. Groenendijk, T. Janssen, and M. Stokhof, Eds., *Formal Methods in the Study of Language: Proceedings of the Third Amsterdam Colloquium*. Amsterdam: Mathematical Centre Tracts, pp. 277–322. Reprinted in J. Groenendijk, T. M. V. Janssen, and M. Stokhof, Eds. *Truth, Interpretation, and Information* (1984). GRASS 2. Dordrecht: Foris.
- Katz, J. J. (1981). *Language and Other Abstract Objects*. Totowa, NJ: Rowman and Littlefield.
- Lappin, S., Ed. (1996). *The Handbook of Contemporary Semantic Theory*. Oxford: Blackwell.
- Larson, R., and G. Segal. (1995). *Knowledge of Meaning: An Introduction to Semantic Theory*. Cambridge, MA: MIT Press.
- Lewis, D. (1970). General semantics. *Synthese* 22: 18–67. Reprinted in D. Davidson and G. Harman, Eds., *Semantics of Natural Language* (1972). Dordrecht: Reidel, pp. 169–218.
- Lyons, J. (1988). *Principles of Linguistic Semantics*. Cambridge: Cambridge University Press.
- Partee, B. (1979). Semantics: Mathematics or psychology? In R. Bauerle, U. Egli, and A. von Stechow, Eds., *Semantics from Different Points of View*. Berlin: Springer, pp. 1–14.
- Partee, B. (1995). Lexical semantics and compositionality. In D. Osherson, Gen. Ed., L. Gleitman, and M. Liberman, Eds., *Invitation to Cognitive Science*. Vol. 1, *Language*. 2nd ed. Cambridge, MA: MIT Press, pp. 311–360.
- Partee, B. (1996). The development of formal semantics in linguistic theory. In S. Lappin, Ed., *The Handbook of Contemporary Semantic Theory*. Oxford: Blackwell, pp. 11–38.
- Sgall, P., E. Hajičová, and J. Panevová. (1986). *The Meaning of the Sentence in Its Semantic and Pragmatic Aspects*. Prague: Academia; and Dordrecht: Reidel.
- Stalnaker, R. (1978). Assertion. In P. Cole, Ed., *Syntax and Semantics*. Vol. 9, *Pragmatics*. New York: Academic Press, pp. 315–332.
- Stechow, A. von, and D. Wunderlich, Eds. (1991). *Semantik/Semantics: An International Handbook of Contemporary Research*. Berlin: Mouton.
- Talmy, L. (1991). Path to realization: A typology of event conflation. In *Buffalo Papers in Linguistics*. State University of New York at Buffalo, pp. 147–187.
- Van Benthem, J., and A. ter Meulen, Eds. (1997). *Handbook of Logic and Language*. Amsterdam: Elsevier.

Semantics, Acquisition of

One area of research in the acquisition of semantics investigates children's use of logical connectives such as *and* and *or*, and QUANTIFIERS such as *every* and *some*. The main goal of this research is to determine the extent to which children assign a semantics to logical words that conforms to classical LOGIC. We will return to this topic. Another area of research investigates children's knowledge of semantic universals (see LINGUISTIC UNIVERSALS AND UNIVERSAL GRAMMAR). Semantic universals are often cast as constraints against certain linguistic forms or meanings. For example, a constraint on form prevents negative polarity items such as *any* from appearing in certain linguistic environments (the asterisk indicates deviance):

- (1) * Every linguist fed any squirrel. Cf. No linguist fed any squirrel.

A second example is a constraint on meaning, called *closure*. Closure prevents pronouns from referring back to particular kinds of quantificational NPs that have appeared earlier in a discourse (e.g., Chierchia 1995). Thus, the pronoun *he* in (2) cannot be linked to the quantificational NP *every linguist*—the pronoun can refer to *Chomsky*, or it can refer to someone who is not mentioned in the DISCOURSE.

- (2) Every linguist went to Chomsky's party. He was happy.

Suppose that children's grammars lack these constraints at some stage of development. If so, the language generated by their grammars would produce sentence forms that are illicit for adults, such as (1), and their grammars would permit illicit links between pronouns and quantificational NPs, as in (2). In the absence of systematically available negative semantic evidence (e.g., parental correction), it is difficult therefore to see how children could *learn* constraints. Embracing the conclusion of the argument from the-poverty-of-the-stimulus, we are led to consider an alternative source: innate specification (see POVERTY OF THE STIMULUS ARGUMENTS).

Among the hallmarks of innate specification are universality and the early emergence of a linguistic principle despite the absence of decisive evidence from experience (see INNATENESS OF LANGUAGE and NATIVISM). Research in the acquisition of semantics is directed at the early emergence hallmark of innateness. For example, 4- to 5-year-old children's understanding of negative polarity items was examined using an elicited production task (O'Leary and Crain 1994). One experimenter acted out stories with toys and props; a second experimenter manipulated a puppet, Kermit the Frog. Following each story, Kermit told the child what he thought happened in the story. The child's task was to decide whether or not Kermit "said the right thing" and, if not, to explain "what really happened." One of Kermit's (false) statements was (3).

- (3) Only two squirrels got any food.

In light of what actually happened in the story, children consistently corrected Kermit's statement, producing sentences like "No, every squirrel got some food." Despite Kermit's