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Glossary of Technical Terms

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ABDUCTION Inference involving the generation and evaluation of explanatory hypotheses. In its strict sense, a mode of creative conjecture introduced by C. S. Peirce. In its looser sense, a species of inductive inference, still associated with Peirce, also known as 'inference to the best explanation', which involves selecting one member from a set of alternative hypotheses as the alternative providing the best explanation of the available evidence. Hypotheses that explain more of the available relevant evidence are preferable to those that explain less. Hypotheses that are preferable are also acceptable when sufficient evidence becomes available. Hypotheses that are incompatible with the evidence are rejected as false. Hypotheses may be false even when they are acceptable, which makes inference of this kind fallible, but they remain the most rational among the alternatives considered.

ABDUCTIVE INFERENCE See ABDUCTION

ABSTRACT DATA TYPE See DATA ABSTRACTION

ABSTRACTION (The result of) a process of simplification, to describe something at a more general level than the level of detail seen from another point of view. This is often achieved by omitting details specific to individual cases or to methods of implementation. For example, a realtor's description of a house may leave out architectural detail so that it is an abstraction of an architect's description. In computer science, language abstraction is the use of high-level language programs allowing computational processes to be described without reference to any particular machine, hence more simply. See also ABSTRACTION, FULL and ABSTRACTIONS/IDEALIZATIONS.

ABSTRACTION, FULL A semantics for a programming language is fully abstract if it does not distinguish programs, or program phrases, which are observationally equivalent. See also ABSTRACTION and ABSTRACTIONS/IDEALIZATIONS.

ABSTRACTION, PROCEDURAL The separation of a computational procedure A's use from its definition, so that another procedure B can call A to get something accomplished while remaining ignorant of how A accomplishes its task.

ABSTRACTION/IDEALIZATION The axioms and theorems of formal systems in *pure mathematics* make assertions about abstract entities that do not exist in space/time, such as points and lines in Euclidean geometry. The truth or falsity of these hypotheses seems to be analytic and a priori. If those formal systems are provided an empirical interpretation and those entities are identified with things that may have instances in space/time, such as the paths of rays of light, the results belong to *applied mathematics*. The truth or falsity of these hypotheses seems to be synthetic and a posteriori. Idealizations, by comparison, are special cases of physical phenomena that might or might not have any instances during the history of the world, such as frictionless planes and perfect spheres. See also ABSTRACTION and ABSTRACTION, FULL.

AI See ARTIFICIAL INTELLIGENCE

AI, STRONG In one sense, the difference between 'weak' and 'strong' AI is that between the use of machines as a tool that is useful in the study of the mind and the claim that these machines actually do possess minds. Alternatively, the difference between 'weak' and 'strong' AI is that between how we do think (the descriptive thesis) and AI as studying how we should think (the prescriptive thesis).

ALETHIC Of true or false value.

ALGOL A programming language, developed in the late 1950's, which established many of the features of modern programming languages.

ALGORITHM Any well-defined sequence of steps (procedure or routine) that takes some value as input and guarantees a value as output in some finite number of steps. See also DECISION PROCEDURE.

ANALOGY See REASONING, ANALOGICAL

ANALYTIC/SYNTHETIC The distinction has typically been drawn between different kinds of hypotheses as possible objects of knowledge, where sentences are qualified as analytic when (i) their predicates are contained in their subjects, (ii) they are logical truths or are reducible to logical truths when synonyms are substituted for synonyms, or else (iii) their negations are contradictory. Other sentences are said to be synthetic. The history of this distinction is important enough to deserve discussion. Hume distinguished knowledge of *relations between ideas* (when one idea includes or excludes another; for example, the notion of being a bachelor includes the notion of being unmarried) from knowledge of

matters of fact (where that is not the case; for example, the height, weight, and colour of hair of a person who happens to be a bachelor are not included in the notion that he is a bachelor). Thus, knowledge of relations between ideas has been viewed as analytic, while knowledge of matters of fact has been viewed as synthetic. Similarly, Kant, who introduced these terms, distinguished knowledge of *conceptual connections* (when one concept is contained in another) as analytic and knowledge that is *informative about the world* as synthetic. While Kant asserted the existence of synthetic a priori knowledge that is both informative about the world and also knowable independently of experience due to the mode of function of the human mind, that position distinguishes specific forms of rationalism and has been rejected by all forms of empiricism.

A PRIORI/A POSTERIORI A distinction between kinds of knowledge that can be acquired *independently of experience* (such as that 2 + 2 = 4 or that bachelors are unmarried) and that can be secured *only on the basis of experience* (such as that some apples are rotten or that John is a bachelor). Often defined relative to analytic/synthetic and necessary/contingent distinctions.

ARTIFICIAL INTELLIGENCE (*abbrev*. AI) Branch of computer science that investigates the extent to which computers can perform tasks that require intelligence when done by people. AI is closely associated to cognitive science.

ASSIGNMENT The process whereby a variable in a program acquires a new value, thereby losing whatever old value it had compositionality. A semantics is compositional if the values it gives to composite entities can be constructed from the values of the components of those entities.

ATTRACTOR Region of a phase space into which all trajectories departing from an adjacent region ('basin of attraction') tend to converge. Example: fixed point, limit cycle, deterministic chaos.

AUTOASSOCIATIVE NETWORKS Connectionist networks (or artificial neural networks) in which each unit (or node) is connected to every other unit, including itself.

AUTOCATALYSIS Self-catalysis, catalysis of a chemical reaction by one of the products of the reaction.

BACKPROPAGATION Backprogation, sometimes called "the generalized Delta rule," is a supervised learning algorithm for weight change that is frequently used in multilayered connectionist networks (or artificial neural networks). The actual output activation pattern for a given input activation pattern is compared with the desired output. The difference between the two—the error measure—is then propagated back into whatever connections were used to get the actual output activation pattern. The connections among units that contributed to the actual output are strengthened (increased in weight) when the match is

good and are reduced in strength (decreased in weight) when it is poor. The weights of connections among units (or nodes) are thus adjusted so as to reduce the margin of error between the actual output and the desired one.

BAYES' THEOREM Derivable from the definition of conditional probability as a feature of the calculus of probability, where $P(h/e)$ -- the probability of hypothesis *h*, given evidence *e* -- equals the product of the probability of evidence *e*, given hypothesis *h* (which is also known as a 'likelihood') multiplied by the probability of hypothesis *h* divided by the probability of evidence *e*. That is, $P(h/e) = P(e/h) \bullet P(h)/P(e)$, where $P(h)$ and $P(e)$ are known as 'unconditional' (or as absolute) probabilities, insofar as they are not formalized as 'conditional' (or relative to) specific conditions. In order for the theorem (in this or more complex forms) to be applied, it is necessary to fix the values of the probabilities on the right-hand side to calculate the value of the probability on the left-hand side. The fashion in which this is supposed to be done is what divides species of Bayesianism.

BAYESIANISM. A theory of knowledge maintaining that Bayes' theorem captures the fundamental principle of scientific reasoning. According to this view, adequate measures of evidential support must satisfy certain mathematical relationships characteristic of the calculus of probability. The cumulative influence of acquired evidence is taken to be determined by a process of conditionalization.

BELIEF The state of accepting an hypothesis as true. Beliefs appear capable of variation in strength, where a person might hold some beliefs more strongly than others. Some quantitative theories supply a means for measuring the strength of beliefs, especially in terms of betting odds that one would accept under certain special conditions. The importance of beliefs arises because (a) we explain and predict events that occur during the course of the world's history on the basis of our beliefs, which thereby supply the foundation for our understanding of nature; and (b) we tend to act on the basis of our beliefs relative to the contexts in which we find ourselves, where these 'contexts' consist of our other beliefs, our motives, our ethics, our abilities, and our capabilities. Alternatively, the state of accepting an hypothesis as true or alternatively as rationally worthy of adoption.

BELIEF, DEGREES OF A person's measure of credibility (or strength of conviction) that something is the case, where those degrees of belief are usually measured by means of betting odds. For example, if a person were willing to bet even money at odds of 2:1 against Duke repeating as the basketball champion of the NCAA, that would presumably make the person's degree of belief that Duke will win equal to 1/3 (or 33 percent) and that Duke will lose equal to 2/3 (or 66 percent). Theories of knowledge that do without acceptance and rejection rules tend to make this a basic concept.

BESTAND A term used by Heidegger to name the way the world appears in technological perspective. Modern technology makes the world appear as 'Bestand' or 'resources' to be

manipulated. Also sometimes translated as 'standing-reserve.' In ordinary German, the word also means 'stock' or 'supply.'

BEST MATCH PROBLEMS. Minsky and Papert's term for problems whose solution involves assessing the satisfaction of multiple soft (i.e., non-mandatory) constraints. A problem that arises for procedures for solving best match problems is that of avoiding local maxima of goodness of constraint fit. It can be characterized as an energy minimization problem. The analog of the goodness maximum is the energy minimum, and the analogs of local goodness maxima are local energy minima. The situation is easy to visualize as an energy landscape. In an energy landscape, the goodness maximum corresponds to the lowest valley in the landscape, while local goodness minima correspond to local valleys in the landscape. The problem of avoiding local goodness maxima is thus the problem of avoiding settling into a local valley, rather than into the lowest valley in the energy landscape.

BOLTZMANN MACHINE. An interactive connectionist network designed by Hinton and Sejnowski (and named after the physicist Ludwig Boltzmann) that is especially efficient at solving best match problems. To handle the problem of local maxima of goodness of constraint fit, the Boltzmann machine employs a computational analog of the metallurgical process of annealing, a process whereby metals are heated to a little below their melting point and then cooled very slowly so that all their atoms have time to settle into a single orientation. The analog of temperature in the Boltzmann machine is random noise that is introduced into network activity. The function of the noise is to jar the network out of local energy landscape valleys, so that it can explore other parts of the energy landscape to find the lowest valley, thereby achieving the global maximum of fit. When the network reaches a stable state, it has settled or relaxed into a solution. Given sufficient time, the Boltzmann machine can find the energy minimum for any best match problem.

BOOLEAN NETWORK A network comprised of some number of binary variables. The state of each variable at each step in discrete time is governed by some logical switching or 'Boolean' function applied to the states of some specific set of other variables in the network.

BOOLEAN See BOOLEAN ALGEBRA

BOOLEAN ALGEBRA Set of algebraic rules, named after George Boole, in which 'true' and 'false' are equated to 0 and 1. Boolean algebra includes a series of operators ('and', 'or', 'not', 'nand', 'nor' and 'xor'), which can be used to manipulate 'true' and 'false' values. In modern notation, a Boolean algebra is any 6-tuple $\{B, \oplus, \otimes, \neg, 0, 1\}$ that satisfies the following conditions:

1. B is a set of elements
2. $\oplus$ and $\otimes$ are two binary operations on B (a binary operation on a set B is a function from $B \times B$ to $\oplus$, for example the truth tables for 'or' and 'and') that are
   2.1. commutative, a binary operation * on B is said to be commutative if and only if

$\forall x\, \forall y\, (((x \in B) \wedge (y \in B)) \rightarrow (x * y = y * x))$

2.2. associative, a binary operation, *, on B is said to be associative if and only if
$\forall x\, \forall y\, \forall z\, ((((x \in B) \wedge (y \in B)) \wedge (z \in B)) \rightarrow (x * (y * z) = (x * y) * z))$

2.3. idempotent, a binary operation, *, on B is said to be idempotent if and only if
$\forall x\, ((x \in B) \rightarrow (x * x = x))$

3. each binary operation is distributive over the other
a binary operation $\otimes$ is said to be distributive over a binary operation $\oplus$ on a set B if
$\forall x\, \forall y\, \forall z\, ((((x \in B) \wedge (y \in B)) \wedge (z \in B)) \rightarrow (w \otimes (y \oplus z) = (w \otimes y) \oplus (w \otimes z)))$
4. the constant 0 is the identity for $\oplus$ and the constant 1 is the identity for $\otimes$
an identity for a binary operation, *, on B is an element e in B for which
$\forall x\, ((x \in B) \rightarrow (x * e = x = e * x))$
5. the *complement operation* $\neg$ is a unary operation satisfying the condition
$\forall x\, (x \in B \rightarrow ((x \oplus \neg x = 1) \wedge (x \otimes \neg x = 0)))$.

Since propositional logic, interpreted as a 6-tuple $\{\{F, T\}, \vee, \wedge, \neg, T, F\}$, can be shown to satisfy such conditions it qualifies as a Boolean algebra, and this holds true in set theory as well, where B is the set of subsets of a given set, the operations of intersection ($\cap$) and union ($\cup$) replace $\wedge$ and $\vee$ respectively, and the set complement plays the role of Boolean algebra complement. The question then becomes how we implement a Boolean algebra electronically. We need electronic switches arranged into logical gates, which can be assembled as components of larger functional units. Once this is achieved, it becomes a matter of technological progress to construct increasingly efficient logic gates that are smaller and faster.

BUTTERFLY EFFECT Said of initial, small and local causes leading to unpredictable, large and global effects in chaotic system. See also DETERMINISTIC CHAOS.

CATALYSIS A modification (usually an increase) in the rate of a chemical reaction that is induced by a substance (e.g. a catalyst like an enzyme) that alters the speed of, or makes possible, a biochemical or chemical reaction whilst remaining unchanged at the end of the reaction.

CAUSAL RELATIONS The relations that obtain between two events when one is the cause of the other. It is sometimes assumed that indeterminism implies non-causation; on other views, causal relations can be deterministic or indeterministic. Sentences that describe causal relations between events may occur in causal explanations. See also CAUSATION.

CAUSATION A process or a property by virtue of which one event brings about (or 'produces') another. The producing event is known as the *cause* and the event produced as its *effect*. One of the most difficult concepts in epistemology and the philosophy of science, causes are usually assumed to be temporally prior to, as well as spatially contiguous with, their effects, where the occurrence of a cause makes its effect necessary (or probable). Although Newton's theory of gravitation appears to violate this conception by introducing action-at-a-distance, contemporary theories of gravitation appeal to the notion of

gravitational waves propagated at finite velocities. According to Einstein's special theory of relativity, furthermore, no causal process can occur at a rate faster than that of the speed of light. Quantum mechanics poses puzzling phenomena that may or may not violate this assumption. The strongest conceptions of causation are those associated with *determinism*, according to which the same outcome is invariably produced as an effect when the same cause occurs ('same cause, same effect'). But this turns out to be the case only when causes are given descriptions that are nomically complete (by including a specification of the presence or the absence of every property whose presence or absence makes a difference to the occurrence of that outcome). Somewhat weaker conceptions of causation are associated with *indeterminism*, where one or another outcome in the same fixed set of possible outcomes variably occurs but with constant probability.

CELLULAR AUTOMATON (pl. AUTOMATA) Systems consisting of arrays (a regular spatial lattice) of connected individuals, known as 'cells', each of which follows some simple 'local' rule or program and can be in any one of a finite number of states. The states of all the cells in the lattice are updated simultaneously and the state of the entire lattice advances in discrete time steps. The state of each cell in the lattice is updated according to a local rule that may depend on the state of the cell and its neighbours at the previous time step. Each cell in a cellular automaton could be considered to be a finite state machine, which takes its neighbours' states as input and outputs its own state. Cellular automata are often offered as examples of how global patterns can arise from purely local interaction, with Conway's 'Game of Life' given as a common example.

CETERIS PARIBUS Latin for 'other things equal'. *Ceteris paribus* clauses are non-strict generalizations but generalizations that hold when other things are equal. They typically occur conjoined with incomplete descriptions of the factors whose presence or absence bring about an outcome. Thus, ceteris paribus, striking a match will cause it to light (but not if the match is wet, if there is insufficient oxygen present or if it is struck in a peculiar fashion).

CHAT A variety of synchronous systems, including IRC (Internet Relay Chat) and ICQ ('I seek you'), which allow two or more people to exchange text messages in real time, in contrast with asynchronous systems such as e-mail.

CHATROOMS Conversational 'spaces' made possible by chat software. Users log on (often under a self-chosen pseudonym) to a chatroom of specific interest (e.g., concerning technical issues) and/or populated by specified users (teenagers, seniors, science fiction fans, etc.) and can then engage in both public and private chat with other users who are also logged on to the chatroom.

CHINESE ROOM An argument advanced by John Searle to illustrate the thesis that similar input/output behaviour is not sufficient to demonstrate that two systems are systems of the same kind in relation to their modes of operation. The Chinese room consists of an enclosure around a person who knows no Chinese but is equipped with a set of directions

(or 'dictionary') that instructs him or her what Chinese characters ought to be sent out when other Chinese characters are sent in. Although the person in the room knows no Chinese, his or her input/output behaviour is said to be identical with that of someone fluent in Chinese. A counterexample to the Turing test, Searle's argument has been the subject of a voluminous literature. See also EMULATION, REPLICATION, SIMULATION, TURING TEST.

CHURCH'S THEOREM Theorem proved by Alonzo Church showing that there is no mechanical routine (or decision procedure) for establishing the validity of arguments in quantificational logic with relations and multiple quantifiers.

CHURCH-TURING THESIS (*abbrev*. CTT) Broadly speaking, CTT suggests that the intuitive but informal notion of "effectively computable function" can be replaced by the more precise notion of "TM-computable function". CTT holds that if a computational problem cannot be solved by a TM then it cannot be solved by an algorithmic system. See ALGORITHM, COMPUTABILITY, DECISION PROCEDURE, TURING MACHINE.

CLOSED-WORLD ASSUMPTION A meta-linguistic rule concerning how database queries are to be handled: the closed world assumption allows the inference of a negative literal $\neg P(t_1, \ldots, P_n)$ from a failure to infer its positive counterpart $P(t_1, \ldots, P_n)$. Although the rule is formally unsound, it does allow for defeasible inference, in that if the literal $P(t_1, \ldots, P_n)$ were to be added to the database, $\neg P(t_1, \ldots, P_n)$ would no longer be inferred.

CLOSURE A set of objects S is closed under an operation R when for every member x of the set S, if x is R-related to y, then y is a member of set S.

COGNITION Any instance of any mental operation at any time where something stands for something else in some respect or other. Ordinary instances thereof include perception, recognition, inference, memory, and problem solving. Alternatively, a causal process that occurs when a system that has the ability to use signs of a certain kind becomes conscious of the presence of a sign in relation to its other internal states. When the system becomes conscious of something that functions as a sign for the system, cognition occurs as an effect of interaction between that sign and those states. Alternatively, any mental state that requires or involves representations.

COGNITIVE FUNCTIONS According to the computational theory of mind, cognitive (mental) abilities are exercised by means of the computation of cognitive functions. An example of a cognitive function in low-level vision is a function that maps patterns of retinal stimulation onto representations of scenes before the visual observer's eyes.

COGNITIVE MODELING The use of computers to simulate aspects of human thinking.

COGNITIVE SCIENCE Study of the nature and laws of cognition in human beings, other animals, and possibly machines. Cognitive science is an interdisciplinary field embracing philosophy, psychology, artificial intelligence, neuroscience, linguistics, and anthropology. The dominant paradigm within cognitive science has been the computational conception, which assumes that human beings and digital computers operate according to the same principles, at some suitable level. More recently, connectionist conceptions of the brain as a neural network have supplied the foundation for alternative theories of cognition, which may afford new solutions to the nature of mind and the mind/body problem. While computers may be useful within cognitive science, they are not essential to its being. A science of cognition could still be pursued even in the absence of these machines.

COHERENTISM A theory of justified belief according to which justification for a belief (or a set of beliefs) derives from confirmation or agreement from other beliefs in the set.

COMBINATORIAL OPTIMIZATION A combinatorial optimisation problem takes the form of minimizing the cost of certain solutions to a given type of task; a typical such task is to maximize the flow of goods in a road network, given that each road has a maximum capacity.

COMBINATORICS The area of mathematics concerned with counting classes of finite structures.

COMPACTNESS THEOREM A fundamental result about the nature and expressive limitations of classical first-order logic: it states that a set Γ of sentences is consistent if and only if every finite subset Γ_0 of Γ is consistent. Together with the Löwenheim-Skolem property, it characterizes first-order logic.

COMPETITIVE NETWORKS Connectionist networks (or artificial neural networks) in which units (or nodes) form pools: the units in a pool are all mutually inhibitory, while units outside of the pool bear excitatory connections to one or more units in the pool.

COMPILER A programming tool that translates a program written in a familiar high-level language like Basic, C++, or Java, into, typically, the machine language of a computer, which is composed only of zeroes and ones.

COMPLETENESS THEOREM A feature of classical first-order logic according to which a sentence ϕ is a logical consequence of a set Γ of sentences if and only if there is a formal proof of ϕ all of whose assumptions are drawn from Γ.

COMPUTABILITY The class of problems that can be solved by means of the application of algorithms to formal systems. The Church-Turing thesis establishes that a universal Turing

machine has the capacity to imitate any formal system, which implies that the boundaries of computability are the same as those of problems that can be solved by universal Turing machines. A parallel thesis about the nature of thought maintains that all thinking is computation because computability itself defines the boundaries of thought.

COMPUTATION, THEORY OF The mathematical analysis of data structures and algorithms.

COMPUTATIONAL PROCESS Generically, any form of behaviour or pattern of actions instantiating a formal specification and resulting in a state transition from input conditions to output conditions. For example, the process by which a card player arranges cards in her hand, and the process by which a computer sorts names in a customer list, though they share nothing in common physically, may nevertheless embody the same computational process. More technically, see ALGORITHM and COMPUTABILITY.

COMPUTER SCIENCE The science concerned with the study of computational processes and with the design and implementation of hardware and of software to solve problems, characteristically by means of algorithms (or effective procedures) implemented in the form of programs.

CONCEPTS What words stand for, signify, or mean, especially when meanings are taken to be in our heads rather than in the world. Words that are synonymous stand for the same concept. When sentences are synonymous, then they may be said to stand for the same proposition. Concepts are sometimes analysed as complex forms of dispositions or habits of mind and habits of action that instantiate different meanings.

CONCEPTUALIZATION An abstract, simplified view of some domain that we wish to represent for some purpose. See also ABSTRACTION.

CONDITIONALIZATION A process of changing degrees of belief under the influence of new information in accordance with (a special application of) Bayes' theorem. If '*Pn*' stands for the new probability distribution ('posterior' to or subsequent to the acquisition of some new information *E*) and '*Po*' stands for the old distribution ('prior' to the acquisition of that new information *E*), then according to the principle of conditionalization, $Pn(X) = Po(X/E) = Po(E/X) \bullet Po(X)/Po(E)$. Given this interpretation, Bayes' theorem functions as a dynamic requirement that must be satisfied by sets of beliefs as they change across time as opposed to its normal use as a static requirement of a set of beliefs at one time. See also BAYESIANISM, BAYES' THEOREM.

CONDITIONALS Complex sentences of 'If . . . then ___' form, where the '. . .' sentence is known as the antecedent and the '___' sentence as the consequent. While many kinds of conditionals occur in English, logicians focus on certain varieties in constructing models for

understanding arguments. The simplest kind of conditional is the *material* or 'truth-functional' conditional, where the truth or falsity of a sentence of this form depends exclusively upon the truth value of its components. When either the antecedent is false or the consequent is true, sentences of this kind are said to be true. A second kind of conditional is the *subjunctive* (or 'were'/'would') conditional, which characterizes how things would be on the assumption that the antecedent were true. Thus, the sentences, 'If this stick of dynamite were ignited, then it would explode', and 'If this stick of dynamite were ignited, then it would not explode', as material conditionals, might both be true as long as their antecedents are false. But as subjunctive conditionals, they cannot both be true, since they characterized different ways things would be on the assumption that their antecedents were true. Subjunctives with false antecedents are also called *counterfactual* conditionals. Among various kinds of conditionals that are also studied by philosophers of science are causal conditionals, nomic conditionals, and probabilistic conditionals.

CONFIRMATION VS. TRUTH Evidence that confirms an hypothesis does not thereby guarantee its truth. Truth appears to be a relation involving sentences in a language where a sentence is true when what that sentence asserts to be the case is the case. But a sentence can be confirmed even if it is false and can be true even if it is never confirmed. The hypothesis of the existence of intelligent life elsewhere in the universe may be true, yet remain unconfirmed. Newtonian mechanics was among the best confirmed theories in science, yet it no longer appears to be true. Truth is a semantic (or ontic) concept, but confirmation is a pragmatic (or epistemic) concept. For theories, such as coherence theories, that reject more traditional conceptions of truth, belief sets that satisfy specific relations of coherence among themselves, in particular, may be viewed as confirmed or as true (or both).

CONJUNCTIVE Pertaining to conjunction, as in A & B, where both A and B are true.

CONNECTED PROBLEMS Problems that do not divide into independently solvable subproblems. A paradigm example is the traveling salesman problem. The goal is to find the shortest route that a salesman can take to visit each of a number of cities, while visiting each city only once. Since which city the salesman visits depends on which cities he has already visited, the problem does not divide into independently solvable subproblems.

CONNECTIONISM An approach to computation, cognitive science and philosophy of mind that views the brain as a neural network of numerous nodes that are capable of activation. These nodes can be connected to other nodes where, depending on their levels of activation, they might bring about increases or decreases in the levels of activation of those other nodes. These patterns of activation, in turn, can function as signs for the larger systems of which they are otherwise meaningless parts by coming to stand for other things for the systems of which they are elements. This process is known as learning, conditioning, or reinforcement, where the impact of experience in the shaping of behaviour depends upon the causal tendencies instantiated by a specific connectionist system. Connectionist architectures of the brain differ from traditional conceptions in many respects. One is that connectionist brains are capable of parallel processing, which means that more than one

stream of data, information, or knowledge may be processed at the same time. Traditional machines can be arranged to process data simultaneously, but each machine can only process one stream of data sequentially. More important is that connectionist brains are capable of distributed processing, which means that the bearers of information or knowledge in connectionist systems are patterns of activation rather than individual nodes. Some versions of connectionist system make individual nodes (or units) the bearers of information, but they fail to exploit what may be the greatest advantage of the connectionist approach. Additionally, different kinds of connectionist systems seem to typify different species. Thus, connectionism offers an approach that promises to clarify and illuminate the mental properties of other species. This is the dominant research program in cognitive science today. Among the most important books within this area is a two-volume set of studies edited by David Rumelhart, James McClelland and the DPD research group.

CONSCIOUSNESS A state of awareness capable of degrees, where a person (animal, machine) might be conscious of some phenomena but not conscious of other phenomena. The range of possible awareness appears to be determined by neurophysiological capacities under the influence of environ- mental histories. Thus, with respect to signs (marks, symbols), for example, a person may be said to be conscious with respect to signs (marks, symbols) of some kind when they have the ability to use those symbols and they are not incapacitated from exercising that ability. When a sign (mark, symbol) of that kind occurs within suitable causal proximity, then cognition results. Consciousness should be distinguished from self-consciousness, which is an awareness of one's own self. Self-consciousness, like consciousness, is amen- able to degrees, where some persons are more self-conscious (self-aware or self-knowing) than others.

CONSTRUCTIVISM Ernst von Glasersfeld defined as 'radical constructivism' the claim that knowledge is actively built up by the knowing subject. Thus, the external world does not exist independently of the subject, as a separate ontological reality; on the contrary, it exists as the world of the subject's experience.

CONVENTIONS Shared habits, tendencies, and dispositions qualify as conventions when they are reinforced by the community, as in the case of natural languages taught by public schools.

COOKIE File placed on a user's computer when the user visits a web site. The file allows the web site to keep track of subsequent visits. Cookies can be sent without the user's knowledge or consent.

COUNTERFACTUAL SUPPORT A generalization is said to be counterfactual-supporting if it is not only true of its instances, but also would be true of relevant non-instances. For example, the generalization 'metals expand on heating' is counterfactual-supporting because it not only says something true about what happens to heated metals, but also says something true about what would happen to unheated metals, were they heated (contrary to

actual fact). In contrast, 'everything in Nelson Goodman's pocket on VE Day was silver' is not counterfactual-supporting because, even if all the things in Nelson Goodman's pocket on VE Day were in fact silver, there are many non-silver objects that might have been in Nelson Goodman's pocket on VE Day. It is widely thought to be a requirement on nomic generalizations (as opposed to mere accidentally true generalizations) that they support counterfactuals.

COVARIATION (OF PROPERTIES) Properties *P* and *Q* covary just in case *P* is instantiated if and only if *Q* is instantiated.

CRYPTOLOGY The study of the mathematics of secret codes or cryptosystems. It encompasses cryptography, the art of designing cryptosystems, and cryptanalysis, the art of breaking cryptosystems.

CURRY-HOWARD CORRESPONDENCE A correspondence between terms in the calculus and proofs in intuitionist logic

CUT A formal property of classical first-order logic and many defeasible systems (more precisely: of the associated consequence relations) according to which adding a previously reached conclusion to the premise-set does not lead to any increase in inferential power.

CYBORG A short form of 'cybernetic organism,' that is, some machine-animal hybrid.

DASEIN Heidegger's name for human being. The German literally means 'being there' or 'there being.' Because of its technical philosophical meaning, it is usually not translated.

DATA ABSTRACTION The specification of computational objects (like customers, recipes, flight plans, chat rooms, etc.) and all operations that can be performed on them, without reference to the details of their implementation in terms of other data types. Such objects, called data types, once they become implemented, assume their place among integers, arrays, and so on as legitimate objects in the computational world, with their representation details, which are necessarily more machine-oriented, being invisible to their users.

DATA Normally, information is conveyed by large clusters of well-formed, codified data, usually alphanumeric, which are heavily constrained syntactically and already very rich semantically. However, in its simplest form a datum is any lack of uniformity or anything that makes a difference: a light in the dark, a black dot on a white page, a 1 opposed to a 0, a sound in the silence, the difference between the presence and the absence of a signal. In chapter five, data are also defined as constraining affordances or answers without questions: 12 is a sign that makes a difference, but it is not yet informative, for it could be the number

of the astrological signs, the size of a pair of shoes or the name of a bus route in London, we do not know which. Computers certainly treat and 'understand' data. It is controversial whether there is any reasonable sense in which they can be said to treat and understand information.

DATA STRUCTURE A way to store and organize data in order to facilitate access and modifications.

DATAGLOVE A glove-like device containing sensors that provides computer input concerning the movements of the user's hand, allowing the manipulation of computer-generated objects in virtual reality.

DEBUGGING The process of eliminating errors (or 'bugs') from a computer program.

DECISION PROBLEM (*ENTSCHEIDUNGSPROBLEM*) Formulated by Hilbert, the decision problem for a given formal system is the problem of providing a formal algorithm to determine whether a sentence Γ can be inferred from a given knowledge base in the system. More broadly, a decision problem takes the form of a family of problem instances, for each of which a 'yes' or 'no' answer is required. In the case of the decision problem for predicate logic, the instances take the form of sentences of first-order logic, for which we want to know the answer: 'Is this sentence satisfiable?' The decision problem for classical first-order logic was proved to be unsolvable by Church and Turing in 1936.

DECISION PROCEDURE (Also known as 'effective procedure'.) A routine or procedure that can be carried out in a finite sequence that in every case yields a definite answer ('Yes' or 'No') to a question within a specific domain of inquiry. The discovery of a decision procedure for a fixed class of problems is known as the decision problem. Once a decision procedure has been found, the problem is solvable and those questions are decidable. See also ALGORITHM and DECISION PROBLEM.

DELTA RULE A supervised learning algorithm for weight change in connectionist networks (or artificial neural networks). The algorithm changes the weights leading from units (or nodes) sending signals to output units on the basis of the discrepancy between the actual output and the desired one so as to lesson the difference.

DERIVABILITY, SYNTACTIC A formula of a formal system is syntactically derivable from a set of formulae of a formal system (as premises) when it follows from those premises in accordance with an accepted rule of inference of that system. When those premises are *axioms* of the system, such a formulae is said to be a *theorem*. Such rules of inference are formal insofar as their application depends exclusively upon the formal properties (of shape and size, etc.) of the marks that constitute (what is usually called) the vocabulary of that system, without concern for possible interpretations that make those formulae meaningful or

true. The construction of a formal system, however, is normally motivated by the desire to reflect corresponding relations of semantic entailment with respect to the objects and relations of some abstract or physical domain.

DETERMINISTIC CHAOS Attractor of a dynamical system with nonlinear dynamics, nonperiodic and bounded trajectories, and exponential dependence on initial conditions. See also BUTTERFLY EFFECT.

DIGITAL A description of data or information that is stored or transmitted as a sequence of discrete symbols from a finite set. Most commonly, this means binary data represented using electronic or electromagnetic signals. In chapter 13 a digital property (or process or system) is one that is finitely recursive.

DOMAIN ONTOLOGY The extension or specification of a top-level ontology with axioms and definitions pertaining to the objects in some given domain.

DYNAMICAL SYSTEMS THEORY Popularly known as chaos theory, the study of the iterative dynamics of classes of mathematical functions, and their applications. A central focus of dynamical systems theory has been iterated mathematical functions that show 'sensitivity to initial conditions': when the output of the function is repeatedly taken as input, initial conditions that are arbitrarily close produce results arbitrarily far apart, something known as the 'butterfly effect'.

EFFECTIVE PROCEDURE See DECISION PROCEDURE.

EMERGENCE Synergetic and macroscopic phenomena of dynamical systems explained by collective and non-linear interactions of their elements.

EMULATION One system emulates another when they stand in a relation of replication and are composed of the same material. Thus, if humans and machines can not only simulate each others input/output behaviour but also share the same modes of operation, then they can stand in a relation of replication. But only systems that are composed of the same components--such as metal and silicon or flesh and blood--can stand in a relation of emulation. In relating systems on the basis of their input/output behaviour, their modes of operation, and their material of composition, this is the strongest possible relationship between systems. See also REPLICATION, SIMULATION, TURING TEST.

ENTAILMENT (SEMANTIC) A set of interpreted formulae of a formal system (the premises) semantically entails another interpreted formula (the conclusion) when the conclusion cannot be untrue if the premises are true (the use of "untrue" instead of "false" is meant to avoid ruling out many-valued versions of entailments). The construction of a formal

system tends to be motivated by the desire to establish relations of syntactic derivability reflecting corresponding relations of semantic entailment. Within sentential logic, for example, an argument is syntactically valid if and only if its corresponding conditional, that is a conditional formed by taking the conjunction of its premises as its antecedent and its conclusion as its consequent, is a logical truth.

EPISTEMIC Of or pertaining to knowledge or justification.

EPISTEMOLOGY See ONTOLOGY/EPISTEMOLOGY

ERGODIC SOURCE A stochastic source of an unlimited number (or ensemble of unlimited sequences) of symbols (messages), which satisfies two properties: (i) the statistical nature of its messages does not change with time (the source is stationary); and (ii) the statistics based on one message apply equally well to all messages that the source generates. A tossed coin is an ergodic source.

EROTETIC LOGIC The logic of questions, answers, and the formal relations between them.

EUKARYOTE One of the two major groupings into which all organisms are divided (the other is prokaryote). Included are all organisms, except bacteria and cyanobacteria. The cells of eukaryotes possess a clearly defined nucleus, bounded by a membrane, within which DNA is formed into distinct chromosomes. Eukaryotic cells also contain mitochondria, chloroplasts, and other structures (organelles) that, together with a defined nucleus, are lacking in the cells of prokaryotes.

EXPERT SYSTEM In its narrower sense, expert systems are restricted to production systems of condition/action rules, where when certain conditions are fulfilled, a certain action is taken (or recommended). In a broader sense, expert systems are any systems that are based upon domain-specific knowledge acquired by an expert. In this sense, scripts and frames and semantic networks may qualify, too. Typically, the construction of an expert system is envisioned as a process of knowledge acquisition, knowledge representation, and knowledge utilization. Perhaps the most important problem encountered in the development of expert systems is picking the right expert.

EXPONENTIAL If F (n) is a quantity depending on a numerical parameter n, then we say that F (n) is exponential in n if there is a constant c ? 0 so that F (n) ? 2 cn for infinitely many n. For example, the truth-table method for deciding satisfiability of propositional formulas requires exponentially many steps as a function of the number of variables in a formula.

EXTENSION OF A THEORY In defeasible reasoning, an extension is a maximally consistent set of defeasible conclusions that reasoners could be regarded as warranted in inferring from the theory. In many formalisms, theories can have zero, one, or more extensions.

EXTERNALISM The view that at least some of the conditions that make knowledge possible may forever lie beyond or external to the ken of the would-be knower.

FEEDBACK Informally speaking, the return of a signal that indicates the effect of an action, in order to determine further action by a (mechanical, electrical, electronic) system. Negative feedback is distinguished from positive feedback. In the first case the returning signal is error correcting; in the second case, it is error amplifying.

FEEDFORWARD NETWORKS A non-interactive connectionist network (or artificial neural network) in which activation flows in one direction only, from input units (or nodes) through however many layers of hidden units the network contains to output units. The Hamming net is a widely used feed-forward network with three layers of units, one of which is a layer of hidden units.

FIXED POINT in a phase space, a point that is attractor of all trajectories of a dynamical system.

FLOATING POINT OPERATION The hardware of current conventional computers (and pocket calculators) is designed to perform 'floating point arithmetic,' that is, their basic arithmetical circuits perform additions and multiplications of numbers represented in 'scientific notation,' as in the case of Avogadro's number N = 6:02252 \Theta 10 23 . A common measure of speed for supercomputers is the number of floating point operations performed per second; a speed of one megaflop represents one million floating point operations per second. The IBM RS/6000 SP supercomputer was reported in June 2000 to have a performance in excess of 1 teraflop (a trillion (10^{12}) floating point operations per second).

FORMAL PROGRAM VERIFICATION DEBATE The debate over whether formal program verification can offer guarantees of program correctness and reliability. Opponents of formal program verification claim that it can offer no such guarantees. Proponents believe that it can largely replace program testing in the identification of program bugs (errors).

FORMAL PROGRAM VERIFICATION The process of determining whether a program conforms to its specification, not by empirically testing the program to observe its behaviour, but by mathematically reasoning about its algorithm as a formal, abstract object.

FORTRAN A programming language, designed in the 1950's, intended for the solution of scientific problems

FOUNDATIONALISM The view that some beliefs are not justified by other beliefs, but by experience, self-justification or some source other than relation to other beliefs.

FRAME PROBLEM There appear to be several versions. The most restricted version takes it as the problem of designing and implementing a program for anticipating what will and what will not change about a situation (or state of affairs) across time. A less restricted version takes it as the problem of discovering the kind of knowledge that would provide the foundation for designing and implementing a program for solving the first version. Moreover, some theoreticians maintain that the problem concerns common sense rather than scientific knowledge, whereas others, with some justification, contend that scientific knowledge is required to resolve it. Among those who deals with this problem are John McCarthy and Pat Hayes.

FUNCTIONAL A mathematical function whose domain is a set of functions. For example, definite integration is a functional which, when given a function, returns a number (the integral of that function over a particular interval).

FUNCTIONAL PROGRAMMING A programming language is functional if it has no assignment statements: this makes its semantics particular tractable.

FUNCTIONALISM There are at least two principal varieties. The first is *machine state* functionalism, which maintains that human beings can be properly understood as special instances of computing machines, and mental activity involves functional transitions from one state to another. This position was advocated by Hilary Putnam in some of his early work. The second is *causal role* functionalism, which maintains that the mean- ing of a mental representation (symbol, sign) either is or is determined by its causal role in influencing behaviour. Machine state functionalism is not widely advocated at present, but causal role functionalism is popular.

GELASSENHEIT German for calmness, composure, tranquillity. Used by Meister Erkhart to name mystical detachment or releasement. Heidegger picks up the term and presents the Gelassenheit as the opposite of the technological attitude toward the world.

GESTELL A German word that in everyday parlance means ‘stand,’ ‘rack,’ ‘shelf,’ etc., which Heidegger adopts as a technical term for what he calls the essence of modern technology, its enframing of the world, transforming the world into Bestand or resources.

GOFAI Good Old-Fashioned Artificial Intelligence, see AI, STRONG.

HEBB RULE A learning algorithm for weight change in a connectionist network (or artificial neural network). The Hebb Rule is based on Donald Hebb’s hypothesis that the connections between two neurons might strengthen whenever they fire simultaneously. According to Rumelhart and McClelland’s formulation of the Hebb rule, the weight of a connection between units should be increased or decreased in proportion to the products of their simultaneous activations.

HALTING PROBLEM The problem of deciding whether a particular computer program will ultimately halt or not. This was historically the first undecidable problem to be discovered.

HAPTIC Pertaining to the sense of touch. In the context of computers, haptic feedback can refer to the simple feel of a keyboard or mouse, or to more sophisticated forms of tactile feedback employed by some virtual reality systems.

HEAD-MOUNTED DISPLAY A helmet or goggle-like device that provides computer input concerning the user's head and eye movements which are then used to change and update virtual reality displays in ways appropriate to those head and eye movements.

HERMENEUTICS From the name for the Greek messenger god, Hermes, hermeneutics is the study of messages or the science of interpretation.

HEURISTICS In the absence of algorithms, generalizations or 'rules of thumb' that are useful but have exceptions can turn out to be very helpful in dealing with problems that might not otherwise be resolved. Since inductive generalizations are amenable to exceptions due to their fallible character as the conclusions of arguments that are ampliative, and non-demonstrative, a terminological decision has to be arrived at as to whether reliance upon induction is or is not a matter of heuristics.

HOLISM OF BELIEF FIXATION The claim that it is impossible to fix, or come to, a given belief without holding in place a number of other beliefs at the same time. According to this view, an experimental datum confirms (i.e. verifies, gives us some reason to believe) a given statement only in conjunction with one's other theoretical commitments, background assumptions about the experiment, and assumptions about the logical and mathematical apparatus connecting the datum to these other beliefs.

HOMEOSTASIS Self-regulation, the ability or tendency of an organism or a cell to maintain internal equilibrium by adjusting its physiological processes and their variables, such as body temperature or blood pressure, which are important for the survival or health of living organisms.

HYPER-DIGITAL A hyper-digital property (or process or system) is one that is transfinitely recursive.

ICONS In the theory of signs advanced by Charles S. Peirce, icons are things that stand for that for which they stand by virtue of a relation of resemblance that obtains between that sign and that for which it stands. Thus, photographs, paintings, and statues are familiar icons.

ICQ (‘I seek you’) See CHAT

ICT Digital Information and Communication Technologies.

IMITATION GAME A game in which a thing of one kind is pitted against a thing of another kind to see if it can cause a contestant to mistake it for the other kind. At a party, a man might be paired up against a woman, where a contestant might be asked to guess which is which based strictly upon their answers to questions. If the man were trying to pose as a woman, then he would be permitted to give false answers, but not the woman. As a serious test, a machine might be paired up with a human being, where a contestant might be asked to guess which is which based strictly upon their answers to questions. The machine would also be permitted to give answers that were false. The presumption is that a machine that could fool a human contestant into thinking that it were human would be equal to its human counter- part with respect to the characteristic tested. Yet even if the man were to fool a contestant into thinking he was a woman, that would not change his sex. (Cf. emulation; replication; simulation; Turing test.)

INDICES In the theory of signs elaborated by Charles S. Peirce, indices are signs that stand for that for which they stand by virtue of being causes or effects of that for which they stand. Thus, smoke is an index of fire and fire is an index of smoke. Excellent examples of indices in this sense are symptoms in relation to a disease.

INDUCTION, MATHEMATICAL Its name notwithstanding, mathematical induction is a special case of deductive reasoning and a fundamental principle of mathematical reasoning for the natural numbers. Mathematical induction allows one to prove that, if 0 has the property P and, whenever a number has P, so does its successor, then every number has the property P. Variants of mathematical induction apply to other well-ordered or recursively defined collections.

INFERENCE The process of drawing conclusions from premises, especially when that process could be justified on the basis of logic. Thus, the free association of ideas does not properly qualify as inference. Rules of deduction and induction are called *rules of inference*.

INFERENCE TO THE BEST EXPLANATION See ABDUCTION.

INFERENCE, RULES OF Both deductive and inductive reasoning are governed by rules of inference, which specify what follows from what (in the case of deductive rules), and what supports what (in the case of inductive rules). A familiar deductive rules of inference is *modus ponens*. Accord- ing to this rule, given ‘if *p* then *q*’ and ‘*p*’, infer ‘*q*’, where the conclusion cannot be false if the premises are true. A familiar inductive rule of inference is *the straight rule*, which is also known as induction by enumeration: if *m*/*n* observed *A*s have been *B*s, infer that *m*/*n* *A*s are *B*s, when a large number of *A*s have been observed

over a wide variety of conditions. But inductive conclusions can still be false even when their premises are true.

INFORMATION (SEMANTIC) Chapters 4 and 9 follow Floridi's definition: in its weaker sense, semantic information is well-formed, meaningful data; in its stronger sense, well-formed and meaningful data that is truthful. See also DATA.

INFORMATION CARRYNG According to Dretske, a signal *r* carries the information that *p* just in case the conditional probability of *p*, given *r*, (and *k*, the knowledge of the receiver of *r*), is 1 (but given *k* alone, less than 1).

INFORMATION SYSTEMS ONTOLOGY A concise and unambiguous description of principal, relevant entities of an application domain. A dictionary of terms formulated in a canonical syntax and with commonly accepted definitions, of such a sort that it can yield a shared framework of knowledge-representation on the part of different information systems communities.

INTELLIGENCE Historically, intelligence has been viewed as the capacity or ability to learn. When that ability or capacity is evaluated in relation to one's chronological age by employing standardized tests, the result is a numerical value known as IQ. The problem that has plagued IQ tests is that IQ must be something more than merely an IQ test score or else it would not be worth measuring. There are those who suggest that the term 'intelligence' carries with it an evaluative connotation, where its meaning presupposes mentality and it indicates a *high level* of mentality. Alternatively, its use in the context of the phrase, 'artificial intelligence', raises the possibility that, even if machines are incapable of possessing 'ordinary intelligence', they might still be described as 'intelligence machines' by virtue of their capacity to perform various complex tasks successfully and reliably, especially ones that have required human beings in the past.

INTENTIONAL About something. Things that are about other things (e.g., mental states, words) are said to have intentional properties. Not to be confused with a different, ordinary usage of 'intentional' to mean *on purpose*.

INTERACTIVE NETWORKS Connectionist networks (or artificial neural networks) in which two units (or nodes) can mutually influence each other's state of activation.

INTERNALISM The view that the conditions that confer knowledge or justification must, in principle, be accessible to the would-be knower.

INTERPRETATION An interpretation for a language L specifies a non-empty domain D of individuals and assigns objects from D to the names of the language and sets of n-tuples from D to the n-place predicates of L .

INTROSPECTION A faculty or capacity for deriving knowledge, especially about one's own mental states, by internal observation. Two kinds of knowledge by introspection can be distinguished, those which attend to mental states at the time of their occurrence and those which attend to mental states that have been acquired in the past. When past mental states are the object of contemplation through a process of recollection or remembering, the introspective faculty is also known as that of memory.

IRC (Internet Relay Chat) See CHAT

ISOMORPHISM A structure preserving, one to one mapping from one structure to another structure, also holding in the inverse relation.

KNOWLEDGE REPRESENTATION Different schemes for representing knowledge have been advanced, including predicate calculus, scripts and frames, and production systems. The theory of knowledge representation, when adequately elaborated, ought to provide a foundation for understanding when one or another mode of knowledge representation is most appropriate and the strengths and limitations thereof.

KNOWLEDGE VS. BELIEF The tradition theory of knowledge holds that *x* knows that *p* if and only if (i) *x* believes that *p*, (ii) *x* is justified in believing that *p*, and (iii) *p* is true. Hence, knowledge is envisioned as warranted true belief. Some alternative conceptions of knowledge have viewed knowledge as true belief, in which case the possession of knowledge can be merely accidental, or as warranted belief, in which case persons can know things that are not true. Belief itself, however, is never viewed as sufficient for knowledge, where the importance of beliefs in practical contexts stems from the guidance that they provide in the conduct of behaviour and in theoretical contexts from the foundation they provide for systematically explaining and predicting events.

KNOWLEDGE, EMPIRICAL Knowledge about the external world, especially knowledge that is justified on the basis of direct perception or inductive or deductive inferences based upon direct perception. Alternatively, any knowledge that is synthetic rather than analytic and a posteriori rather than a priori. A distinction may be drawn between empirical and scientific knowledge, where the objects of *empirical knowledge* are singular sentences that describe the contents of relatively isolated regions of space/time and the objects of *scientific knowledge* are generalizations (hypotheses and theories) about laws of nature that define the world's structure. Scientific knowledge can then be said to be based on empirical knowledge, yet not be reducible to it.

KNOWLEDGE, STANDARD DEFINITION OF The definition of 'knowledge' as true belief supported by evidence. Beginning with Plato's *Theaetetus*, 'knowledge' is viewed as true belief *plus* something which has the function of preventing knowledge from being merely a matter of accident or hunch, superstition or a lucky guess. This conception assumes that knowledge requires satisfying a suitable condition of *evidential justification* that goes beyond having a belief that happens to be true.

LAMBDA CALCULUS A logical calculus based on the idea of the application of functions to their arguments

LANGUAGE A system of signs used for communication between human beings. *Ordinary* languages include English, French, German, and any other used by a community of humans. *Artificial* languages can be constructed for special purposes, such as the development of formal systems, the programming of computers, and the like. Se also ARTIFICIAL LANGUAGE, NATURAL LANGUAGE, SEMANTICS and SYNTAX.

LANGUAGE OF THOUGHT HYPOTHESIS The thesis that there is a system of mental representation with a compositional syntax and semantics. This language is often called *Mentalese*. Perhaps the leading theory of thinking in the computational theory of mind appeals to the language of thought hypothesis, maintaining that thinking consists in the manipulation of mental symbols in virtue of their syntactic properties. These syntactic operations are supposed to are such that the mental symbol transitions can be interpreted as processes of reasoning (deductive, inductive, or analogical) given the meanings of the mental symbols. The theory of meaning for mental symbols is called *psychosemantics*. (See entry SYMBOLS [2], on the meanings of mental symbols.) Jerry Fodor, the leading proponent of the language of thought hypothesis, has argued that concepts are words in the language of thought, and that having a propositional attitude in a certain intentional mode (e.g., belief, desire, intention, etc.) with the content that P consists in bearing a computational relation constitutive of the intentional mode to a mentalese sentence that means that P. Thus, for instance, to believe that P is to bear a certain computational relation R constitutive of the belief relation to a mentalese sentence that means that P, to desire that P is to bear a certain computational relation R* constitutive of desire to a mentalese sentence that means that P, and so on. This theory of propositional attitudes, he contends, offers the best explanation of the systematicity of capacities to have propositional attitudes and of the productivity of propositional attitudes. Fodor has also maintained that every (neurologically normal) human being has an innate stock of primitive mental symbols (concepts) that are sufficient, in principle, to draw every distinction that may ever be drawn in any human language. This innateness hypothesis is, however, logically independent of the language of thought account of thinking, concepts, and propositional attitudes.

LANGUAGE, ARTIFICAL Any system of notation and its rules of correct use (syntax) which has been constructed for special purposes other than ordinary communication between the members of a language-using community. Good examples include formal systems in logic and pure mathematics (as uninterpreted systems) or programming languages in computer science (as interpreted systems). According to this definition, certain special

cases (such as Morse code) can be viewed as falling in between natural and artificial language. See also LANGUAGE, SEMANTICS, SYNTAX.

LANGUAGE, NATURAL Any system of notation and its rules of use which has been developed for the general purpose of facilitating communication between the members of a language-using community. Examples include English, French, German, Russian, Japanese, and Chinese. They are often viewed as conventional. Though the basic unit of meaning for a language appears to be the habits, tendencies, and dispositions of individual language users, communities (usually typified by the populations of specific geographical regions, with their traditions and practices) promote the use of the same linguistic habits, tendencies, and dispositions between different language users to promote communication and cooperation between them. See also ARTIFICIAL LANGUAGE, LANGUAGE.

LIGHT AI The alternative to GOFAI (Good Old-Fashioned Artificial Intelligence), see AI, Strong.

LIMIT CYCLE In a phase space, closed orbit that is attractor of all trajectories of a dynamical system.

LINEAR DYNAMICS Dynamics determined by a linear equation: The rate of dynamical effects is proportional to its cause.

LINEAR PROGRAMMING Suppose that we are given a number of variables that can take real or integer values, and that we wish to maximize an objective function given as a linear function of the inputs such as 5x+3y polynomial: A polynomial in one variable n is an expression such as 5n 3 +3n 2 n lies in the fact that in a polynomial, n occurs in the base, but the exponents are fixed, while in the second expression, n occurs in the exponent.

LISP Historically the first functional programming language

LISTSERV An e-mail system that distributes messages to and from a list of subscribers. While most listservs automatically redistribute messages to members as they are sent, some listservs are moderated: messages first go to the moderator/editor who then determines whether they are appropriate for further distribution and discussion by the list members.

LOGIC The study of arguments, which are usually separated into the categories of deductive and inductive. The first system of logic was that of classical term logic, formalized by Aristotle, which studied the validity of arguments that can be formulated by means of a restricted class of sentences having specific kinds of logical form. Classical term logic characterizes the conclusions that follow from one premise (called immediate inference) and the conclusions that follow from two premises (called syllogistic inference), when premises

and conclusions are restricted to so-called categorical sentences. Until around the mid-19th century, Aristotelian logic was widely viewed as exhaustive of the subject. But the introduction of the sentential function by Gottlob Frege revolutionized the subject, and today Aristotelian logic is recognized to be only a special and relatively modest fragment of modern logic, which includes sentential logic (or the study of arguments when whole sentences are the basic units of analysis) and predicate logic (or the study of arguments when sentences are analysed on the basis of their internal structure). Although elementary logic is exclusively extensional (or 'truth functional'), advanced logic pursues the formalization of intensional relations that are not merely truth-functional, including the nature of subjunctive, causal, and probabilistic conditionals, but also set theory, recursive function theory, and the theory of models.

LOGIC, AUTOEPISTEMIC The modal logic of the operator 'the agent knows that p'. The agent can reach (defeasible) conclusions about the world based on its own epistemic state.

LOGIC, CLASSICAL TERM A system of logic studied by Aristotle that is restricted to the validity of arguments that are composed of sentences of four basic kinds called 'categorical sentences', namely: (A) *universal affirmative*: All *S* are *P*; (E) *universal negative*: No *S* are *P*; (I) *particular affirmative*: Some *S* are *P*; and (O) *particular negative*: Some *S* are non-*P*. There are two principal branches, know as *immediate inference* (which studies arguments having one categorical premise and one categorical conclusion) and *syllogistic inference* (which studies arguments having two categorical premises and one categorical conclusion). Medieval logicians discovered that two sets of logical relations are involved here, depending upon whether the subject (*S*-term) and predicate (*P*-term) classes are assumed to have at least one member, which is known as *the existential presupposition*. On the existential presupposition, for example, (I) sentences follow from (A) sentences, but not when that presupposition is not made. Hence, even with respect to immediate inference, there are two sets of logical relations, known as the *strong* and as the *weak* squares of opposition, whose respective differences depend upon whether the existential presupposition is adopted.

LOGIC, DEFAULT A particularly flexible, non-monotonic formalism introduced by R. Reiter, based on the notion of a defeasible inference rule called a 'default'.

LOGIC, EXTENSIONAL Any system of logic that restricts its attention to truth-functional operators and truth-functional properties of and relations between sentences. Operators, properties and relations of this kind are exclusively ones for which semantically relevant features of language and logic are limited to functions of truth values (true/false) exclusively.

LOGIC, INTENSIONAL Any system of logic that goes beyond merely truth-functional operators and truth-functional properties of and relations between sentences. Among the kinds of sentences that are studied within intensional logics are subjunctive conditionals,

counterfactual conditionals, nomological conditionals, deontological conditionals, and others unnamed.

LOGIC, INTUITIONIST A logic, invented by Brouwer and based on the idea of mental constructions, which rejects the principle of excluded-middle.

LOGIC, MODAL A logic designed to represent state transitions: the logic associate a modality $\Box$ with each state transition $\rightarrow$, where semantically a sentence $\Box$ A is true at a state s if and only if A is true at every state s′ such that $s \rightarrow s'$.

LOGIC, PREDICATE Any system of logic that analyses the validity of arguments on the basis of the internal structure of sentences rather than treating them as basic units of analysis. Even the traditional argument, 'All men are mortal; Socrates is a man; therefore, Socrates is mortal', cannot be successfully analysed within sentential logic, since it has the form, '*p*; *q*; therefore, *r*', where '*p*', '*q*', and '*r*' are variables standing for unspecified sentences, which is not a valid form. Within predicate logic, however, it can be analysed as having the form, '$(x)(Hx \rightarrow Mx)$; *Hs*; therefore, *Ms*', where '*Hx*' means '*x* is a man (human)', '*Mx*' means '*x* is mortal', and '*s*' stands for 'Socrates'. When predicate logic is restricted to properties of and relations between individuals with no quantification over properties, it is known as 'first order'; when quantification over properties is allowed, it is 'second order' instead. Almost all investigations within contemporary logic go beyond predicate logic.

LOGIC, SENTENTIAL Any system of logic that restricts it attention to entire sentences, while ignoring the internal structure of the sentences themselves.

LOGICAL CONSEQUENCE A relation between sets Γ of sentences and single sentences ϕ. Logical consequence for classical first-order logic (denoted by $\models$) requires that ϕ be true on every interpretation on which all sentences in Γ are true. Other formalisms, most notably defeasible ones, employ alternative definitions.

LOGICAL POSITIVISM/LOGICAL EMPIRICISM Closely related, influential philosophical movements that emerged between World Wars I and II. Logical positivism accepted the analytic/synthetic distinction, the observational/theoretical distinction, and a methodological commitment to the use of extensional logic for philosophical explications. Sometimes it embraced the thesis that every meaningful non-analytic sentence is either an observation sentence or a deductive consequence of observation sentences, as in A. J. Ayer's *Language, Truth and Logic*. Logical empiricism succeeded logical positivism by abandoning this overly stringent conception of cognitive significance and, in some cases, by abandoning the analytic/synthetic distinction or, in other cases, by abandoning the observational/theoretical distinction. Rudolf Carnap, one of the most important members of these movements, later abandoned even the methodological commitment to extentional languages as indispensable for philosophical explications.

LOGICISM The view that all of mathematics can be reduced to logic.

LOGICS, DEFEASIBLE Logics in which the implications of a given piece of information can be overridden by later additions. A piece of information P may be taken to warrant a conclusion Q, though later additional information R 'defeats' that conclusion.

LOGICS, INFINITE-VALUED In classical logics, sentences or propositions are thought as taking only one of two values: True or False. In infinite-valued logics, including 'fuzzy logics', sentences or propositions are allowed to take intermediate truth-values: 1/3 true or 1/2 false, for example.

LOGICS, MONOTONIC Logics that allow 'strengthening of the antecedent': if P entails Q, then P conjoined with any other R also entails Q. Contrasted with non-monotonic or defeasible logics.

LOOPING The process of repeatedly executing a section of a program until some condition is met.

LÖWENHEIM-SKOLEM THEOREM Any theory in classical first-order logic (with identity) that has a model has a countable model.

MACROSCOPIC STATE Global state of a dynamical system determined by the collective interactions of its microscopic elements.

MATHEMATICS, PURE VS. APPLIED Mathematics may be pursued as the study of formal systems, where applications of those formal systems are restricted to abstract domains. This is the area of pure mathematics. Mathematics may also be pursued as the study of formal systems where those systems are subject to empirical interpretations. This is the area of applied mathematics, which also qualifies as a branch of empirical science. Alternatively, the domain of mathematics can be restricted to comparative (or topological) relations and to quantitative (or metrical) relations exclusively.

MEANING The problem of meaning, sometimes also referred to as the problem of representation or the problem of content, is among the central issues confronting cognitive science. Since different signs (words, sentences) can have the same meaning, the meaning of a sign (word, sentence) cannot be properly identified with its linguistic (or other) formulation. In the case of defined signs (words, sentences), there exist equivalence classes of signs (words, sentences) that have the same meaning, but that two or more signs (words, sentences) have the same meaning as does not explain what it means for any of them to have any meaning at all. Among the various theories of meaning that have been proposed, the *language of thought hypothesis* maintains that every (neurologically normal) human being

has an innate mental language, where learning an ordinary language simply involves pairing up the words in that ordinary language with innate concepts in the language of thought. The *inferential network model* holds that words and sentences, especially, derive their meaning from their location within a network of logical relations by virtue of definitional connections and other inferential relations.

MEANING, THEORY OF In the sense of Davidson and Dummett, a philosophical project of investigating the meaning of natural language in order to solve philosophical problems.

MECHANISM Generally speaking, the claim that living organisms are machines, i.e. material systems, and that the principles regulating the behaviour of living organisms are the same as those regulating the behaviour of physical systems.

MENTALESE See LANGUAGE OF THOUGHT HYPOTHESIS.

MENTALITY Among the most basic problems confronted by cognitive science is the nature and range of mentality, where mentality is a property possessed exclusively by things that have minds. Some conceptions of the nature of mentality are inspired by parallels with computers and hold that syntactical manipulations may be sufficient for something to have a mind. One of the first versions of this view was the symbol system hypothesis associated with Newell and Simon. Their approach is part of a much more general trend known as *the computational theory of the mind* (see also the entry on CONNECTIONISM). Within this trend, some philosophers consider syntactical manipulation necessary but insufficient for mentality, and maintain that any mind must also possess the capacity for representation, meaning, or content as semantical rather than merely syntactical phenomena. This approach is also known as *the representational theory of the mind*. Still other conceptions envision minds as properties of the users of signs, which makes the nature of mentality a pragmatical phenomenon. A variety of theories of representation, meaning, or content have been advanced by Robert Cummins, Fred Dretske, and Stephen Stich, among others. An adequate theory of mentality should have the potential to explain why human beings, other animals, and computing machines do or do not possess it and the extent to which mental states make any difference to our behaviour. See PHYSICAL SYMBOL SYSTEMS, RTM, SEMIOTIC SYSTEMS and STM.

MEREOLOGY The formal theory of part-whole relations, sometimes used as an alternative to set theory as a framework of formal ontology.

METAPHYSICS Commonly used as a synonym of ‘ontology’. Sometimes used to refer to the study of competing ontologies with the goal of establishing which of these ontologies is true of reality.

METHODOLOGICAL SOLIPSISM In the theory of knowledge, solipsism is the position of assuming that nothing exists but the contents of one's own mind. In the theory of cognition, methodological solipsism is the position of assuming that minds themselves have access exclusively to the formal properties of representations, meanings, or content. This is therefore a corollary of the computational theory of the mind, which im- plies that minds never have access to the semantic properties of representations, meanings, or contents, including any connections that obtain between them and their possibly environmental causes. (Cf. mentality.)

MICROSCOPIC STATE Local state of a single element of a dynamical system.

MIND, REPRESENTATIONAL THEORY OF THE Any theory that maintains that representations (marks, symbols, signs) cannot be understood purely syntactically but essentially involve relations between those representations and that for which they stand, by virtue of which they acquire meaning (content, information). (Cf. mentality; minds; STM.)

MIND, SYNTACTICAL THEORY OF THE Any theory that maintains that the nature of mentality can be adequately captured by means of purely formal operations over purely syntactical entities. Essentially the same position is endorsed by those who subscribe to the computational theory of the mind, the physical symbol system conception, and the conception of minds as automated formal systems. See also INTENTIONALITY, MENTALITY, MINDS, RTM.

MIND/BODY PROBLEM The problem of discovering the connection between minds and bodies, including whether minds are properties that only bodies can possess or could possibly exist without benefit of bodies. According to some supporters of the (symbolic and) computational conception of the mind, the relationship of mind to body is essentially the same as that of software to hardware. This does not hold true for computational approaches based on connectionist theories (see the entry on CONNECTIONISM). In general, a computational conception of the mind assumes that the mode of operation of human minds is essentially the same as the mode of operation of computing machines (including networks) at some appropriate level. This has been widely disputed. An adequate theory of mind must resolve this problem.

MIND/BRAIN The neurophysiology of the brain is a structure that is (or at least appears to be) lawfully related to mental functions that collectively constitute the mind. Though materialists of various persuasions argue that mental states are reducible to brain states (or that the mind can be eliminated in favour of the brain), that position seems to be implausible in light of the consideration that brains are important precisely because they are related to different kinds of (internal and external) behaviour under the influence of specific environments when they have been subjected to different histories of learning, conditioning, or reinforcement. Descriptions of these behavioral tendencies remain indispensable to under- standing the brain, even when the causal role of mental states is ignored.

MINDS Minds are the possessors of mentality. If what it is to be a thinking thing (a mind) is to have the capacity to use language, for ex- ample, then things that have the capacity to use language are thinking things (or minds). According to syntactical conceptions of the mind, the capacity to process syntax is sufficient for something to have a mind. On stronger conceptions, the capacity to process syntax may be necessary but is not sufficient for something to have a mind. Within the philosophy of mind, there are three great problems, namely: the nature of mind (what does it take for something to possess mentality?); the mind/body problem (how are minds related to bodies?), and the problem of other minds (how can we know whether anything besides ourselves possesses mentality?). An adequate theory of mind ought to have adequate answers to all three. (Cf. mentality; mind/body problem; other minds, problem of.)

MINDS, PROBLEM OF OTHER One of the three great problems in the philosophy of mind, this is the problem of establishing the existence of any other minds besides one's own.

ML A functional programming language with a sophisticated type system

MODUS PONENS (MP) The deductive inference rule, 'Given a line of the form, 'if *p* then *q*', and another of the form, '*p*', then infer a new line of the form, '*q*'. The application of MP produces logically valid arguments.

MODUS TOLLENS (MT) The deductive inference rule, 'Given a line of the form, 'if p then q', and another of the form, 'not-q', then infer a new line of the form, 'not-p'. The application of MT produces valid arguments.

MONOTONY A feature of classical first-order logic due to nature of the associated consequence relation: it states that if ϕ can be inferred from a set Γ of sentences, then it can be inferred from any superset of Γ.

MONOTONY, CAUTIOUS A feature of certain systems of defeasible reasoning (more precisely: of the associated consequence relations) in which adding a previously reached (defeasible) conclusion to premise-set does not lead to any decrease of inferential power.

MONOTONY, RATIONAL A feature sometimes proposed for systems of defeasible reasoning according to which if a sentence $\neg \phi$ cannot be defeasibly inferred from a given body of knowledge, then adding ϕ to the body of knowledge itself does not lead to any decrease in inferential power.

MOO see MUD OBJECT-ORIENTED

MUD OBJECT-ORIENTED (MOO) A MUD specifically designed to allow users to easily create objects (texts, slide shows, fictional entities, etc.) that others may encounter and manipulate.

MUD see Multi-User Dungeon.

MULTI-USER DUNGEON (MUD) Originally, an elaborate role-playing computer game (based on Dungeons and Dragons) that allows geographically dispersed users to participate via computer networks, including the Internet. Participants can define their names and identities as a variety of virtual personas or avatars. MUDs have expanded and evolved into a number of different systems – e.g., 'MOO's' (MUD Object-Oriented) – with a variety of uses, including education.

NATIVISM In response to Chomsky's argument that experience cannot account for language acquisition ('the poverty of the stimulus' argument), he has suggested that linguistic ability must be innate, inborn, or native to human beings. Ramsey and Stich have suggested that there are three different kinds of nativism, namely: *minimal rationalism* (that children must have some innate mechanism for learning language); *anti-empiric- ism* (that no ordinary learning mechanism could possibly account for the learning of language), and *rationalism* (that some specific set of language mechanisms must be part of the genetic endowment of every neurologically normal human being). The rationalist position advanced by Chomsky thus maintains that a universal grammar is part of our native inheritance, while Fodor goes further by suggesting that it also includes mentalese (or 'the language of thought'). One alternative appears to be the hypothesis that human beings have a genetic predispositions toward the acquisition of languages within some specific range of possible languages, where which language a person acquires within this range is determined by experience.

NATURALISM The view that the natural properties, events, and individuals are the only properties, events, and individuals that exist.

NECESSITY, ANALYTIC A proposition (or a sentence expressing a proposition) is said to be analytically necessary if it is necessary in virtue of its meaning. For example, many believe that the sentence 'bachelors are unmarried' is analytically necessary. Compare with METAPHYSICAL and NOMIC NECESSITY.

NECESSITY, METAPHYSICAL A proposition (or a sentence expressing a proposition) is said to be metaphysically necessary just in case it is necessary by virtue of metaphysical truths. For example, if the correct metaphysics of the constitution of water says that water is H_2O, then it is metaphysically necessary that non-H_2O stuff even if clear, potable, odourless, tasteless, etc. is not water. Compare with ANALYTIC and NOMIC NECESSITY.

NECESSITY, NOMIC A proposition (or a sentence expressing a proposition) is said to be nomically necessary just in case it is necessary by virtue of natural laws. For example, the proposition that metals expand when heated is nomically necessary. Compare with ANALYTIC and METAPHYSICAL NECESSITY.

NECESSITY/POSSIBILITY/IMPOSSIBILITY, HISTORICAL A state-of-affairs is historically possible when its occurrence is both logically and physically possible and not precluded by the history of the world at a time. Relative to ordinary English, Newton's laws, and the history of the world until now, it is an historical possibility that the book on my desk will remain at rest until tomorrow (it is an historical necessity that the book on my desk will remain at rest until tomorrow unless it is acted upon by an external force; and it is an historical impossibility that the book on my desk will be acted upon by an external force and nevertheless remain at rest until tomorrow).

NECESSITY/POSSIBILITY/IMPOSSIBILITY, LOGICAL A state-of-affairs is logically possible when its description does not violate the laws of logic, given a language. Relative to ordinary English, for example, it is a logical possibility that a bachelor is a millionaire (it is a logical necessity that, if he is a bachelor, then he is unmarried; and it is a logical impossibility that, if he is a bachelor, then he is not unmarried), assuming satisfaction of the requirement of a uniform interpretation, where the same words have the same meaning throughout.

NECESSITY/POSSIBILITY/IMPOSSIBILITY, PHYSICAL A state-of-affairs is physically possible when it is both logically possible and its occurrence does not violate laws of nature. In relation to English and Newton's laws, for example, it is a physical possibility for an object to continue its motion in a straight line or remain at rest (it is a physical necessity that, if an object is not affected by an external force, then it will continue its motion in a straight line or remain at rest; it is a physical impossibility that, if an object is not affected by an external force, it will not continue its motion in a straight line or remain at rest. Physical possibility (necessity/impossibility) implies logical possibility.

NESTING Following Dretske, the information that *p* is nested in the information that *q* just in case *q* carries the information that *p*. Specifically, *p* is *nomically nested* in *q* just in case it is nomically necessary (necessary by virtue of natural laws) that *p* is nested in *q*. Similarly, *p* is *analytically nested* in *q* just in case the sentence '*p* is nested in *q*' is analytically necessary (necessary in virtue of its meaning).

NETtalk A three-layered feedforward connectionist network designed by Terrence Sejnowski and C.R. Rosenberg (1987) that learns to map letters onto phonemes. NETtalk's input units (or nodes) represent letters (individual letters are represented by patterns of activation over 29 input units and there are 7 such groups of 29 input units) and its output units represent phonemes. The network feeds into a synthesizer. After sufficient training using backpropagation, when presented strings of letters comprising the words of

actual English text, the network drives the synthesizer to sound like a robotic voice literally reading the text.

NETWORK, DEFEASIBLE A network of 'is-a' links for the representation of taxonomic information, in which links are interpreted defeasibly.

NEURAL NETS Simplified mathematical models of the brain's neurons, remarkable for an ability demonstrated in a range of applications to be 'trained' on a small number of samples and to generalize successfully to a larger sample.

NEURAL NETWORKS See CONNECTIONISM

NOISE A reduction in uncertainty at a receiver that is independent of the reduction in uncertainty at a source or sending point.

NOMIC Ordinarily used as a synonym for lawful or law-governed. Any non-logical necessary connection or causal relation involving laws of nature is a nomic connection or relation. Most importantly, what is described by a sentences is *nomically possible* if its occurrence does not violate the laws of nature, *nomically necessary* if its non-occurrence would violate the laws of nature, and *nomically impossible* if its occurrence would violate the laws of nature. See PHYSICAL NECESSITY/POSSIBILITY/IMPOSSIBILITY.

NOMOLOGICAL Of or pertaining to laws.

NONLINEAR DYNAMICS Dynamics determined by a non-linear equation. The rate of dynamical effects is not proportional to its cause. See for example the BUTTERFLY EFFECT in DETERMINISTIC CHAOS.

OBJECT-ORIENTED PROGRAMMING A currently popular programming paradigm, based on the principles of data abstraction, that de-emphasises traditional algorithmic forms of program control in favour of the notions of classes, objects, and methods.

OBSERVABLE/THEORETICAL Traditional distinction between properties (or predicates that refer to properties) that are directly accessible to sense experience and those that are not. It can be drawn in several different ways. One is to define *observable properties* as properties whose presence or absence can be directly ascertained, under suit- able conditions, by means of direct observation; *theoretical properties* are then defined as non-observational. Alternatively, a distinction is drawn between *observable*, *dispositional*, and *theoretical* predicates, where observable predicates describe observable properties of observable entities, dis- positional predicates describe unobservable properties of

observable entities, and theoretical predicates describe unobservable properties of unobservable entities.

OBSERVATIONAL EQUIVALENCE Two program phrases are observationally equivalent if they can be substituted for each other in all contexts.

ONTOLOGICAL COMMITMENT The ontological commitment of a theory (or individual or culture) consists in the objects or types of objects the theory (or individual or culture) assumes to exist.

ONTOLOGICAL ENGINEERING The branch of information systems devoted to the building of information systems ontologies.

ONTOLOGY, ADEQUATIST A taxonomy of the entities in reality that accepts entities at all levels of aggregation, from the microphysical to the cosmological, and including also the mesocosmos of human-scale entities in between (contrasted with various forms of reductionism in philosophy).

ONTOLOGY, PHILOSOPHICAL A highly general theory of the types of entities in reality and of their relations to each other.

ONTOLOGY, TOP-LEVEL The general (domain-independent) core of an information systems ontology.

ONTOLOGY/EPISTEMOLOGY Among the most central domains of philosophical inquiry. Ontology (sometimes called metaphysics) aims at discovering a framework for understanding the kinds of things that constitute the world's structure, and epistemology aims at discovering the principles by means of which the world's properties might be known. The third branch of philosophy, axiology, concerns the theory of value.

OOP See OBJECT-ORIENTED PROGRAMMING

ORDER PARAMETER Variable of a dynamical system characterizing the global order of its elements.

PARALLEL DISTRIBUTED PROCESSING See CONNECTIONISM

PARAMETER A variable, belonging to a subroutine, which receives a value when the subroutine is executed.

PHASE SPACE Space of points representing the macroscopic states of a dynamical system.

PHASE TRANSITION Transformation of macroscopic states in dynamical systems near to points of instability.

PHILOSOPHY OF SCIENCE Reflection on the aims, methods, and results of scientific inquiry.

PHILOSOPHY OF TECHNOLOGY Philosophical reflection and analysis of the nature and meaning of making and using things.

PHYSICAL SYMBOL SYSTEM A physical symbol system is a physical system that has the capacity to manipulate symbols, where 'symbols' are understood to be accessible to operations on the basis of their for- mal properties exclusively. Thus, the conception of a physical symbol system coincides with that of a universal Turing machine and with that of an automated formal system, when things of each of these kinds are provided with a program. This conception has been developed in the work of Newell and Simon, see PHYSICAL SYMBOL SYSTEM HYPOTHESIS.

PHYSICAL SYMBOL SYSTEM HYPOTHESIS According to Newell and Simon, the necessary and sufficient conditions for something to be cap- able of general intelligent action (or to have mentality, to have a mind) is that it should be a physical symbol system. They thereby endorse the computational conception of mentality, according to which the capacity to manipulate syntax is what it takes to have a mind. According to this conception, universal Turing machines and automated formal systems possess the necessary and sufficient conditions to have minds.

PRAGMATICS The study of the relations between signs, what they stand for, and sign users. Alternatively, the study of the relations between words, what they stand for, and word users. Alternatively, any study that involves essential reference to the purpose (or motive) that causes us to act as we do.

PRION Acronym for 'proteinaceous infectious particle', it is a infectious micro-organism a hundred times smaller than a virus. It is composed solely of protein, without any detectable amount of nucleic acid (genetic material). How it can operate without nucleic acid is not yet known.

PROBABILITY THEORY, BAYESIAN An approach in which mathematical details reflect a notion of probabilities not as objective frequencies but degrees of subjective confidence.

PROBABILITY, CONDITIONAL The probability of X given (conditional upon) Y is the quotient Pr (X&Y)/Pr Y.

PROBABILITY, INTERPRETATIONS OF Any interpretation of the principles of probability. In view of the variety of different axiomatizations of mathematical probabilities, however, this should be broadly construed to encompass measures that satisfy principles of summation, of addition and of multiplication, whether or not they qualify as conditional probabilities in the technical sense. The most important conceptions of probability are the classic, frequency, logical, personal, propensity, and subjective interpretations.

PROGRAM A set of instructions that controls the operation of a computer. The concept of a program is highly ambiguous, since the term 'program' may be used to refer to (i) algorithms, (ii) encodings of algorithms, (iii) encodings of algorithms that can be compiled, or (iv) encodings of algorithms that can be complied and executed by a machine. As an effective decision procedure, an algorithm is more abstract than a program, since the same algorithm might be implemented in various specific programs suitable for execution by various specific machines by using various programming languages. From this perspective, the senses of 'program' defined by (ii), (iii), and (iv) provide conceptual benefits that definition (i) does not. See also ALGORITHM and ARTIFICIAL LANGUAGE.

PROGRAM CONTEXT A program with a gap in it, into which program phrases may be substituted.

PROGRAM PHRASE A syntactic constituent of a program recursion. A subroutine is recursive if it repeatedly calls itself until some condition is satisfied referential.

PROGRAM SPECIFICATION A detailed description of a computer program's input and output, ignoring the details of how the program actually accomplishes its task.

PROGRAM VERIFICATION See FORMAL PROGRAM VERIFICATION.

PROKARYOTE One of the two major groupings into which all organisms are divided (the other is eukaryote). Prokaryotes are organisms (bacteria and cyanobacteria, i.e. blue-green algae) that do not have a distinct nucleus.

PROOF, FORMAL In classical first-order logic, a finite sequence of sentences, each of which is either an axiom, an assumption, or follows from previous one by means of one of the rules. A crucial feature is that it must be decidable when a sentence ϕ follows from given sentences $\psi_1,\ldots,\psi_k$ by one of the rules.

PROPRIOCEPTION Concerned with the body's internal sense of position, balance, and movement. In the context of computer-generated virtual reality, this involves taking into account the orientation of a person's actual body with that of their virtual body and environment.

PROXIMATE The immediate, next element in a chain or series.

PSYCHOSEMANTICS The theory of meaning or content for mental symbols.

REAL-TIME Time as measured outside of a computer simulation, as opposed to time as measured within the simulation.

REASONING, ANALOGICAL Inference that transfers information from one problem or situation to another that is relevantly similar. It occurs when two things (or kinds of things) are compared and the inference is drawn that, because they share certain properties in common, they probably also share other properties. Because the first, *x*, possesses properties *A*, *B*, *C*, and *D*, for example, while the second, *y*, possesses properties *A*, *B*, and *C*, the inference is drawn that probably *y* possesses property *D* as well. The weight (or 'force') of an analogy tends to depend upon the extent of the comparison and the relevance of the reference properties to the corresponding attribute. Reasoning by analogy tends to be fallacious when (i) there are more differences than similarities, (ii) there are few but crucial differences, or (iii) the existence of similar properties is assumed to be conclusive in establishing other similarities.

REASONING, CREDULOUS A feature of certain systems of defeasible reasoning according to which a maximally consistent set of defeasible conclusions is inferred. In particular, in the case of conflicting defeasible conclusions, all of which are equally warranted, the system selects a maximal conflict-free subset. See also SKEPTICAL REASONING.

REASONING, SKEPTICAL A feature of certain systems of defeasible reasoning according to which conflicting defeasible conclusions, all of which are equally warranted, are discarded, and only non-conflicted conclusions are drawn. See REASONING, CREDULOUS.

RECURSIVE A recursive property is defined by means of a basis clause (the initial conditions for some operation) and a recursion clause (a rule for the re-application of an operation to its own results); if it is transfinite, then it also has a limit clause (which defines the property at infinity).

RELIABILISM The view that knowledge or justified belief is a function of the truth-preserving nature of the cognitive processes leading to belief (justified beliefs are those deriving from cognitive processes that tend to produce more true than false beliefs).

REPLICATION One system replicates another when they stand in a relation of simulation and have the same modes of operation. Thus, if humans and machines can not only simulate each others input/output behaviour but also share their principles of inference, then they may stand in a relation of replication. Only systems that are composed of the same components--such as metal and silicon or flesh and blood--can stand in a relation of emulation. In relation to questions about whether or not machines can think or have minds, the relation of simulation appears to be too weak, while the relation of emulation appears to be too strong. Replication appears to be the relation that is required. See EMULATION, SIMULATION and TURING TEST.

REPLICATOR DYNAMICS A formal model of how percentages of individuals with certain traits in a biological population will change with selective reproduction over time.

REPRESENTATIONS Things that represent or stand for other things by virtue of some natural or artificial connection between them. See MINDS, MENTALITY, RTM, STM and the next entry.

REPRESENTATIONS IN NETWORKS Connectionist networks (or artificial neural networks) can contain either local or distributed explicit representations. Local representations are individual units (or nodes), or individual units at certain levels of activation. A distributed representations is a pattern of activation over a group of units. The pattern of connectivity of a network is sometimes characterized as implicitly representing.

ROBOTICS, BEHAVIOUR-BASED An approach in robotics whose goal is to develop methods for controlling artificial systems and to use these as models of biological systems. It is usually based on Rodney Brooks' subsumption architecture, in which robots' low-level control routines, operating via continuous feedback loops with the environment, are connected to high-level routines that control more complex behaviours.

ROBOTICS, EVOLUTIONARY An approach in robotics in which artificial systems are developed mainly using the methods of genetic algorithms, which are a highly idealized model of natural selection processes. Genetic algorithms begin by randomly generating a population of strings corresponding to genotypes in natural evolution, each of which represents a possible solution to a given problem. The population is made to evolve by applying operators based on mutation and recombination criteria that simulate genetic processes in natural evolution. In this way, the 'parent' strings generate other strings, which represent new, perhaps better, solutions to the problem.

RTM See REPRESENTATIONAL THEORY OF THE MIND

RULES Patterns or regularities, descriptive or normative, that may have any number of instances. One of the most ambiguous words that occur in philosophical discourse, the term 'rule' can be used to refer to any custom, practice, or tradition, any habit, convention, or law, or any algorithm, principle, or heuristic, where the content of that rule can be specified in relation to conditions and responses, behaviour, or outcomes under those conditions. Semantic rules, such as dictionary definitions, specify the meaning of words, but there are innumerable other kinds.

SCHEME A functional programming language, which is a version of Lisp with cleaner semantics

SCIENCE Formal science is the study of formal systems, while empirical science aims at the discovery of laws and theories. The former is or appears to be an a priori and analytic pursuit; the latter is or appears to be a posteriori and synthetic. Empirical science may be described as aiming at the development of a model (theory) of the world, just as the philosophy of science might be described as aiming at the development a model (explication) of science. But some contributions to science take the form of specific discoveries of particular phenomena (such as new planets, for example) that involve the application of laws and theories.

SCOPE The portion of a program within which a particular variable has a value semantic value The value assigned to a program phrase by a semantic theory.

SEMANTIC ENGINES Formal systems for which the semantics of the system automatically follows the syntax, perhaps because the syntax has been designed to satisfy the semantics (as its 'intended interpretation').

SEMANTICS Study of relations between signs and what they stand for. Alternatively, the study of the relations between the formulae of an interpreted formal system and their meaning. Among the most important concepts studied within this area are those of meaning and of truth.

SEMANTICS, POSSIBLE-WORLD A semantic device for specifying the truth conditions for various types of intensional sentences, especially those of modal statements and of subjunctive conditionals, in relation to the properties of classes of possible worlds. While some theoreticians contend that possible worlds are 'just as real' as the actual world, when properly understood, possible worlds are ways things might be or might have been as described by classes of sentences, where two worlds are the same possible world just in case they are described by all and only the same sentences. Those who believe that semantics can avoid possible worlds may overlook the distinction between *true* and *false*,

where consistent sentences that are true describe ways things might be and are, whereas those that are false describe ways things might be and are not. Anytime we distinguish between the true and the false, therefore, we are distinguishing between different possible worlds and the actual one. The principal problem that confronts possible-world semantics is explaining which worlds are possible and why.

SEMIOTIC SYSTEMS The conception of minds as semiotic systems is built on the theory of signs elaborated by Charles S. Peirce. According to this approach, minds are the kinds of things that can use signs. This construction thereby generalizes and inverts Peirce's conception, which implies that sign users must be human beings ('somebodies'), precluding the possibility that other animals or inanimate machines might have the capacity to use signs and thus qualify as endowed with mentality.

SIGNS In the theory of signs (or 'semiotic') elaborated by Charles S. Peirce, a sign is a something that stands for something (else) in some respect or other for somebody. The sign relation is therefore triadic, where a sign bears a stand-for relation to something else, it bears that stand-for relation to something else for somebody, and that somebody bears some other relation to that something else by virtue of that signs standing for it for him. See SEMIOTIC SYSTEMS.

SIMULATION One system simulates another when they yield the same outputs given the same inputs, whether or not they have the same modes of operation or are made of similar materials. Thus, if humans take numbers and add them to obtain their sums and machines take the same numbers and add them to obtain the same sums, then to that extent they stand in a relation of simulation to one another. Since the modes of operation by means of which simulations take place may be entirely different, the relation of simulation appears to be too weak to qualify two systems as having the same mental powers. See also EMULATION, REPLICATION, TURING TEST.

SKEPTICISM The view that there is no (hardly any) knowledge (or justified belief).

STM See SYNTACTICAL THEORY OF THE MIND

STOCHASTIC Of or being statistically random; sequential process in which the probabilities at each step do not depend on the outcomes of previous steps.

SUBJUNCTIVE CONDITIONAL A conditional is a hypothetical statement of the form 'if *p* then *q*'; the component *p* is called the antecedent of the conditional, while component *q* is called the consequent. Conditionals whose antecedents are in the grammatical subjunctive mood neither presuppose that their antecedents are true nor that they are false; these are called subjunctive conditionals. For example, 'if I were to eat a bagel, then I would be full' is a subjunctive conditional: its antecedent is in the subjunctive mood, and it presupposes neither that I do eat a bagel, nor that I do not.

SUBROUTINE A fragment of code, with parameters, which can be invoked with particular values of its parameters

SUPERVISED/ UNSUPERVISED LEARNING In supervised learning, a connectionist network (or artificial neural network) is provided explicit feedback from an external source about what output is desired as a response to a certain input. The Delta rule and backpropagation are supervised learning algorithms. In unsupervised learning, no such external feedback is provided to the network; rather the network monitors its own performance through internal feedback. The Kohonen algorithm is an unsupervised learning algorithm for weight change.

SYMBOLS [1] In the theory of semiotic introduced by Charles S. Peirce, symbols are signs that stand for that for which they stand by virtue of an habitual associate or a conventional agreement rather than because of any relation of resemblance or any causal connection. More generally, a symbol is something that stands for something for someone who uses it. [2] The leading view in cognitive science is that mental symbols get their meaning and/or reference though naturalistic relations of some sort: e.g., causal relations (see the entry on FUNCTIONALISM), information-theoretic relations, and/or evolutionary history. The theory of meaning and/or reference for mental symbols is called psychosemantics.

SYNTAX The study of the relations that signs bear to other signs, including how signs can be combined to produce new signs, especially with respect to their sizes, shapes, and other characteristics. With respect to language, syntax tends to be identified with grammar and semantics tends to be identified with meaning. Among the most important concepts of syntax is that of a *well-formed formula*, which is any sequence of marks from the vocabulary of a specified system of signs that satisfied the formation rules of that system. Thus, the *formation rules* specify which sequences of marks are formulae (or 'sentences') of that system (or 'language'). The *transformation rules* (for example, modus ponens and modus tollens) specify which formulae follow from which other formulae. Some syntactical systems are studied as formal systems relative to an abstract domain without concern for their possible interpretation in relation to some physical domain that might render those formulae meaningful assertions about the world. When this is the case, the notion of truth is displaced by that of theoremhood, where a formula of a formal system is a theorem of the sys- tem if it is derivable from that system's axioms. The crucial questions relating formal systems and abstract interpretations concern sound- ness and completeness. See THEORIES, STANDARD CONCEPTION OF.

SYSTEM, CONSERVATIVE Dynamical system determined by the reversibility of time and conservation of energy.

SYSTEM, DISSIPATIVE Open (non-conservative) systems with energetic dissipation (e.g. friction).

SYSTEM, DYNAMICAL System of elements with time-depending development of their states (see MICRO-, MACROSTATES) in linear or nonlinear dynamics.

SYSTEM, FORMAL A collection of marks of varied shapes and sizes together with specified axioms, formation rules, and transformation rules qualifies as a formal system. The *formation rules* specify how those marks can be combined to create well-formed formulae (or 'sentences') of that system, while the *transformation rules* specify what follows from what, that is, which formulae are syntactically derivable from which other formulae in accordance with the rules. The *specific axioms* of a formal system are primitive (or 'unproven') assumptions, which are typically adopted with respect to the elements and relations of some abstract domain as its intended interpretation. A formal system is sound when every formulae ('theorem') that is derivable from the axioms is true with respect to the intended interpretation. If every sentence that is true with respect to the intended interpretation is also derivable as a theorem, the system is complete.

TECHNE A Greek word that is variously translated as 'art,' 'skill,' 'knowledge,' and 'technique.' It is the root of our word 'technology.'

TELEOLOGY In Greek 'tèlos' means 'goal' or 'end'. Teleological behaviour was considered by dualist philosophers and psychologists as a distinctive mark of living organisms, and the teleological explanation was opposed to mechanical or physical explanation. Cybernetic machines were originally used to refute this claim.

TELEPRESENCE The use of technology to create the impression of being present at a remote location. Telepresence can allow for communication, action, and interaction with people and environments at a distance. Both telephones and video-conferencing allow for limited types of telepresence, while some forms of virtual reality may enable a greater range of interactions.

THEORIES, STANDARD CONCEPTION OF The standard conception views theories as *abstract calculi* conjoined with *empirical interpretations*. Thus, they are formal systems that describe the world. An example would be the difference between empirically-uninterpreted Euclidean geometry and empirically-interpreted Euclidean geometry, where the lines and points of pure geometry become features of applied geometry by identifying lines with paths of light rays and points with their intersections in space. Once a formal system has been given an empirical interpretation, it becomes empirically testable. The observable/theoretical distinction and the analytic/synthetic distinction are assumed. Theoretical laws are generalizations whose non-logical terms are exclusively theoretical. Empirical laws are generalizations whose non-logical terms are exclusively observational. A scientific theory thus consists of theoretical laws and correspondence rules, which relate theoretical laws and observable phenomena by employing a mixed non-logical vocabulary. An empirical law might there- fore be explained by its derivation from that theory. The

standard conception has been attacked by denying the adequacy of the distinctions that it takes for granted, especially by the proponents of alternative conceptions.

TIME SERIES ANALYSIS Reconstruction of the phase space and attractors of a dynamical system from finite sequences of measurements in a time series.

TIME SERIES Geometric representation of the time-depending development of a dynamical quantity along the time axis.

TRACTABILITY, MATHEMATICAL The extent to which aspects of a phenomenon can be described in simple mathematical formulae.

TRAJECTORY Orbit of points in a phase space representing the time-depending development of a dynamical system.

TRANSDUCER Any process or procedure (or any structure performing the process or procedure) of converting an input of one kind into an out- put of another kind.

TRANSFINITE Anything greater than or more complex than every finite object is transfinite; mathematics defines a whole system of transfinite numbers and transfinitely recursive functions. Chapter 13 mentions only limit conditions at the first (the least) non-finite number, but it is possible to extend recursive definitions to arbitrarily high infinities.

TRANSPARENCY A program context is referentially transparent if it allows program phrases with the same value to be substituted for each other.

TRUTH, LOGICAL Any instance of a logical form which has only true uniform interpretations is known as a logical truth. Often sentences that are true simply on the basis of their meaning or by virtue of definitions are also qualified as logical truths, because they are reducible to logical truths by substitution of definiens for definiendum. See ANALYTIC/SYNTHETIC and A PRIORI/A POSTERIORI.

TURING MACHINES An abstract or ideal automaton that is capable of making a mark on a roll of tape, which functions as a memory for the system. The mechanism can perform just four kinds of operations: it can make a mark; it can remove a mark; it can move the tape forward; and it can move the tape backward. The tape itself is divided into segments (or 'cells'), each of which may or may not be marked, and must be of unlimited length. No matter how much tape we use, there is always more. When such a machine implements a program that instructs it what to do (when to mark and when to unmark, etc.), then it formally qualifies as a Turing machine. Any marks with which it begins can be viewed as 'input' and any marks that remain when its program has been executed can be viewed as

'output'. If two marks were on adjacent cells, for example, a program might cause the machine to mark three more cells to produce five marks together (perhaps thereby adding two and three to obtain five). Turing machines that are designed to operate on the basis of just one set of instructions are 'special purpose' machines. Universal Turing machines, by comparison, can imitate the performance of any special purpose machine when provided with the corresponding program. In this sense, they are 'general purpose' machines. Note that designing the state-transitions of a *physical* TM is a matter of hardware design, whereas giving programs to a universal TM is a matter of software. In fact, universal TMs have both a special hardware (described by a universal machine table) and a program written on the tape. It is because their hardware is special that they are universal. The striking feature of universal Turing machines is their enormous computational power. Alonzo Church proved that a universal Turing machine is powerful enough to imitate any formal system, where a 'formal system' consists of any collection of arbitrary elements and rules for their manipulation, so long as operations on the elements depend exclusively on their formal properties. See also CHURCH-TURING THESIS.

TURING TEST A special case of the imitation game, this test pits an inanimate machine against a human being, with the objective of seeing whether an observer can guess which is the machine and which is the human being. Since the test is conducted by asking questions using a means of communication that will not give the game away, the observer has to draw an inference based upon the answers that are provided as to which is which. Presumably, if the observer guesses that the machine is the human or cannot distinguish between them, then the machine has presumably displayed that it is as good as a human being with respect to its performance of the assigned task and has thereby passed the test. The success of the Turing test as an indicator of intelligence has been challenged by Searle in the form of his Chinese room counterexample. Moreover, it is by no means clear whether the Turing test adequately reflects the differences between relations of simulation, replication, and emulation. Its significance is thus a matter of dispute. See CHINESE ROOM, EMULATION, IMITATION GAME, REPLICATION and SIMULATION.

TYPE An attribute of a component of a program (especially of a variable): it specifies what sort of values that component can have.

UNDECIDABILITY A problem is undecidable if there is no algorithm that will solve all particular instances of it.

USENET NEWSGROUPS One of the most widely used text-messaging systems. Users post messages on a publicly accessible site, messages are then readable either in temporal sequence and/or as organized according to message 'threads' or topics.

VARIABLE An entity in a computer program whose role is to hold arbitrary data.

VIRTUAL MACHINES Abstractions that simulate the behaviour of possible machines but which are not vulnerable to the operational or other problems that can be encountered by actual physical machines.

VIRTUAL REALITY Computer-generated, interactive simulations that may be experientially real and shared by multiple users.

VIRUS In biology, any of a large group of parasitic, acellular entities that are regarded either as the simplest micro-organisms or as extremely complex molecules. A virus typically consists of a protein coat surrounding a core of DNA or RNA. It is capable of growth and reproduction only if it can invade a living cell to use the cell's system to replicate itself. In the process, it may disrupt or alter the host cell's own DNA and hence cause various common diseases in other organisms.

WEAK AI See AI, STRONG