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Abstract: This paper looks at the developing field of cognitive science showing how its epistemic power can be explained using key constructions from my model of emerging truth (MET). The MET sees warrants as tied to a field of models in definable relationships that account for the relative power of the arguments in which they are employed. The paper identifies epistemologically crucial model relationships in various strands of cognitive science accounting for its explanatory potential.

Keywords: argument, brain, cognitive science, epistemology, MET, psychology, truth, warrants

1. *Introduction*
This paper continues an agenda that has exercised me for more than two decades (Weinstein, 1990; 1994 are early contributions. Weinstein, 2013b is a recent sustained effort). The core of my approach can be succinctly states as follows: evaluating arguments put forward whether in defense or attack essentially requires being able to give a comparative estimate of the strength of the warrants employed, whether tacit or overt (Weinstein, 2006). This challenges much of the theory of argument, since it precludes dialogical and dialectical considerations from being definitive, focusing rather on epistemology.

My initial agenda was practical, concerned with critical thinking across the disciplines (Weinstein, 1994, 2012b). My subsequent agenda was theoretical (Weinstein, 2009a; 2012a), resulting in a metamathematical theory of emerging truth (MET) that offered a formal account of warrant strength and the dialectics of its application to arguments (Weinstein, 2013b). The metamathematics gives formal substance to a foundational concept upon which the construction of the MET is based: the history of mappings between models of a theory over time. The MET distinguishes between two classes of models, empirical models, models of the theory in available data, and reduction models, higher order theoretic models that reinterpret a theory in terms of more abstract theories of greater explanatory power. The MET can be seen as formal metaphor for three essential and hopefully intuitive epistemological desiderata: consilience, the increasing adequacy of empirical descriptions over time; breadth, the scope of theories as applied to a range of empirical descriptions and generalizations; and depth, a measure of levels of theoretic redefinitions which results in increasing breadth and higher levels of consilience.

A crucial aspect of all the relations defined in the MET is that they permit mappings across models that are approximations (see Apostel, 1961 for a early and salient discussion of the possibilities). In the MET levels of acceptable approximation are determined by the practice in the field, but there is a requirement that approximations improve over time. Consilience requires that empirical models achieve better approximations to intended models over time, And similarly for breadth, the scope of explanations, which should increasingly approximate the range of concerns as they become apparent and depth, reducing theories should capture increasing numbers of accepted generalizations, reinterpreting them in terms of the intended models of the reducing theory. And so the MET moves from increased acceptability to emerging truth (Weinstein, 2002, 2013b).

Given the novelty of my approach, an exploration of actual cases is needed. My first application of the theory to an exemplar was an examination of a core logical moment within the development of the periodic table of elements: Prout's hypothesis (Weinstein, 2011). Physical chemistry was the basis for my theoretic intuition and so a fit between theory and exemplar was not surprising. So I looked to an argumentative context that was far removed from physical science. I looked at the arguments that can be seen as supporting the defeat of scientific racism (Weinstein, 2013a). Unlike physical chemistry, which, at least in retrospect, can be seen as forming a unified theoretical context within which arguments can be appraised, arguments against scientific racism draw upon many theoretical points of view, including anthropological, biological, psychological and sociological perspectives. This paper presents another case: cognitive science seen as an emerging research agenda.

The application of the MET to the history of the periodic table was straightforward. The key logical relations in the MET, empirical modeling and theoretic redefinition are easy to interpret in the sort of unified theoretic complex that physical chemistry was to become. The key epistemological elements in the

MET, the progressive nature of sequences of models over time and the increasing unification of empirical and theoretic generalizations through higher-order reducing theories, reflected the history of the table and so estimations of warrant strength were both natural and consistent with obvious trends in physical chemistry. No such easy interpretation was available for the network of theoretically disparate concerns found in argumentation relevant to the scientific basis for racism. But the exploration of the arguments against scientific racism highlighted another aspect of the MET, the flexibility of its model relations. The core logical relations, partial mappings across models and the tracking of such mappings over time could capture relations between disparate points of view, and the possibility of deeper theoretic unification could offer reinterpretations of empirical models drawn from different theoretical perspectives that enabled a stable and coherent platform for drawing together disparate bodies of empirical evidence. Both of these features will become apparent as we look at the developing framework of cognitive science.

2. *The search for an underlying mechanism*

The beginning of cognitive science can be connected with a number of distinct events (Gardner. 1987), but from our perspective two stand out. The first was the seminal paper by Warren McCulloch and Walter Pitts "A Logical Calculus of the ideas Immanent in Nervous Activity" (McCulloch and Pitts, 1943) and the publication of Noam Chomsky's Syntactic Structures (Chomsky, 1957). The first of these made the connection between the work of logicians in the preceding decades and the growing interest in neuropsychology, resulting in part from the increase of neurological trauma as a result of WWII (Gardner, 1987, p. 22). The second responding to the obvious inadequacy of behaviorist accounts of language learning and use posited a complex theoretic account of an abstract mechanism deemed potentially sufficient to ground the complex and creative use of language characteristic of human beings as a class. Further, the connection with the newly develop attempt at an abstract theory of information advocated by Claude Shannon and Warren Weaver as well as the work of John von Neumann and Norbert Weiner linking logic and cybernetics with neurological metaphors set the stage for the developments that followed. Although these various approaches had affinities in that they were all willing to use abstract logical characterizations for complex phenomena, mirroring the demand of psychologists as Karl Lashley who rejected the simple models of behavior that reflected the dominant behaviorist paradigm, each of these projects were independent in structure and method and each reflected the particular concerns that drove their progenitors (Gardner, 1987, chapter 2).

The connection between abstract models with clear affinities to logic and mathematics began to bear fruit as the computer revolution began to show the enormous power of simple ideas of computation in performing tasks that heretofore had been the function of human reasoning alone. Early on, the field that would be called artificial intelligence by John McCarthy developed computer programs that were both based on and applied to logical reasoning. The availability of computational power enabled simulations of characteristic cognitive tasks, showing 'learning' across many iterations and with complex variables (Rumelhart and McClelland, 1986: Sejnowski and Rosenberg, 1987).

This foreshadowed the central dispute concerns the underlying logic of thought as the field of cognitive science emerged. The competing perspectives were so called classical accounts, which use rule based inferential structures, as in Jerry Fodor's 'language of thought' (Fodor, 1975) and connectionism, replacing rules by a dynamic probabilistic weighting of factors, describable in physiological metaphors. Rather than changes of state as a function of a rule as in the classical account, connectionism identified states of virtual neurons as the outcomes of the states of other virtual neurons, seen as forming a network, responsive to thresholds that sum across myriad connections, by analogy with neurons in the human brain. The first of these is clearly a computer-based metaphor and binary machines have proved powerful beyond human imagining. The logic of computation, as envisioned in the seminal ideas of logic based computer programs gave the hope that such constructions would ultimately prove effective in identifying the basic structure of human cognition. But whatever the reach, the basis was a logical construction on rules. Connectionism, drawing on developing neurological understanding, saw things in a very different way. Seen physiologically and as realized in computer models of neural functioning the connectionist account offered a very different logical image of cognitive architecture.

Arguments brought forward in attack and defense of the competing positions including deep philosophical issues, including such basic issues as the nature of status of mental representation on the competing accounts. Argument, often a priori, included 'impossibility proofs' showing that a proffered cognitive structure cannot logically account for aspects of cognitive behavior. Context determined semantic meanings seem to be unavailable in principle to classical rule-based accounts. Alternatively, 'systematicity' in language production and understanding, that is the ability to produce and comprehend variations, is easy to account for in classical approaches but seemingly intractable within connectionism (Garson, 2112 offers an overview and examples). As often the debate is based on available applications in salient areas of cognitive function. Both connectionist and classical models have been applied with some degrees of success to a number of areas of cognitive functioning, including offering different structural models of the same phenomena, as for example, aspects of language production and understanding (Thagard, 2012, pp. 60-61 offers a summary table). The argument is ongoing and not decided.

The MET gives a particular perspective on reconstructing the developing inquiry. Like the early atomic theory, cognitive science begins with deep theoretic concepts that serve as potential reducing theories for newly acquired, but relatively impoverished empirical data. From the perspective of the MET it is not surprising that theories are inadequate in many ways and the debate among proponents of competing points of view is unresolved as inquiry progresses. Taking physical chemistry as a paradigm we should expect deep theoretical metaphors that are inadequate to the phenomena, which as described is subject to both empirical and conceptual flaws (Weinstein, 2011). So, for example, in early physical chemistry, data sets for the relative proportions of chemical components were subject to the vagaries of inadequate measurement (Scerri, 2007, p. 40). And even as measurements improved empirical models of chemical reactions could not possibly be given an adequate theoretical account until the discovery of isotopes (Scerri, 2007, p. 58). When applied to physical chemistry, the MET looks to the developing of the network of ideas over time and the interplay of empirical evidence and theoretic modeling. This exposes an essential aspect of argument that moves far beyond how argument in inquiry is generally addressed.

The perspective of the MET moves beyond argument resolution in either the rhetorical or logical sense. Certainly convincing others is an essential aspect of argument in inquiry. It creates adherents, funding and possible recognition. But being right is another thing all together. Once thought of as the purview of logical principles, methodological principles as viewed from the perspective of the MET look beyond argument structure, whether deductive or inductive and sees the satisfaction of dialogical rules to be insufficient to identify the core of an argument: the strength of the warrants in support of a claim or counter-claim. The theory of warrant that the MET puts forward moves away from the local context of argument resolution and towards that larger concerns upon which the ultimate evaluation of the arguments must ultimately turn. This is seen in the MET as the evolving strengths of the warrants that underlie a claim in terms of the evolving properties of the network within which the warrant sits. The network and its history, both actual and projected, serve as an index of the warrant's power to support inference.

And so as heated and philosophically ingenious the arguments about classical versus connectionist models in cognitive science appear, from the point of the ongoing inquiry, who is right remains to be seen. The MET tells us what to look for, and so we can evaluate where the argument has been and speculate as to where it is headed: the three properties of the MET: consilience, breadth and depth. This moves us to why, despite foundational problems and difficulties of all sorts, cognitive science is an ongoing concern.

3. *Increasing the range of concerns*

Breadth of concern is perhaps the most apparent characteristic of cognitive science. The *Cambridge Handbook of Cognitive Science* (Frankish and Ramsey, 2012) lists 8 related research areas that reflect different aspects of cognition, including perception, action, learning and memory, reasoning and decision making, concepts, language, emotion and consciousness. In addition, they list 4 broad area that extend the reach of cognitive science from human cognition standardly construed to include animal cognition, evolutionary psychology, the relation of cognition to social entities and artifacts and most essential, the bridge between cognitive science and the rest of physical science: cognitive neuroscience. Each of these is a going concern, and none of them is free of difficulties. Yet in all cases there is a sense of advance, of wider and more thoughtful articulation of theoretical perspectives that address a growing range of cognitive concerns. The MET offers a logical account of why that is a telling epistemological attribute, crucial for evaluating the structure of support that warrants confidence in the truth-likeness of the enterprise and, perhaps, its ultimate vindication as the basis for emerging truth.

Like the inquiry project surrounding the periodic table from its onset, cognitive science has a wide variety of empirical projects, reflecting the range of concerns and available theories. In chemistry it was the entire range of the physical world and its processes. Cognitive science looks to analogously comprehensive concerns, the mental life of humans, that rich competence that human beings show in their engagement with their environments, their fellows and their cultures. In order to ascertain the adequacy of the projects within cognitive science we must look to examples. The study of learning and memory as contrasted with work on reasoning and decision-making serve as indications of the progressive nature of cognitive science.

The cognitive architecture of memory, the discussion between short and long-term memory has been understood for some time. With the additional concept of working memory the model for understanding memory encoding and retrieval was in place. Elaboration and controversies still abound, but the basic physiological structures though which memory can be physically impaired have been identified. Additional details and functional analyses have been postulated, for example the distinction between declarative and episodic memory, the deepening understanding of recollection and familiarity has all been explored both experimentally and physiologically. In terms of the MET there has been a steady increase in the models of memory and elaborations that form related sequences of models each supported by empirical evidence that link models to cognitive tasks and physical deformations. The connection with brain anatomy connects different levels of analysis in that some aspects of the cognitive tasks can be interpreted in terms of an underlying mechanisms; more detailed reductions to neurophysiological theories have been have been identified through fMRI studies linking visual memories with high-level visual cortical areas (see Ranganath, Libby and Wong, 2012 for a review and bibliography).

The study of reasoning and decision-making, rather than looking at basic cognitive tasks, hopefully, interpreted in physiological terms, developed from the normative model already understood in logic and probability theory. Empirical studies were focused on the contrast between the normative models and actual performance (Wason and Johnson-Laird, 1972). Formal logic, the basis for the mental models that articulated the image of reasoning under investigation was expanded to include probabilistic accounts of logical inference and which of these was the most productive arena for further studies remains an issue in the field (Oaksford and Chater, 2007). Probability theory formed the normative basis for an analogous attempt to understand errors in inductive reasoning (Nisbett and Ross,

1980) and decision-making (Kahneman, Slavic and Tversky, 1982). The need to assign weight to both probabilities and utilities in decision-making has proven to be a fruitful basis for mathematical elaboration and experimentation (Stewart, Chatter and Brown, 2006).

The MET sees a very different status for the work on reasoning and decision-making in contrast to theories of memory. There are competitive models for understanding reasoning, all of which have some evidence and capture aspects of the cognitive domain, but the theories of reasoning are at best as strong as their available empirical support. Since they are based on empirical models of behavior the warrants are generally weaker than those in memory research, which draw upon a richer theoretic basis in brain research. If the discussion of reasoning and decision making is to have the robustness of theories of memory additional work has to be done, and recent efforts, moving away from logic-based discussion of reasoning and to broader considerations show indications of deeper understanding than normative-based paradigms afford. The link is the connection between memory, emotions and the levels of commitment, whether in terms of probabilities or utilities, required to make sense of decision-making. The connection between memory and emotions was postulated as early as Freud and continues to be an active area of research (for example, Lewandowsky, et. al, 2005, 2012). And there are attempts to conceptualize cognitive function within a knowing brain and feeling body (Damasio, 1995).

Seeing reasoning in the light of normative models, whether logical or probabilistic may seriously underestimate how the brain reasons and decides. Emotions or other biasing constraints on reasoning are more than impediments to sound practice. Cognitive science points to possibility of deep understanding, looking at cognitive functioning within the possibilities and constraints of the supporting mechanism. This has been typical of advances in all of the life sciences, and cognitive science fits the model.

Speculations as to the neural mechanisms have systemic power much greater than their evidentiary weights. We look briefly at two ambitious accounts that attempt to bridge the gap between abstract structure and physiological knowledge: Thagard and Aubie (2008) and Damasio (2010). Although speculative and very likely inadequate they offer an image of enormous potential warrant. For their enterprise, bridging between fundamental pre-cognitive processes such as physiological control and emotions to build the functional potential for memory and cognition, offers deep structural warrants supported by reliable evidence and accepted theories. Moreover their materialist assumptions point to the deep reduction to physiology, neurobiology, biochemistry and electrochemistry that an adequate theory of brain function would depend on. And this is despite the enormous gap between the simple models of neurological activity proffered and the brute facts of the living brain: 30 billion neurons making countless trillions of connections and sensitive to a wide array of known biochemical agents, with more perhaps to come. The MET tells us why this so.

4. *Measures of increasing adequacy*

Thagard and Aubie draw upon both neurophysiology and computer modeling. This enables both theoretic depth and the possibility of increasing adequacy, even if the latter is no more that computer simulations of simplified cognitive tasks. They cite ANDREA, a model which "involves the interaction of at least seven major brain areas that contribute to evaluation of potential actions: the amygdala, orbitofrontal cortex, anterior cingulate cortex, dorsolateral pre-frontal cortex, the ventral striatum, midbrain dopaminergic neurons, and serotonergic neurons centered in the dorsal raphe nucleus of the brainstem" (Thagard and Aubie, 2008, p. 815). With ANDREA as the empirical basis, they construct EMOCON, which models emotional appraisals, based on a model of explanatory coherence, in terms of 5 key dimensions that determine responses: valance, intensity, change, integration and differentiation (pp. 816ff). EMOCON employs parallel constraint satisfaction based on a program, NECO, which provide elements needed to construct systems of artificial neural populations that can perform complex functions (p. 824ff. see pp. 831 ff. for the mathematical details). This points to the potential power of their approach. Computer models, even if gross simplifications, permit of ramping up. A logical basis with a clear mathematical articulation has enormous potential descriptive power as evidenced by the history of physical science.

Damasio (2010) has a similarly ambitious program. He begins with the brain's ability to monitor primordial states of the body, for example, the presence of chemical molecules (interoceptive), physiological awareness, such as the position of the limbs (proprioceptive), and the external world based on perceptual input (extroceptive). He construes this as the ability to construct maps and connects these functions with areas of the brain based on current research (pp. 74ff.). This becomes the basis for his association of maps with images defined in neural terms, which will ground his theory of the conscious brain.

Given that much he gives an account of emotions elaborating on his earlier work, but now connecting emotions with perceived feelings. As with the association of maps and images, Damasio associates emotions with feeling and offers the following account: “Feeling of emotions are composite perceptions of (1) a particular state of the body, during actual or simulated emotion, and (2) a state of altered cognitive resources and the deployment of certain mental scripts” (p. 124). As before he draws upon available knowledge of the physiology of emotional states but the purpose of the discussion is not an account of emotions per se, but rather to ground the discussion of memory, which becomes the core of his attempt at a cognitive architecture (pp. 339ff.). The main task is to construct a system of information transfer within the brain and from the body the brain. The model is, again, mediated by available physiological fact and theory about brain function and structure. The main theoretic construct in his discussion of memory is the postulation of ‘convergence-divergence zones’ (CDZs), which store ‘mental scripts’ (pp. 151ff.). Mental scripts are the basis of the core notion of stored ‘dispositions,’ which he construes as ‘know-how’ that enables the ‘reconstruction of explicit representation when they are needed” (p. 150). Like maps (images) and emotions (feelings) memory requires the ability of parts of the brain to store procedures that reactivate prior internal states when triggered by other parts of the brain or states of the body. Dispositions, unlike images and feelings are unconscious, ‘abstract records of potentialities’ (p. 154) that enable retrieval of prior images, feelings and words through a process of reconstruction based in CDZs, what he calls ‘time-locked retroactivation’ (p. 155). CDZs form feedforward loops with, e.g. sensory information and feedback to the place of origination in accordance with coordinated input from other CDZs via convergence-divergence regions (CDRegions) by analogy with airport hubs (pp. 154ff.). Damasio indicates empirical evidence in primate brains for such regions and zones (p. 155) and offers examples of how the architecture works in understanding visual imagery and recall (pp. 158ff.).

The result of all of this is an attempt, as the title of the book suggests, to construct a brain-based theory of self, which building on what he has developed so far distinguishes three stages, the proto-self “a neural description of relatively stable aspects of the organism…. spontaneous feeling of the living body,” the core self, “which connects the body to the external world through “ a narrative sequence of images, some of which are feelings” and an autobiographical self “when objects in one’s biography generate pulses of the core self that are, subsequently, momentarily linked in a large-scale coherent pattern” (p. 192).

Damasio like Thagard and Aubie offer speculative models that reference current physiological knowledge, rely on concepts from computer science and information theory and bypass the deep philosophical issues that are seen by many to create an unbridgeable gap between the mental and the physical short of deep metaphysical reorientation (Chalmers, 1996). Yet, whatever the ultimate verdict on these two authors, the rich program in cognitive science persists and has a strong appeal. The reason is the potential strength of the warrants, that is to say, if such models prove to be correct the epistemic force of the warrants that support them will be enormous, swamping the force of alternative approaches that rely on, for example, psychological evidence alone. This requires a more careful look at the perspective that the MET provides.

The MET determines a hierarchy of epistemic adequacy in terms of models and chains of models viewed over time. Each level of adequacy supports correlative levels of warrant strength. The level of warrant strength has consequences both for the acceptance of the theory and for its power to resist counterexamples (see Weinstein, 2013b, chapter 4 for the dialectical details and a related adaptive logic.). For a theory to have sufficient warrant to be taken seriously it must reflect its intended models in that it either holds in the models or is increasingly adequate to the evidence it strives to explain. But the models in which it holds, whether exactly or with better approximations over time, are frequently a small set of the available concerns potentially within the scope of the theory. Looking at the history of the periodic table we find a similar pattern. Theoretic models held for small subsets of the known chemical elements and theoretic approximations to empirical data were typical. But as the research program persisted more and more chemicals were brought under the scope of explanatory models and approximations of empirical data improved as both theoretical and the experimental understanding was refined.

Given the claims of both Thagard and Aubie and Damasio to base their models on accepted facts about brain function, if proved correct, the accounts, however speculative meet the first test and so are warranted at a minimal level. That is their views capture aspects of the brain or they approximate accepted knowledge to a degree that is close enough to merit consideration. If they are close enough approximations, we look to their progress as they refine their models and as knowledge of brain function increases. If the approximations are becoming closer the speculations are seen as increasingly adequate. Adequacy in light of neurological facts is compelling and increasing adequacy is a sign of the fecundity of the theoretic approach as chains of linked models progress.

Both Thagard and Aubie and Damasio take synoptic approaches and offer models which cross the boundaries of brain functions, offering generalizable schemes for neural architecture. This shows enormous potential for breadth. Cognitive scientists who connect cognition with other brain functions, that like cognition, require and mediate information across systems (for example, physiological control and emotions) add empirically relevant models of essential brain functions, so the theory is not merely more adequate to its models, but there is an increasing range of models to which it applies. Again this is typical of the history of the periodic table and was a predictor of its potential strength as the research program flourished.

The far-ranging interests of cognitive science lend prima facie force to any reasonable attempt at articulating a neurophysiological account of core cognitive functions that might increasingly account for aspects of the field. The wide range of empirical and theoretic studies characteristic of cognitive science points to enormous potential breadth for anybody who gets it right, mirroring the history of the periodic table. Physical chemistry was initially concerned with gases; over time, independent areas of studies, ultimately including the entire range of physical substances, were incorporated under the basic concept of periodicity, as the basic ideas were reorganized around theoretic advance and more adequate empirical evidence. The result is a massive unification of the entire field of physical chemistry, arguable the most successful inquiry project in human history. Whatever the challenges, the epistemic payoff of a correct cognitive science is enormous, whence the power of the field despite its many problems

Tying cognitive science to neurophysiology gives an evolving empirical basis with warrants tied to the underlying structures of physiology. Physiological understanding is increasingly grounded in foundational sciences such as biochemistry and electro-chemistry. The empirical basis is necessary but it is the foundational knowledge that ultimately has the more powerful evidentiary force. Reducing neuroanatomy to a functional neurophysiology is the pathway to physicalism. Claims within physical science have the most powerful warrants, supported by networks of evidence at the highest level of articulation and affording enormous explanatory depth. Speculative talk about c-fibers reflecting what little was known about the physical correlates for mental episodes (in this case pain) was deemed worthy of decades of philosophical discussion just because the possibility of reducing the mental to the array of physical knowledge grounded the mental firmly within the scientific worldview. Unlike much of the discussion of the mind-body problem, which was concerned with identity, the MET sees reduction through identification. The reduction relation in the MET does not seek identities, but rather tracks the reinterpretations of aspects of theories when appropriate model relations hold. As we can reinterpret more and more phenomena in terms of a more basic theory our confidence in the warrants that result increases, first as a function of the adequacy of the reduction, then the increasing depth of the reduction, the increase in theoretic adequacy in light of the reduction, the increases in theoretical reach as the various reductions mutually reinforcement refinement in theory in light of symmetries between the various theories in light of the over-arching reducing theory and finally the increase in scope across large areas of inquiry as the reducing theory captures networks of theories. It is on the basis of such a history of progress that ontological claims are warranted and is the basis for the view that scientific materialism is the most plausible candidate for what the world is really made of.

5. *Conclusion*

If cognitive scientists are successful in modeling cognitive behavior in terms of brain processes, and if, as is becoming more evident, a wide range of psychological processes are implicated in cognition, possible co-extensive with the range of phenomena identified with so called folk psychology, the possibility of a scientific basis for the mind becomes more than philosophical speculation. Whether cognitive scientists will succeed remains to be seen. Whether a grounding of the mental in the physical will satisfy philosophers is even more uncertain, especially as phenomenology becomes a favored perspective among philosophers. But short of a wholesale disregard of science, perhaps in the name of some heir of post-modernism, the network of concepts and generalizations that constitute cognitive science has a potential for epistemic adequacy that transcends the arguments that support particular claims. The metamathematics of the MET shows how such a network can be precisely envisioned. Analysis of actual cases indicates how complex substantive arguments may the understood.

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